Digital divides in nursing students: an exploration of the relationship between self-perceived digital competencies and digital barriers.

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Abstract

Purpose

In the context of Higher Education nursing education, digital competencies are increasingly recognised as a necessary skillset, within a continuously evolving healthcare professional landscape. This study sought to explore nursing students' digital competencies and to further understand the digital literacy gaps and barriers they encounter for both learning and future work.

Design/methodology/approach

The research involved a cross sectional, discipline-based empirical study of nursing students' self-assessed digital competencies via a questionnaire survey, which collected quantitative and qualitative data from a total of five hundred and fifty-three students. The study explored the role of demographics (age, urban/rural geographical location of growing up, study year, learning disabilities (neurodiversity) and experiences of digital divides (e.g., access, contextual and behavioural barriers) play on students' digital competencies and outcomes.

Findings

Students' digital competencies were found at intermediate level with younger and first year students self-assessing higher. Significant differences were identified between students who had encountered digital barriers/divides and those who had not, with the former, self-reporting lower digital competencies. Students with learning disabilities reported complex support needs for processing and organizing digital information and for productivity. Almost all the individual digital competencies items assessed had strong statistical correlations between them.

Originality

The research offers key recommendations for academic libraries for the on-going, evolving exploration of students' digital competencies and for the need to follow tailored, discipline-related, holistic, practice-based and curriculum embedded approaches to students' digital skills development and support. It provides novel insights into digital competencies development for nursing students and particularly those who experience digital divides.

Introduction

Within the context of university nursing education, digital competencies are increasingly recognised as a necessary skillset for studying, keeping up with technological advancements (Harrison, 2024; RCN, 2024) and developing an "ability to adapt and innovate" (Hughes 2024), preparing students for the future healthcare professional landscape and for roles that demand digital skills in the provision of effective nursing care (Isidori *et al*, 2022; RCN, 2021). The rapid digital transformation caused by the pandemic necessitated digital competence development needs in both nursing education and practice with changes that are "likely to be sustained", while the need for nurses who have "digital expertise and the ability to lead change is increasing exponentially" (NHS England, n.d.). Within the next two decades, most jobs in the UK National Health System (NHS) will have a digital component, as staff navigate a data-rich healthcare environment and develop digital competence skills for fast growing technologically enhanced work settings (Topol Review, 2019) dealing with increased digital data (Capgemini, 2022) and a "digital future" that "is already transforming the way nursing care is delivered" (RCN, 2024). A priority area for the health and care sector is, therefore, "when, why and, crucially, how to use digital", with essential digital workforce development (Scottish Government, 2021).

The Code of the Nursing and Midwifery Council (2023) identifies digital skills as integral for all registered nurses, however, a lack of formal digital competencies training structure in nursing education results in fragmented digital knowledge and experiences (De Leeuw *et al.*, 2022). Frustration with new and ongoing integration of technology and lack of confidence/skills with healthcare technology is associated with emotional exhaustion among nurses in practice (Tawfik *et al*. 2021). Among nursing students, who prepare for increasingly digitalised future careers, the existence of digital divides also creates significant challenges (Saeed and Masters, 2021). Despite the widespread presence of digital technology in nursing students' lives, students still experience gaps even in baseline digital literacy (NMC, 2023). For example, targeted digital literacy education interventions around technology-enhanced learning and simulation are needed as part of foundational nursing studies to improve nursing students' baseline digital literacy before commencing clinical placement (Lokmic-Tomkins *et al*., 2022).

To realise the true potential of digitally enabled health and social care services, it becomes necessary to develop a unified and concentrated effort to transform the education and skills provision for those working in delivering health and social care (Morrison *et al*., 2022). This necessitates a deeper and on-going exploration of nursing students' development needs and readiness to apply digital skills within a constantly evolving nursing education and professional environment.

Academic libraries have established expertise in developing subject support for nursing and offering training for students on the basis of health information literacy (Purnell, Royal and Warton, 2020), such as how to identify database search techniques across different health related sources, using effective search approaches (e.g., Boolean operators and advanced searching), and how to evaluate and ethically use information following referencing standards and academic integrity. However, health information literacy is also a crucial professional skill for the delivery of evidence-based health information services (e.g., systematic literature reviews). Academic libraries have been supporting nursing students to develop different digital skills to navigate broader technological developments, from using internet search engines and Web 2.0 to sourcing and analysing big data and to the use of digital health services for their potential to advance clinical practice and the delivery of patient care as well as the current focus on the ethical use of generative artificial intelligence for information discovery (e.g., using AI Search Tools). Davenport and Kalakota (2019) discuss the opportunities created by Natural language processing (NLP) in the health professional environment for "understanding and classification of clinical documentation and published research" for the purpose, for example, of analyzing unstructured clinical notes, reports and patient interactions. Academic libraries empower students to engage with technology, explore digital content, and develop their digital literacy skills. Increasingly, academic libraries have also started to develop support and guidance in the form of LibGuides that focus on navigating the artificial intelligence (AI) landscape. For example, the University of Cambridge libraries offer guidance on the use of AI answering questions such as which AI tools to use, how to get the best results from AI and how to reference AI tools (University of Cambridge 2023). Subject specific Libguides in health developed by academic libraries, aim to increase awareness of how it is currently transforming

