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Higher education students' media usage: A longitudinal analysis

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Abstract: Responding to the lack of longitudinal analyses on media usage in higher education, this study explores the changes of higher education students' access to and use of technology for learning in 2012, 2015 and 2018. Using an online questionnaire, a total of 5,572 German higher education students participated. Via descriptive and inferential analysis, the data show a clear trend towards using flexible, location-independent devices, accompanied by a rapid increase in the use of instant messaging. This is in line with an increasing demand for digital and flexible learning opportunities such as web-based training and lectures as podcasts or vodcasts, which is not met by higher education institutions. On that basis, improvements in development and application of these digital tools seem crucial for German higher education institutions and should be considered by educational technologists and decision makers. Of particular relevance against the background of the COVID-19 pandemic that started in Spring 2020, this longitudinal analysis provides a framework for the ongoing development and implementation of digital media in teaching and learning at higher education institutions.

Keywords: Distance education and online learning, user behavior, media selection, educational technology, higher education, longitudinal analysis

Highlights

What is already known about this topic:

- Digital media are ubiquitous in higher education students' everyday life.
- Students use tools and services differently and for different purposes.

What this paper contributes:

- An analysis of the changes of higher education students' access to and use of technology for learning from 2012, through 2015, to 2018.
- Students increasingly use flexible, location-independent digital devices.
- Students' acceptance of e-learning tools consolidates from 2012 to 2018.
- Students indicate a lack of digital teaching and learning formats in higher education institutions.

Implications for theory, practice and/or policy:

- Digital and flexible learning opportunities should be considered in higher education institutions.
- Faculty should consider knowledge about students' media usage behaviour when planning learning designs in higher education.
- Policymakers and administrators should consider students' media usage behaviour when developing digitalization strategies.

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Introduction

Digital technologies have become an integral part of higher education and affect all dimensions of higher education (Barak, 2018; Henderson et al., 2017; Rosenbusch, 2020). In order to design meaningful technology-enhanced learning environments, it is crucial to give attention to the characteristics of learners, alongside their needs, motivation, prior knowledge and experience gained, to name a few. Morrison et al. (2011) claim that an analysis of learners and context builds the basis of the instructional design process. Particularly in the design of online, distance or blended learning courses, it is important to consider students' access to media and digital devices, and to understand their use of media, tools and services for learning. As the available digital media, tools and services are subjected to a constant dynamic of change and renewal, it is hardly possible to come up with a uniform definition of media. In the context of this study, media are understood as all different kinds of digital technologies and tools to present course content and to facilitate interaction and collaboration in higher education learning environments. Media usage then describes the use of digital technologies, which is shaped by personal preferences and experiences.

Surprisingly little is known about student media usage behaviour in higher education, however. Two recent reports that partially address this matter are the EDUCAUSE 2020 Student Technology Report (Gierdowski et al., 2020) in the U.S., and the Jisc Report in the UK (Killen & Langer-Crame, 2020), both including a large sample of higher education institutions. A meta-analysis of media usage typologies by Brandtzaeg (2010) revealed that only one (Johnson & Kulpa, 2007) out of 22 studies addressed Internet usage patterns of college students in the U.S. A more recent study is based on a sample of Turkish higher education students (Özlü & Kalyoncuoglu, 2017). In contrast, most media usage studies deal with general media usage behaviour for non-learning related activities (e.g. online shopping, gaming) or are related to children, teenagers, and young people (e.g. Chaudron et al., 2018; Hallfahrt, 2018; Bolton et al., 2013).

Whilst previous cross-sectional studies have provided individual snapshots into digital media use by higher education students, a lack of in-depth studies can be maintained (Akçayır & Akçayır, 2018; Crook, 2019). The present longitudinal study seeks to reveal dynamics in higher education students' use of digital media for studying in greater detail. By uncovering these dynamics and (socio-demographic) influencing factors, educational technologists can learn more about their target group and the reasons and effects of media use. This knowledge can inform the future design of technology-enhanced learning offers. The aim of this study, therefore, is to explore changing media usage patterns of higher education students over time, by means of a longitudinal analysis, with data from 5,572 German students collected in 2012, 2015 and 2018. In particular, the study addresses the following research questions and always considers the development in 2012, 2015 and 2018:

RQ 1: What kind of digital devices do the students own and how frequently and how long are they using the Internet?
RQ 2: Which media and e-learning tools and services are used for learning and what is their perceived value for learning?
RQ 3: What is the difference between the supply and demand of digital teaching and learning practices offered by higher education institutions?
RQ 4: What kinds of different media usage types can be identified?

Literature

Educational technology use in higher education

In light of growing recognition of the importance of students' access to information and communication technologies (ICT), and the development of ICT skills (OECD, 2018; Rampelt et al., 2019), a range of

international research has been undertaken in a variety of higher education contexts, in order to investigate student use of and readiness towards using technology for learning. This has included research undertaken in Australia (e.g. Henderson et al., 2016; Ng, 2012; Selwyn, 2016), Canada (e.g. Bullen et al., 2011), Chile (e.g. Ayala-Perez & Joo-Nagata, 2019), India (Kaushik & Agrawal, 2021), Israel (e.g. Barak, 2018), Malaysia (Lateef et al., 2020; Lee et al., 2020), New Zealand (e.g. Lai & Hong, 2015), Nigeria (e.g. Adenusi et al., 2019), Saudi Arabia (e.g. Al-Husain & Hammo, 2015), Spain (Prendes et al., 2016), Turkey (e.g. Sumuer, 2018), the United States (e.g. Bowe & Wohn, 2015; Gierdowski et al., 2020; Dabbagh et al., 2019; Thompson, 2013, 2015), and the UK (e.g. Margaryan et al., 2011; Newman & Beetham, 2017). Whilst research has found that students who are both ICT proficient and collaborative learners think more flexibly (Barak & Levenberg, 2016), and are potentially better prepared to "work in a global market" (Barak, 2018, p. 121), multiple studies report that student use of technology in higher education is largely limited to basic, assimilative tasks (Ayala-Perez & Joo-Nagata, 2019; Henderson et al,, 2017; Margaryan et al., 2011; Parkes et al., 2015).

The Learning Management System (LMS) is often identified as the most useful tool related to university study (e.g. Henderson et al., 2016, 2017; Koh & Kan, 2020), with students frequently using it as a content repository and mostly just for administrative functions (Koh & Kan, 2020; Margaryan et al., 2011), rather than demonstrating deeper understanding and the use of more complex features (Parkes et al., 2015). However, as Koh and Kan (2020) highlight in their study with 232 university students in an Arts academy in Singapore, students' current experiences with media shape how they desire to use LMS and, therefore, there is place for improvement in terms of upgrading infrastructures and preparing faculty. Lecture recordings have also been identified as beneficial, allowing students to catch up when absent, or to clarify concepts and review material (Henderson et al., 2017; Newman & Beetham, 2017), although they should be integrated into the course design in the LMS space for enhanced navigation (Selwyn, 2016). Collaborative technologies, such as live polling, Google Docs, blogs and content creation tools, are used infrequently (Ayala-Perez & Joo-Nagata, 2019; Henderson et al., 2017; Killen & Langer-Crame, 2020; Newman & Beetham, 2017; Ng, 2012; Thompson, 2013), despite the importance placed on communication and collaborative skills for university graduates (Oliver & Jorre de St Jorre, 2018; Redecker, 2017). Although the use of social media for learning within classrooms has been found to have a positive impact and multiple benefits (e.g. Twitter in Malik et al., 2019; Facebook in Chugh & Ruhi, 2018), students' usage apart from a course design focused on interactions with other students to work on their assignments is more common (Gómez-Aguilar et al., 2012). For example, with an Australian study of 253 postgraduate students, Henderson et al. (2016), found 68.9% using social networking sites (e.g. Facebook) for working with other students on their courses, and 45.6% using Twitter in their university studies. However, challenges in the use of social media for learning are also identified as ongoing issues of data security, accessibility and students not wanting to mix their private and public lives (Andergassen et al., 2009; Chugh & Ruhi, 2018), alongside cultural differences (Bartosik-Purgat et al., 2017), as well as teacher digital skills and willingness to use ICT – and concretely, social media – in their teaching (Marcelo & Yot-Domínguez, 2018; Margaryan et al., 2011; Jääskelä et al., 2017; Gómez-Aguilar et al., 2012).

On the other hand, mobile technologies for learning have been broadly studied in different higher education geographical contexts with varying results. For example, in a study of 400 undergraduate students from two universities in Nigeria, positive perceptions about the use of mobile technologies for learning were found and their adoption was recommended (Lateef et al., 2020). In another study with 234 undergraduate students at a university in Malaysia, the authors found out that while students were fairly comfortable with the use of mobile technologies for learning (61%), students were only moderately ready to adopt m-learning (Lee et al., 2020). As the bibliometric review of mobile learning in higher education by Sobral (2020) concludes, although this phenomenon is a reality, there still seems to be a possibility for evolution regarding good quality studies.

Digital higher education in Germany

The digitalisation of higher education in Germany has been recognised as a key component in shaping the future of teaching and learning (Rampelt et al., 2019), and since 2014, the German Federal Government has driven a national digital agenda, including funding research projects through the German Ministry of Education and Research (BMBF) (BMI, BMWi & BMVI, 2014). A particular emphasis has been placed on the development of digital competencies and skills (European Commission, 2018), including basic functional digital skills (e.g. information retrieval and modification), generic digital skills (e.g. communication and collaboration), and using digital technology manipulation (e.g. coding) alongside computational thinking (Rampelt et al., 2019, p. 14). However, whilst conversations and research continue into organisational, technological and pedagogical aspects of digitalisation, individual higher education institutions have been slow to react. An investigation of the digitalisation strategies of German doctoral degree granting universities (*n* = 155) in 2018, for example, revealed that only four had publicly available strategies (Bond et al., 2018). The digital competence of German citizens has also been cause for concern, with the latest D21-Digital-Index in which the factors digital competence (40%), openness (20%), access (30%) and usage behaviour (10%) are represented on a scale of 0 to 100 points (Initiative D21, 2020, p. 10f.). The Index reveals that, whilst the overall national Digital-Index has risen by three points, digital competence is now on the same level as in 2013 (p. 11), and 69% believe that digitalisation should be strengthened in higher education and training (p. 54). Given that young people (aged 14-29) continue to be the biggest consumers and users of the internet and digital tools, this raises questions as to how prepared German higher education students are for the new digital age.

Whilst most German students have a mobile device and a laptop (Initiative D21, 2020; Statista, 2019b), far fewer use tablets and e-book readers (Dolch, 2020; May et al., 2016), which is similar to other international studies (e.g., Al-Husain & Hammo, 2015). In the second round of federal funding, within the research line 'Digitale Hochschulbildung' (Digital higher education), two systematic reviews were undertaken into German and international student media usage and usefulness in higher education between 2010-2017 (Pensel & Hofhues, 2017; Steffens et al., 2017). Both reviews highlighted the use of educational technology as supplemental learning support and for sharing materials, rather than changing teaching and learning in profound ways (e.g. Prendes et al., 2016). Similarly, Wekerle et al. (2020) argue that the potential of educational technology for encouraging students to perform high-quality learning processes might not yet be fully exploited. For example, in a study of 27,473 students from 153 German higher education institutions (Persike & Friedrich, 2016), digital media tools were not found to be an integral part of teaching and learning. The most used tools were digital texts (e.g. e-books, PDF documents, 98% of students), followed by email (95%), digital presentation tools (e.g. PowerPoint, 92%), social networks (e.g. Facebook, 82%) and wikis (78%). Social media tools have been found, however, to be particularly useful in the organisation or coordination of group work (Hrastinski & Aghaee, 2012). As found in other national (e.g. May et al., 2016) and international studies (e.g. Henderson et al., 2016), the use of micro-blogging (e.g. Twitter, 22%), blogs (31%) and online collaborative tools (48%) were used particularly infrequently in Persike and Friedrich's (2016) study. Students also rated IT infrastructure, such as wifi quality and access, to be far more important than having access to a range of eLearning tools.

Typologies of students' media usage behaviour

The above analysis of studies analysing students' media usage behaviour presents an overall picture regarding digital higher education in Germany. However, typologies can more clearly show differences among students' media usage within those aggregated data, and support faculty in the development of digital learning designs that are more adjusted to that particular usage. According to Barnes et al. (2007), developing typologies helps to classify persons or objects by typical behaviour or other patterns. "[T]he term user typology is defined as a categorisation of users into distinct user types that describes the various ways in which individuals use different media, reflecting a varying amount of activity/content

preferences, frequency of use and variety of use“ (Brandtzaeg, 2010, p. 941). Thus, user typologies offer the possibility to categorise media users according to their actual usage behaviour and not according to individual variables such as age, gender or context, such as experience or field of study. This kind of categorisation offers a beneficial and necessary complement for media-supported teaching and learning (Morrison, et al., 2011).

As a typology that focuses on general users and not higher education students specifically, Brandtzaeg's (2010) Media-User Typology divides users into eight different user types, according to media usage behaviour: non-users, sporadics (newcomers and low level users), debaters (contributors in blogging, discussion and debating), entertainment users (gaming and television users), socialisers (social media applications users), lurkers (time-killing or "goofing off" users), instrumental users (media use for utility and as an information tool), and advanced users (use of wide range of media and also the most advanced facilities). Only one of a total of 22 media user typologies, on which Brandtzaeg (2010) comparative meta-analysis was based, dealt with Internet usage patterns of college students in the USA (Johnson & Kulpa, 2007). A validation, with a representative sample of 2,000 Norwegian online users, resulted in the identification of five of those eight original types of social networking sites users: advanced users (frequent and broad media users), debaters, socialisers, lurkers and sporadics (Brandtzaeg, 2012).