healthcare with new applications and advancements which enhance health related clinical practice and as well as evidence-based research (e.g., systematic reviews) (Khalil, Ameen, & Zarnegar, 2022). For example, King's College Libraries and Collections (2024) offers access to AI tools for evidence synthesis providing resources for health students on AI tools and how to use them for learning, research and healthcare related practice.

However, developing library support and implementing digital skills programmes necessitates understanding of students' existing digital skills gaps. Not all students arrive to education with the same digital skills and competencies and therefore, ongoing critical exploration of existing digital divides and needs is crucial for offering meaningful digital literacy programmes and support.

Literature Review

Recent research exploring the development of nursing students' digital skills or competencies has found variability in focus and directions (Matthews 2021; Nes, 2021) and a lack of a holistic approach to digital literacy skills development in academia. For example, in a scoping review of technological literacy in nursing education, Nes identified several different foci, including computer literacy, health/nursing informatics and technology acceptance, while a direction towards higher level digital skills, such as problem-solving and critical thinking was omitted. Similarly, Harerimana *et al*. (2022) highlighted a need to incorporate digital literacy education beyond basic computer, internet and digital device use–related skills, while Brown *et al*. (2020) noticed the lack of advanced/more specialised digital skills for transferal to the clinical/care working environment. Other research has emphasised gaps in students' knowledge on eHealth literacy (Holt *et al*., 2020; Jeon and Kim, 2022; Mather *et al*., 2022; Blakemore *et al*., 2020) and students' attitudes to technology (Lekalakala-Mokgele *et al*., 2023). However, overall, studies are inconclusive as the methodologies and measurements followed are either dissimilar or focused on different digital skills required (Erdat *et al*., 2023).

Bove and Sauer (2023) explored levels of knowledge and skills that nursing academic staff should possess to teach their students, and the need for both educators and nursing practitioners to embrace AI-enabled innovations to "lead the digital future" (Castonguay *et al*., 2023). The need for continuous education has been identified for years as a priority in the European agenda to digitize healthcare (European Health Parliament, 2016, p.8) with a call for mandatory, continuous and tailored training programs on digital skills. At UK level, however, although "Digital health is a high priority in government, NHS organisations and Royal Colleges" there is a gap between expectations around digital skills development and the actual implementation of education within school curricula and training for staff via professional development activities. Post pandemic, the need for digital health education is even greater with remote health consultations and digital health solutions (Holland Brown and Bewick, 2022, p.214).

Despite the urgent call for the ongoing development of digital skills, "digital divides" amongst the health and social care workforce (including nurses) still exist. For example, in relation to the geographical interest of this study, NHS Education for Scotland indicates a digital literacy skills gap in the healthcare sector, with key findings from a large-scale digital skills user research study (Digital Health and Care, 2022), which indicates both a lack of digital skills training and agreed terminology which can result in digital exclusion, manifested though lack of engagement or confidence, competence and access (Capgemini, 2022).

To support nursing students building digital competencies as future professionals operating within a complex digitally enabled health arena, a holistic understanding of digital skills, gaps and barriers is required, focusing on moving from baseline to more advanced digital literacy skills development and to an effective transition towards technologically advanced health working environments (Lokmic-Tomkins *et al*. 2022). This study therefore aims to offer a better understanding of nursing students' different levels of digital competencies and explore how digital exclusion experiences may play a role in the way in which they develop them.

Aims and Objectives

This research presents an approach that aims to explore students' diverse digital competencies that are key for learning and for supporting a digital evolving professional environment, as well as examine students' diverse experiences of digital divides. Specifically, the research addresses the following objectives:

1. To explore how nursing students self-assess their digital competencies for nursing related learning and professional practice.
2. To examine nursing students' digital barriers/divides related to technological access and connectivity (first level divide), digital competencies development (second-level divide), and digital outcomes (third-level digital divide)
3. To identify the impact of students' demographic divides on their digital competencies' development.

In relation to Objectives 2 and 3, two working hypotheses were put forward:

H1. Self-assessed digital competencies of students will be correlated with students' experienced digital divides/barriers (age, learning disabilities (neurodiversity), urban/rural geographical location of growing up and study year).