Table 1. Comparison of user types identified in the two major studies (Lee et al. 2016) and Brandtzaeg (2010)

Typology according to Lee et al. (2016, pp. 7-9)		**Typology according to Brandtzaeg (2010, pp. 952)**	
User types	**Characteristics**	**User types**	**Characteristics**
Inactives	Lack of use / dropout service	Non-users	Lack of use
Advanced User	Frequent use with varied usage pattern	Advanced users	High use for all purposes, e.g. gaming, shopping, work-related, etc.
Socializer	Focus on communication and social behaviour	Socializers	Mostly use of media for socializing, keeping in touch with family and friends and meeting new acquantances, especially in social networking sites.
Hedonic User	Search of fun and enjoyment	Entertainment users	Use based on gaming or passively watching videos, also programming and shopping
Sporadic Users	Less service access and fewer skills	Sporadics	Low use, interest and less experienced, Internet is rarely used for private purposes
Onlooker	Use and engagement but small participation degree	Lurkers	Use of media based on lurking, time-killing, with major media being social networking sites, shopping, user-generated sites.
Utilitarian User	Search of utility	Instrumental users	Choose media content for information and civic purposes, also utility-oriented and work-related, low entertainment use
Communicator	Role as sharer of information	Debaters	Use focused on discussion and information acquisition and exchange. Major use of blogs and social networking sites
The Angels	Fond of sharing advice, information and knowledge		
Refusals	No perceived service needs and use old way		
Heavy User	Cannot imagine a life without the service		
First Stepper	Not familiar with the service but knowledge of its importance		
The Virtuosi	Master of all functions of services		
Attention attractor	Enjoyment by showing their lives		

Apart from the well-known typology of Brandtzaeg (2010), it seems relevant for the present study to also acknowledge the extensive systematic review of Lee et al. (2016), in which 14 user types were extracted from 32 media user typologies from 2010 to 2015. Although some of them are similar to the types proposed by Brandtzaeg, there are other newly identified user types (see table 1).

The two media user typologies outlined above provide an overview of possible patterns of media use. For a deeper understanding of media-supported teaching and learning of higher education students, user typologies that focus precisely on this target group appear to be more beneficial. For instance, Kennedy et al. (2010) present a typology of technology users based on a sample of 2,096 Australian higher education students, divided into four distinct types of technology users: power users, ordinary users, irregular users and basic users, which accumulated the highest percentage of the four types. Basic users refer to the infrequent use of technologies (less than weekly or monthly use) but regular users of mobile features (call and text people). Irregular users engage in technology-based activities infrequently, are moderate users of standard web (look up reference information, browse for general information, send/receive email, instant messenger, for commerce and services) and mobile technology, and are low users of all other technologies, with the exception of Web 2.0 publishing (creating/commenting on blogs, using social network sites or contributing to a wiki). Ordinary users are regular users of standard Web and mobile technology particularly, do not engage in Web 2.0 activities of Web publishing and file sharing, and use games more than monthly. Power users use a wide range of technologies significantly more frequently than all other users.

Another international user typology is the one based on a sample of 995 Turkish higher education students, where Özlü and Kalyoncuoglu (2017) identified six different clusters in terms of user behaviours in social media platforms: movers and shakers (active users in creating original content and producing multimedia content), game lovers (intensive game players and content consumption), abstainers (low level use, to read/consume contents), followers (active Twitter use, engaging in content consuming and content sharing), sharers (content reading/consuming, intensively criticising/sharing), and socialisers (intensive interaction with content, game players, and active Twitter use/contents consumption, but not creating original content). Taking a slightly different approach to user typologies, Gonzalez et al. (2019) surveyed 84 higher education students in Spain studying Human Resource Management about their perceptions of online social networks. They used factor and cluster analysis to develop a typology of students' approaches to social networks, categorising them into 'worried and anxious', 'balanced', and 'motivated and committed'.

In the German context, two typologies of higher education students' media use can be identified. Using a factor analysis and based on a population of 2,098 students at 20 higher education institutions in Germany, Austria and Switzerland, four profiles were developed by Schulmeister (2010): Virtual/technical oriented (strong communication on the web, online games, data exchange, wikis, learning platforms, own website), high culture-oriented (museum, theatre, culture, concerts, classical music, reading), realistic (normal online use: e-mails, newspapers, sports) and sociable (TV, Pubs, Social Networks, Meeting Friends, Dining Out). Based on 2,339 higher education students at German higher education institution, Zawacki-Richter et al. (2015) identified four clusters: entertainment users, intensive users, peripheral users and utilitarian users. Typologies, as a way to synthesize the different ways in which digital media are used, offer a possibility to describe individuals on the basis of their actual use and not on socio-demographic characteristics e.g. age and gender. Research Question 4 in this study aims to show how the relation of these profiles to other variables associated with the students develops over time. On this basis, developments can be traced, and trends can be identified.

Methodology

Sample and Instrument

The present longitudinal study is conducted using a repeated cross-sectional design that – in contrast to a panel design, which provides repeated observations of the same sample over time (De Keulenaer, 2008) – allows to track changes at the aggregate level (Steel, 2008) – in this case at the level of German higher education students. An online questionnaire was conducted between April and June 2012 (N2012 = 2,317), April and June 2015 (N2015 = 1,327) and October and December 2018 (N2018 = 1,928). To exclude repeated participation cookies were set. In total, 5,572 higher education students from 42 different German higher education institutions participated in the study. The questionnaire was distributed via an e-mail list of the project directors and coordinators of the BMBF [German Federal Ministry of Education and Research] programme “Offene Hochschulen” [“Open Universities"]. The online questionnaire was shared through the homepage and the learning management system (LMS) of higher education institutions. Participation was voluntary and self-recruited.

The items and scales of the questionnaire focus on the access to digital media and mobile devices, students’ attitudes toward technology, the use of social networks (for learning), as well as demographic variables. For further elaboration on the questionnaire, please see Dolch (2020) and Zawacki-Richter et al. (2015). According to the dynamic development of digital media, the media, tools and services queried changed slightly over the nine years. Overall, 60 (N2012 = 49, N2015 = 51, N2018 = 57) media, tools and services according to the media typology of Grosch et al. (2014) were queried. Using likert scales, participants were asked how often they use those tools for studying (5 = almost every day; 4 = a few times a week; 3 = between once a week and once a month; 2 = less than once a month; 1 = never) and how useful the tools are for academic purposes (5 = very useful - 1 = not useful at all). Beyond that, participants were asked to assess how important the use of digital teaching and learning formats is for them (5 = very important - 1 = not important at all) and how often those formats are used at their higher education institution (5 = very often - 1 = not at all). The answers “I’m not familiar with that” or “I don’t know” are defined as missing values.

Table 2. Study subjects per survey year

Study subject	2012	2015	2018
Humanities and cultural sciences, Art	12% *n* = 258	14% *n* = 170	10% *n* = 164
Pedagogy, Sports, Psychology	11% *n* = 245	12% *n* = 153	10% *n* = 160
Economics and Law	22% *n* = 494	19% *n* = 243	24% *n* = 403
Social Sciences	15% *n* = 341	15% *n* = 183	9% *n* = 144
Mathematics, Natural and Agricultural Sciences, Veterinary Medicine	19% *n* = 419	17% *n* = 218	11% *n* = 180
Human Medicine, Health Sciences	2% *n* = 52	9% *n* = 116	4% *n* = 62
Engineering	18% *n* = 409	14% *n* = 180	33% *n* = 539

In all three years, about 60% of the participants were female and 40% were male. The surveys show no significant difference in the distribution of female and male participants ($\chi 2$ (*df* = 2; *n* = 2,564) = 0.995; *p* = 0.608). The average age in 2012 was 25 years (*SD* = 7.07, *Mdn* = 23), with students being between 17 and 61 years old. In 2015 the average age was 27 years (*SD* = 7.94, *Mdn* = 24), with students being between 17 and 69 years old, and in 2018 the average age was 25 years (*SD* = 6.65, *Mdn* = 23), with students being between 18 and 75 years old. At the time of all three surveys, students had studied five

semesters on average (2018: *M* = 4.80, *SD* = 3.75; 2015: *M* = 5.45, *SD* = 3.86; 2012: *M* = 4.80, *SD* = 3.39).

In 2012 and 2015, most of the students in the sample were studying subjects from the field of Economics and Law (see table 2). However, whilst there was in an increase in the number of students studying Economics and Law in 2018, most of the students (33%) in the sample were studying a subject from the field of Engineering (χ2 (*df* = 12; *n* = 5,133) = 314.42; *p* = .000).

In all three survey years, more than two thirds of participants were on campus students. Courses in a blended learning or fully online design were taken comparatively rarely (χ2 (*df* = 6; *n* = 5,279) = 39.96; *p* = .000) (see table 3).

Table 3. Type of study per survey year

type of study	2012	2015	2018
on campus	77 % *n* = 1,744	69 % *n* = 905	78 % *n* = 1,326
blended learning	8 % *n* = 185	11 % *n* = 147	8 % *n* = 141
online	3 % *n* = 73	5 % *n* = 67	3 % *n* = 54

Data Analysis

In addition to descriptive analyses and contingency tables, a number of univariate ANOVAs and t-tests were conducted to investigate differences in media usage behaviour in the three survey years. To take the premises of the ANOVA, especially to ensure the equal occupation of the cells, into account, a sample of *n* = 1,990 was drawn for the calculations (Field, 2018). For post-hoc analysis, the Games-Howell test was applied, which is suitable for variance heterogeneous data. To calculate effect sizes, partial eta-squared (η^2) (small: .01 ≤ η^2 < .059; medium: .059 ≤ η^2 < .138; large: η^2 ≥ .138) and Cramer's V (small: .1 ≤ Cramers's V < .3; medium: .3 ≤ Cramers's V < .5; large: Cramers's V ≥ .5) are used (Cohen, 1969). Cronbach's Alpha internal consistency coefficients (α) was calculated to assess reliability for the scales in the study (Streiner, 2003). The calculations were carried out using IBM SPSS Statistics 25.

To establish a typology of media usage patterns of higher education students, a latent class analysis (LCA) (Hagenaars & McCutcheon, 2002) was carried out. Like factor analysis, LCA is a structure-giving statistical method. Different from factor analysis, the latent variables in LCA are discrete and not metric. The LCA was performed using Latent Gold 4.0 software, which allows the analysis of latent class models based on manifest variables that have nominal, ordinal or metric scale levels. To estimate the parameters of class models the software uses maximum likelihood and posterior mode methods. Latent Gold provides a goodness of fit statistic to compare and select competing class models (chi-square statistics L2 and the model information criteria AIC (LL), BIC (LL) and CAIC (LL)) (see table 4). This information weight the fit and economy of a model (Vermunt & Magidson, 2005). 1 to 6 cluster solutions were calculated. The information criterion BIC (LL) meets its minimum with the 4-cluster solution. However, the p-value shows that the chosen model differs significantly from the available data. The analysis was therefore repeated using the bootstrap method considering all valid cases (*n* = 1715). This resulted in an insignificant p-value of .168. For a more extensive illustration of the establishment of the typology of media usage patterns of higher education students, we refer to Zawacki-Richter et al. (2015) and Zawacki-Richter et al. (2014).

Table 4. Overview of the 2 to 8 cluster models of LCA

Model	LL	BIC(LL)	Npar	L^2	*df*	p-value	Class. Error
1-Cluster	-9453.86	18997.09	12	952.32	243	$1.4e^{-84}$	.00
2-Cluster	-9185.32	18497.25	17	415.24	238	$9.1e^{-12}$	.10
3-Cluster	-9129.38	18422.58	22	303.34	233	.0013	.18
4-Cluster	-9110.39	18421.85	27	265.38	228	.045	.21
5-Cluster	-9101.12	18440.55	32	246.83	223	.13	.23
6-Cluster	-9094.48	18464.50	37	233.56	218	.22	.25

Limitations

This longitudinal study relates to German higher education students, which implies that the results are limited to Germany and might not apply to other regions but can still guide decisions or be used as an example in an international context. As data were collected using an online questionnaire that was distributed using institutional homepages and/or LMS, the sample is voluntary and self-selective and might be biased towards technically experienced students. However, the mentioned bias applies equally for all three survey years. Also, the questionnaire is based on self-reported answers from students, which means that memory, experiences or perceptions could influence their evaluations. Another limitation is that the data is up to 2018, and other findings could have emerged regarding the time afterwards. Nevertheless, by showing the development over nine years, the data make a relevant contribution to the field and can be further expanded in a three-year rhythm. Furthermore, the used Likert scales must be critically examined. Assuming that the intervals between the scale values can be interpreted as homogeneous, and that the interpretation leads to meaningful results in terms of content, the scales are used for parametric statistical procedures (Gardner, 1975). In addition, it has to be mentioned that the practical relevance of statistically significant results has to be interpreted with caution and critically examined if there are small effect sizes (η^2 and Cramer V).

Findings and Discussions

What kind of digital devices do the students own and how frequently and how long are they using the Internet?

In all three survey years, at least 99% of students stated that they have Internet access at home, and in 2018, 96% of participants reported access to mobile internet. The average amount of Internet usage increased over time, while the three survey years differ significantly ($F(2, 5067) = 88.65$, $p < .001$; $\eta^2 = .03$). The post-hoc analysis revealed significant differences ($p < .001$) between the three survey years. In 2012, students indicated they spent 3.8 hours ($SD = 2.28$) actively online per day on average, compared to 4.2 hours ($SD = 2.48$) in 2015, and 4.8 hours ($SD = 2.51$) in 2018. Of these 4.8 hours a day, students use the mobile Internet for 2.1 hours ($SD = 1.57$) a day.

Overall, students are well equipped with digital devices (see table 5). In all three survey years, they owned five different digital devices on average ($M_{2018} = 4.66$, $SD_{2018} = 1.70$; $M_{2015} = 5.07$, $SD_{2015} = 1.56$; $M_{2012} = 4.87$, $SD_{2012} = 1.42$).

There was a strong increase in the ownership of smartphones with Internet access, with a notable increase between 2012 and 2015 in particular. Furthermore, the possession of laptops continues to grow constantly, whereas fewer respondents over time owned a desktop PC. The decrease of printer and scanner ownership could be explained by the increased possession of mobile devices, such as notebooks, tablets and particularly smartphones, which removes the need to print or scan documents in many cases. Wearables and digital language assistants, which are fairly new devices, were added in 2018. With one fifth and one quarter of the students owning them, respectively, they show a relatively high level compared to tablets or e-book readers when they were ‘new‘ in 2012.

Table 5. Possession of digital devices in 2012, 2015 and 2018 (multiple answers possible)

digital device	2012	2015	2018
desktop PC	51%	42%	39%
printers	79%	76%	65%
scanner	64%	65%	58%
notebook/laptop	86%	92%	95%
netbook	24%	16%	n.q.
tablet computer	9%	39%	45%
e-book reader	7%	19%	21%
smartphone with Internet access	56%	91%	98%
mobile phone without Internet access	60%	25%	13%
MP3 player	75%	63%	n.q.
wearables	n.q.	n.q.	22%
digital language assistant (e.g. Apple Siri, MS Cortana)	n.q.	n.q.	27%

n.q. = not queried

In summary, there is a trend towards digital devices that can be used flexibly and location-independently (Initative D21, 2020; Statista, 2019b). This leads to the assumption that technology enhanced (online) learning increasingly takes place via mobile devices. The study of Lee et al. (2020) in the Malaysian context and the EDUCAUSE 2020 (Gierdowski et al., 2020) in the U.S. confirm a relevant students' readiness to use mobile devices for learning purposes, especially for accessing information. However, faculty banning smartphones in the classroom may be an obstacle to this possibility (Gierdowski et al., 2020). In addition, there is therefore a need for increased higher education teachers' professional development on how to create effective materials for students, alongside appropriate support structures for faculty.

Which media and e-learning tools and services are used for learning and what is their perceived value for learning?

Following Grosch (2014), the acceptance of digital media can be understood as a two-dimensional indicator for the quality of media use. Subsequently, Grosch (2014) suggests that the acceptance values for the 60 media, tools and services, result from the averaged ratings of the frequency of media use and the perceived usefulness of media for academic purposes ((Usage frequency + Perceived usefulness) / 2). The values range from 5 (high) to 1 (low). High acceptance values indicate that using the tool adds value to students' learning experience.

Search engines lead the list of acceptance for media, tools and services across all three survey years (see table 6). With the exception of chat/instant messaging and PDF readers, the top ten consist of the same media as in the previous years. Chat/instant messaging moved up from rank 13 in 2015 to second place in 2018. This rapid rise could be explained by the tremendous popularity of WhatsApp. With 79% of German internet users WhatsApp is the most used messaging service. For comparison Facebook messenger is used by 40% (Statista, 2019a). PDF readers, considered for the first time in 2018, directly hit rank six. Online translators (rank 16), VPN services (rank 21) and online calendars (rank 22), which are tools that were queried for the first time in 2018, are accepted quite well. The bottom of the list shows that the usage of Skype, RSS feeds and micro blogging are not important to higher education students, which has also been found in a range of other German (e.g., May et al., 2014; Persike & Friedrich, 2016) and international studies (e.g., Henderson et al., 2016). Interestingly, in contrast to previous research (e.g., Henderson et al., 2017; Newman & Beetham, 2017), lecture video recordings, which were ranked 12 in 2012 and ranked 34 in 2015, slipped to rank 43 in 2018. One explanation for this could be that after an initial 'innovation phase', higher education institutions do not (any longer) offer lecture video recordings in general or in many degree programmes. This leads to students not being able to use them, which in turn leads to students not knowing that lecture recordings would be helpful, which ultimately leads to low acceptance values. Other explanations could be that lecture video recordings have poor

quality or are too long to be beneficial for and well accepted by higher education students (see Bond et al., 2018).

Table 6. Ranked acceptance of media, tools and services in 2012, 2015 and 2018 (ordered by 2018)

2012	2015	**2018**		***n***	***M***	**Type[a]**
1	1	**1**	search engines	1,909	4.71	(K)
20	13	**2**	chat/instant messaging	1,885	4.50	(T)
6	5	**3**	word processing software	1,832	4.32	T
3	3	**4**	email account (external)	1,902	4.32	(T)
2	2	**5**	computer terminals outside of the university	1,759	4.30	
n.q.	n.q.	**6**	PDF readers	1,879	4.25	T
4	4	**7**	Internet based learning platform	1,688	4.10	
7	8	**8**	electronic texts (e-books, PDFs)	1,880	4.00	T
9	7	**9**	university email account	1,910	4.00	(T)
5	6	**10**	printed texts	1,887	3.87	(T)
13	12	**11**	mailing lists for courses	1,766	3.77	T
10	10	**12**	spreadsheet software	1,782	3.75	
8	9	**13**	presentation software	1,782	3.74	
18	19	**14**	videos (e.g. on YouTube)	1,877	3.63	
11	11	**15**	online library services	1,742	3.54	K
n.q.	n.q.	**16**	online translator	1,841	3.40	T
16	14	**17**	wikis	1,634	3.33	
14	17	**18**	social networks	1,869	3.28	
21	15	**19**	file storage/file sharing (external)	1,659	3.28	K
23	28	**20**	music (e.g. iTunes)	1,799	3.26	
n.q.	n.q.	**21**	VPN services	1,387	3.21	
n.q.	n.q.	**22**	online calendar	1,739	3.19	K
17	18	**23**	file storage/file sharing (internal)	1,398	3.15	K
15	16	**24**	computer terminals on campus	1,663	3.07	
31	21	**25**	cloud computing	1,141	2.92	K
29	23	**26**	reference management software	1,067	2.80	K
26	26	**27**	educational multimedia learning software of the university	875	2.80	
19	20	**28**	internal university forums	1,360	2.80	T
25	24	**29**	online exams/tests	1,249	2.72	
31	29	**30**	virtual seminars/webinars, synchronal	1,077	2.70	
28	22	**31**	statistical software	1,012	2.65	
24	27	**32**	graphics software	1,299	2.58	
22	25	**33**	forums/newsgroups	1,503	2.55	T
37	32	**34**	e-portfolios	712	2.50	T
41	38	**35**	presentation sharing (e.g. SlideShare)	1,063	2.38	K
30	31	**36**	educational multimedia learning software online (free)	808	2.37	
38	33	**37**	software for qualitative text analysis	673	2.37	
44	42	**38**	business networks	1,348	2.34	
n.q.	37	**39**	MOOCs	354	2.32	
n.q.	n.q.	**40**	collaborative writing	713	2.32	T
42	41	**41**	virtual labs	629	2.31	
33	35	**42**	podcasts/vodcasts	1,162	2.28	
12	34	**43**	lecture video recordings	1,162	2.28	
40	45	**44**	simulations or learning games	872	2.27	
39	40	**45**	video software	1,148	2.24	
n.q.	n.q.	**46**	mindmap tools	864	2.23	
36	39	**47**	audio software	1,003	2.20	
35	44	**48**	blogs	1,553	2.17	
n.q.	43	**49**	etherpads	450	2.15	T
n.q.	n.q.	**50**	QR code scanner	1,614	2.07	
27	30	**51**	Skype (1:1 call)	1,558	2.06	
45	48	**52**	photo communities	1,697	2.02	
32	36	**53**	Skype (conference call)	1,511	1.99	
n.q.	n.q.	**54**	audience response tools	601	1.99	
43	46	**55**	RSS feeds	735	1.86	K
n.q.	n.q.	**56**	digital voice control (e.g. OK google, Siri, Alexa)	1,656	1.79	
46	47	**57**	micro blogging (e.g. Twitter)	1,577	1.56	T
47	49	n.q.	social bookmarking			(K)
48	50	n.q.	geo tagging			

49	51	n.q.	virtual worlds (e.g. Second Life)

n.q. = not queried

[a] media type according to Bower (2016): T = text-based tools,
K = knowledge organization and sharing tools,
( ) = excluded from scale to improve reliability

It is noteworthy that, compared to 2015, computer terminals (i.e. desktop computers) on campuses (rank 24), as well as internal university forums (rank 28), lost eight ranks in 2018. That computer availability on campuses became less important is accompanied by the finding that more and more students (95% in 2018) own their own laptop and are less dependent on desktop computers on campus. The finding that PDF readers, electronic and printed texts and the Internet based learning platform show equally high acceptance values, indicates that printed materials are still relevant, and content should be provided using different channels and devices. Prendes et al. (2016) also found that "students still prefer analogical formats for their work and learning activities" (p. 19).

To broaden this quite detailed view on the acceptance of various digital media, tools and services, the frequency of use of different types of tools is further examined. As the media typology of Grosch et al. (2014) divides media, tools and services quite roughly, and taking into account that existing tools and ways of structuring them have changed over the past nine years, the research team decided to employ selected types of Bower's (2016) typology of learning technologies. Assuming that "the type of learning that results from the use of the tool is dependent on the task and the way people engage with it rather than the technology itself […], the typology is presented as descriptions of what each type of tool enables" (Bower, 2016, p. 774). This function-orientated classification builds a solid foundation to further investigate the media usage patterns of higher education students (Lai & Bower, 2019).

The composition of the scales frequency of use of text-based tools (α = .78) and frequency of use of knowledge organisation and sharing tools (α = .74) is indicated in the column 'Type' in table 6. Text-based tools are tools that enable synchronous and asynchronous authoring, reviewing of texts (e.g. etherpads) as well as discussions (e.g. forums). Knowledge organisation and sharing tools enable all kinds of storing (e.g. cloud computing), organising (e.g. library services) and sharing (e.g. SlideShare) information respectively content. For supplementary illustration on the typology of learning technologies, we refer to Bower (2015).

The survey year has a significant influence on the frequency of use of text-based tools ($F (2, 5234) = 17.01$, $p < .001$; $\eta^2 = .01$), as well as on the frequency of use of knowledge organisation and sharing tools ($F (2, 5076) = 84.33$, $p < .001$, $\eta^2 = .03$). For text-based tools, post-hoc analysis shows significant differences between 2018 ($M = 2.63$, $SD = 0.52$) and the previous year ($p < .001$), but not between 2012 ($M = 2.55$, $SD = 0.55$) and 2015 ($M = 2.53$, $SD = 0.55$). The use of text-based tools increased in 2018. For knowledge organisation and sharing tools, post-hoc analysis revealed significant differences between all three survey years ($p < .001$). A consistent increase of the frequency of use of knowledge organisation and sharing tools from 2012 ($M = 1.94$, $SD = 0.62$) to 2015 ($M = 2.21$, $SD = 0.64$) to 2018 ($M = 2.22$, $SD = 0.68$) can be identified. In contrast to these results, it has been observed that the frequency of use of printed texts decreased from 2012 ($M = 3.95$, $SD = 0.98$) to 2015 ($M = 3.75$, $SD = 1.00$) to 2018 ($M = 3.41$, $SD = 1,09$) ($F (2, 5229) = 137.88$, $p < .001$; $\eta^2 = .05$). Post-hoc analysis revealed significant differences between all three survey years ($p < .001$). These results indicate that higher education students used digital tools progressively and that printed texts seem to become less important along the years, but are still present within the ten most accepted tools (see table 6). Furthermore, with $M_{2018} = 3.41$, the frequency of use of printed text is higher than the use of text-based or knowledge organisation and sharing tools.

Taking the trend towards using flexible digital devices into account, reasons for students to use their mobile devices were investigated (see table 7). In 2012, 84% of students used their mobile device to write SMS to other students. By 2018, this amount had decreased to 36% and the use of instant

messaging services like WhatsApp became more popular (88% in 2018). This trend is also evident when looking at the changes in the frequency of use of chat/instant messaging from 2012 to 2018 (F (2, 5124) = 1191.44, $p < .001$; $\eta^2 = .32$). Post-hoc analysis shows significant differences between all three survey years ($p < .001$). The frequency of use of chat/instant messaging constantly increased from 2012 (M = 2.70; SD = 1.46) to 2015 (M = 3.13; SD = 1.56) and from 2015 to 2018 (M = 4.67; SD = 0.87). The very high mean value in 2018 pleads for a high diffusion of chat/instant messaging services like WhatsApp for higher education students, which has also been shown to increase student achievement, motivation and success when used for teaching and learning (e.g., Cetinkaya, 2017). However, it is important that both educators and students first understand how to use WhatsApp to support their learning (Gasaymeh, 2017), including through establishing appropriate language and boundaries, especially in light of privacy concerns (Tang & Hew, 2017). Furthermore, it is notable that, with the exception of sending SMS and access to social networks, for all other queried ways of using mobile devices, more students had started using them by 2018 (see table 7). This indicates that mobile devices, especially smartphones, integrate the functions of other devices (e.g. MP3 player) and can be used for multiple purposes. This so-called convergence of media, tools and services has led to a situation in which a distinction between online learning and mobile learning has no longer made sense for some time (Ally, 2009; Brown, 2004).

Table 7. Usage of mobile devices for studying in 2012, 2015 and 2018 (in %; multiple replies possible)

mobile activity	2012	2015	2018	Difference (2018 - 2012)
send SMS to students	84%	61%	36%	-48%
library services	28%	45%	53%	25%
collect data for assignments	24%	35%	48%	24%
research for assignments, presentations, etc.	45%	55%	69%	23%
send e-mails to teachers	51%	65%	74%	23%
listen to music while learning	27%	31%	49%	22%
book courses	39%	46%	57%	18%
look up grades	55%	66%	69%	14%
take pictures	66%	70%	78%	12%
writing texts for assignments	6%	11%	18%	12%
buy books	24%	30%	35%	11%
search the Internet beyond courses	76%	81%	86%	10%
access the learning platform	68%	75%	78%	10%
access social networks (e.g. facebook)	73%	66%	66%	-7%
search the Internet during classes	71%	71%	74%	4%
post texts or pictures	41%	41%	45%	4%
send e-mails to students	70%	72%	73%	3%
location-based services	9%	7%	12%	3%
communication via the LMS	36%	41%	38%	3%
send SMS to teachers	8%	13%	9%	1%
instant messaging (e.g. WhatsApp, Threema)	n.q.	n.q.	88%	
phone calls	n.q.	n.q.	74%	

The decrease and respectively stagnation of using mobile devices to access social networks (73% in 2012, 66% in 2015 and 2018) equals the undulating development of the proportion of students who started being active on social networks, predominantly Facebook. Compared to 80% of students in 2012, and 79% in 2015, 84% of students were active on social networks in 2018. Likewise, the frequency of use of social networks alternates over the three survey years (F (2, 5205) = 28.16, $p < .001$; $\eta^2 = .01$) and significant differences ($p < .001$) between the survey years can be found (M_{2012} = 3.52; SD_{2012} = 1.60; M_{2015} = 3.29; SD_{2015} = 1.56; M_{2018} = 3.71; SD_{2018} = 1.55).

In summary, the results show that, with the exception of the rapid rise of chat/instant messaging, acceptance – i.e. the value attached to the various media for learning – remained relatively consolidating between 2012 and 2018. Chat/instant messaging, in the German context especially WhatsApp, seems to be a 'big player' that has to be considered when designing teaching and learning in higher education. The constantly increasing use of text-based tools and knowledge organisation and sharing tools also indicates that these tools should play a certain role higher education. In contrast, social networks seem to play a minor role. This perhaps mirrors the finding by Pensel and Hofhues (2017), Steffens et al. (2017) and Prendes et al. (2016), that educational technology is being used by students more as supplemental learning support, rather than profoundly changing teaching and learning.

What is the difference between the supply and demand of digital teaching and learning practices offered by higher education institutions?

In addition to the frequency of use and the perceived usefulness, students were asked how important the use of digital teaching and learning practices is to them, and how often those formats are used at their higher education institution. The importance of the use of digital teaching and learning practices recorded in this way can be seen as a need (target), and the indicated frequency of use as the available offer (actual). To compare the items, z- standardized values were used. A positive value is an indication of a demand and a negative value indicates that the requirement has been exceeded. The difference (Δ) between the need and the available offer of digital teaching and learning practices (see table 8) illustrates that there is a demand for web-based training, online exams and exercises, as well as lectures as podcasts or vodcasts. In all three survey years, the largest demand was recorded for web-based training. This shows that higher education students desire such offers and expect them to be beneficial for their learning. It should be emphasised, that the demand for lectures as podcasts or vodcasts was largely met in 2012 and 2015, but considerably increased in 2018. An increased demand means that the higher education students consider lectures as podcasts or vodcasts as important for their learning, but these are not made available in sufficient frequency by higher education institutions in 2018. Together with the finding that the acceptance of lecture video recordings dropped from rank 12 in 2012, to rank 34 in 2015, to rank 43 in 2018 (see table 6), a deficit in the provision of lectures as podcasts or vodcasts at German universities can be derived in 2018. If recordings are not made available, they cannot be used by students, and therefore they cannot be considered useful. Given that previous international studies have found that students value lecture recordings (Henderson et al., 2017; Newman & Beetham, 2017), and its timely access (Killen & Langer-Crame., 2020), consideration should be given by institutions to providing infrastructure and appropriate professional development to lecturers to facilitate this, including data protection and ethics (Selwyn, 2016). The demand for online exams and exercises was largely met in 2015, but not in 2012 and 2018. However, it is important to be mindful that online assessment tools have been found to lead to increased disengagement (Bond et al., 2020), and therefore students should be provided with sufficient training prior to implementation.

For all other digital teaching and learning practices, the need is covered, although, with the exception of materials accompanying courses, the (negative) values are small ($|\Delta| \leq 0.20$). Considering that a higher education student has to know and to gain experience with digital teaching and learning practices to be able to consider it important for their learning, it can be assumed that the range of digital practices of teaching and learning at higher education institutions is capable of expansion. Only for materials accompanying courses is the need exceedingly fulfilled in all three survey years.

Table 8. Demand for digital teaching and learning practices 2012, 2015, 2018 (z-standardised values)

	2012			2015			2018		
	n	Δ	***SD***	***n***	Δ	***SD***	***n***	Δ	***SD***
materials accompanying courses	2,157	-0.49	0.52	1,244	-0.52	0.50	1,675	-0.51	0.56
interactive multimedia	1,884	-0.003	0.82	1,123	-0.02	0.80	1,512	-0.05	0.84
virtual seminars and tutorials	1,714	-0.01	0.83	1,026	-0.04	0.82	1,432	-0.01	0.85
lectures as podcasts or vodcasts	1,823	0.05	0.88	1,037	0.01	0.88	1,396	0.11	0.90
virtual internships and labs	1,441	-0.15	0.76	817	-0.17	0.76	1,182	-0.11	0.80
online exams and exercises	1,845	0.13	0.87	1,087	0.03	0.85	1,499	0.13	0.84
web-based trainings	1,577	0.20	0.87	917	0.15	0.90	1,302	0.19	0.88
e-portfolios / learning logs	1,390	-0.06	0.82	833	-0.11	0.81	1,159	-0.04	0.83

What kind of different media usage types can be identified?

By using a latent class analysis (LCA) (Hagenaars & McCutcheon, 2002) a typology of media usage patterns was established based on the survey data of 2012 and transferred to the data of 2015 and 2018 (Zawacki-Richter et al., 2015). The following four scales have been included in the LCA: use of e-learning tools (e.g. virtual seminars), recreational use of the Internet (e.g. music download/streaming), acceptance of office software and use of social networks for learning (e.g. forming study groups) (Zawacki-Richter et al., 2015, pp. 146). The four identified media usage types were labeled entertainment users, peripheral users, intensive users and utilitarian users. Figure 1 shows the distribution of media usage types in the three survey years. A significant difference can be observed between the survey years ($\chi 2$ (6, n = 3,781) = 150.17, p = .000; Cramer's V = .14).

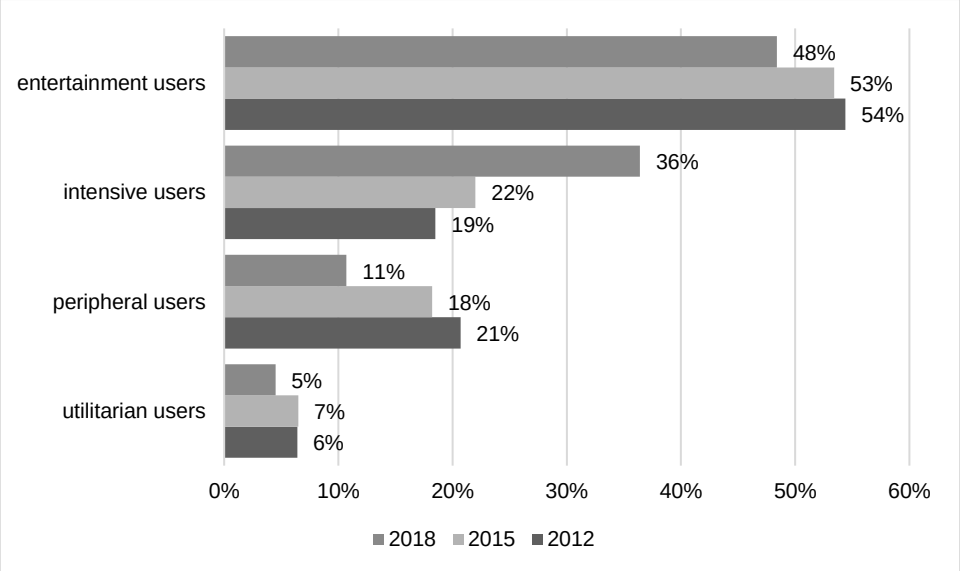

Figure 1. Distribution of media usage types in 2012 (n = 1,596), 2015 (n = 920) and 2018 (n = 1,265)

Approximately half of the students can be assigned to the group entertainment users in all three survey years, whereby in 2018 with 48%, a decline of 5% or rather 6%, compared to previous years, can be noted. Compared to the three other media usage types, entertainment users use the Internet quite often for leisure purposes. In particular, they use social networks frequently for their studies. The acceptance of office software, and the usage of e-learning tools and services, are likely to be minor for this group. Among intensive users, the use of social networks for their studies, leisure Internet use and especially

the use of e-learning tools is strongly pronounced. With 36%, the group of intensive users considerably increased in 2018, while the group of peripheral users decreased to 11% of participants. Peripheral users show the comparatively lowest frequency of use and acceptance of all media, tools and services. With 5%, a slight decrease can be stated for utilitarian users, too. Utilitarian users accept office software higher than all other groups. They also use e-learning tools comparatively often, while the study-related use of social networks and the leisure-related use of the Internet are less important for them (Zawacki-Richter et al., 2015).

Based on the increase in the group of intensive users and the decrease in the group of entertainment users, a trend toward using e-learning tools can be assumed. Furthermore, the use of social networks as well as leisure-oriented use, play a major role in those groups compared to the other two. This leads to the assumption that educational technologists should improve and develop e-learning tools and also should have the use of social networks and recreational tools for teaching and learning in higher education in mind.

Conclusion and Suggestions

The aim of this study was to investigate dynamics and trends of students' media usage patterns for learning, in the context of German higher education, by means of a longitudinal analysis conducted in 2012, 2015 and 2018. Even though our results are limited to the German context, they are of international interest as an exemplary development of the digitization of higher education. Based on the developments revealed in this longitudinal study, and the implications for the development and use of educational computer systems, an informed handling of developments in other educational systems can be supported.

Overall, it can be concluded that students are well equipped with all kinds of digital devices and hardware. Already in 2012, over 99% had access to the Internet at home, and there is a clear trend towards mobile devices that enable learning anywhere and anytime; the digital divide is not an issue for German students in higher education, which is similar in other countries (e.g. Killen & Langer-Crame, 2020). In terms of the acceptance of digital media, tools and services for learning, a stunning result of this study is that the acceptance of e-learning tools is overall consolidating, meaning that, with some exceptions, tools that were ranked high in 2012, still rank highly in 2018, and tools that were ranked low can still be found at the bottom of the list (see table 6). One noteworthy exception is the climb to second place by chat/instant messaging in 2018. This can be explained by the tremendous popularity of WhatsApp in Germany. A second noteworthy exception is that lecture recordings have continuously dropped from twelfth to 43rd rank, which is consistent with the increasing demand for lectures as podcasts or vodcasts. As an explanation, it can be assumed that higher education students may not be aware of the potential usefulness of them. However, in the current practice of Emergency Remote Teaching (Hodges et al., 2020) during the COVID-19 pandemic, video-based teaching and conferencing are widely used in Germany (e.g. Skulmowski & Rey, 2020). Based on this experience, it is to be expected that video-based learning will gain higher acceptance rates in terms of the frequency of use and perceived usefulness for learning.

The relative restraint in the use of digital media for learning and teaching at German universities is in line with the current Index of Readiness for Digital Lifelong Learning, published in November 2019 by the Centre for European Policy Studies (CEPS, 2019). Germany is in last place of all EU-27 countries, which is due to under-investment in digital infrastructure, but also related to sceptical attitudes towards digital technologies that are often perceived as a threat rather than as an opportunity for innovation and change. However, the data shows a demand for digital and flexible learning opportunities, especially for web-based training, online exams and exercises, as well as lectures as podcasts or vodcasts, which is hardly met by German higher education institutions, with the full potential of interactive and collaborative online learning, that goes beyond the uploading of lecture slides, not being exploited. Also, the

development of the distribution of the media usage types shows that a trend towards an increased need for e-learning tools and the use of social networks and leisure-orientated activities for learning can be anticipated. Due to the increasing frequency of use of text-based tools and knowledge organisation and sharing tools, it can be assumed that they are particularly important for the design of digital learning opportunities in higher education institutions.

Based on these findings, educational technologists and decision makers within higher education institutions are encouraged to accelerate the provision of (digital) text-based tools, such as e-books, online translators or discussion forums, as well as knowledge organisation and sharing tools such as file sharing, cloud computing or reference management software. This recommendation is in accordance with a systematic review with an international scope by Bond et al. (2020). Furthermore, the use of web-based training, lecture video recordings and online exams / exercises should be focused on and further developed by higher education institutions in Germany. However, to avoid overload and consequent disengagement, students should be adequately prepared for the use of these tools (Bond et al., 2020; Gonzalez et al., 2019). To ensure a meaningful and appropriate use of digital media in higher education, it is essential to not only prepare students but, in particular, to train and support faculty and upgrade infrastructures (Koh & Kan, 2020).

This longitudinal analysis provides valuable data and a more differentiated understanding of how higher education students are using digital media for learning over a time period of nine years. This type of data is unique for the German higher education context (see Autorengruppe Bildungsberichterstattung, 2020). It enables policymakers and administrators to adequately develop digitization strategies responding to the student's demands for digital tools to support their learning. In implementing digital media to enhance teaching and learning, instructional designers and faculty members can make better-informed decisions with regards to media selection in the learning design process, based on the knowledge of students' media usage behavior. Although this study is based on German university students, implications derived from this study may prove to be useful for other higher education contexts. In addition to a continuation of the longitudinal study to trace and anticipate developments, future qualitative analyses can contribute to deepening the knowledge of higher education students' preferences and use of digital media. Such results can especially contribute to a pedagogically meaningful implementation of digital teaching and learning. As a concluding remark, the use of digital media should be avoided for the sake of using media and a demand-oriented use of digital media should be fostered. However, that does not mean that other technology-enhanced learning approaches cannot be explored, if they are oriented towards improving teaching and learning, and ensuring flexible and device-independent learning pathways.

The data for this study were collected in the pre-Corona era. As in all other areas of society, COVID-19 has also had a huge impact on German higher education institutions. Without any possible careful planning and professional development, the transition to online learning was made within weeks in April 2020. Representative studies on the practice of Emergency Remote Teaching are not available for Germany: "It seems that we probably will not have this data in the near future, because planned or approved projects on the topic do not seem to be in sight" (Kerres, 2020, p. 3). At this point, it is not clear if COVID-19 will be an accelerator for the digitization of German higher education in general and if it will have a sustainable impact on students' media usage behaviour for learning in particular. Therefore, the team of authors is planning further data collection, hopefully shortly after the full re-opening of universities in April 2021 and later in 2024, to assess the longer-term effects of remote teaching and learning.

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Declarations of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data statement

The data of the present study is available upon request. Please contact to the corresponding author.

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