H2. Self-assessed digital competencies of students will be correlated with demographic differences (age, learning disabilities (neurodiversity), geographical location and study year).

Methodology

This study followed a cross-sectional survey of nursing students by means of an online questionnaire administered to all students studying in undergraduate (Year 1, 2 and 3) and postgraduate nursing courses within a single Scottish HE institution. The questionnaire instrument collected quantitative and qualitative data in a concurrent mixed methodological survey design, with a) closed ended questions exploring students' demographics (age, learning disabilities (neurodiversity), urban/rural geographical location of growing up and study year), students' self-perceived digital competencies, and digital divide barriers and b) open-ended questions which aimed to examine, in more detail, challenges and strategies of students with learning disabilities/neurodiversity.

Digital competencies

The main position of this research is that students do not arrive at university with the same digital competencies and that it is important to consider the issue of "widening participation" and "digital inclusion" in nursing education. Previous research with students has found that they have positive attitudes and feel competent towards information and communication technology use in clinical practice to support care values and work efficiency (Warshawski *et al.,* 2019). However, not only the digital environment is constantly evolving, but also more recent studies have extended a focus on technological skills to cover additional areas of digital capability that have a behavioural and "soft skills" focus, encompassing digital "learning and development", "identity and wellbeing", "problem solving and innovation", "information, data and media literacies" and "digital communication, collaboration and participation". These emphasise the importance of improving students' digital capabilities to enhance their self-efficacy, confidence and self-actualization in their academic studies (Ibrahim and Aldawsari, 2023).

In this study, we utilised an empirically tested digital competencies self-assessment survey tool that was adapted based on the European Digital Competence Framework for Citizens (Carretero *et al*., 2017) and The Digital Capabilities framework (JISC, 2022) to holistically explore digital competencies from a nursing-based perspective. The survey explored digital competencies within everyday life, nursing related education and practice, addressing nursing related digital competencies with examples from the context of nursing: for example, the use of health related information sources (such as CINAHL,

Medline, Cochrane Library), the application of digital creation skills in nursing (such as those for using simulation/virtual reality tools and discipline specific apps, e.g., BNF British National Formulary) and for the use of health digital research skills (such as those for using health specific critical appraisal tools, e.g., Critical Appraisals Skills Programme (CASP) and evidence-based research tools). The structure and the dimensions of the questionnaire survey are available in Supplementary_material_appendix_A, Table A1. The survey measurement was based on a five-point Likert type scale of digital competencies which represented different levels of knowledge and self-sufficiency based on performing specific digital tasks (Supplementary_material_appendix_A, Table A2).

Digital barriers/divides

Wei, Chan and Tan (2011) highlight three potential levels of digital divide including access to information technology (first level divide), digital capability (second-level divide), and digital outcomes (third-level digital divide) which relate to learning and productivity. In relation to first level divides, data in the survey were collected on information technology access barriers experienced by students related to an urban/rural divide (up to the time of finishing school), such as lack of access to electricity, and access to basic computer training, broadband, desktop computers/laptop, and smart mobile phones use (Sparks, 2013, p.28; DiMaggio *et al.* 2010; Wei, Chan and Tan, 2011). Second-level divides were explored by means of identifying self-assessed digital competencies gaps, described above, which were further elaborated based on contextual and behavioural barriers students experienced in developing them, such as lack of time, up-to-date training in specific digital skills (Gilmour *et al*., 2008) and students' interest, urgency, confidence and their perceptions of difficulty around developing these skills. These questions helped to explore more holistically intersecting digital divides variables that may play a role in students' digital competencies development.

Third-level digital divides were explored via an overarching question that addressed students' overall digital abilities to fulfil academic outcomes (Supplementary_material_appendix_A, Table A1).

Age demographics divides

The impact of age demographics, may be difficult to delineate with different studies following diverse ways of categorising age groupings (Dimock, 2019). This study focused on a binary categorisation, given the focus of the research on digital skills and digital connectivity: students born before the year 2000 and students born in that year or after (which characterises approximately the start of Generation Z learners) (Shorey *et al*., 2021). The change of the millennium marked an important technological shift in everyday life digital access and interaction, with the widespread adoption and use of the Internet, digital technologies and social media. People born after the change of the millennium had experiences of growing up in a more technologically saturated world and this may have shaped up for them different online experiences. Prensky describes these individuals as 'Digital Natives', in other words the "native speakers" of the digital language of computers, video games and the Internet" and the first generation to grow up with these new technologies (2001a; 2001b). In a literature review of 80 studies, Alruthaya, Nguyen and Lokuge (2021) reported on different research where Gen Z students were found "to be able to access digital technologies more than other generations" (Sakdiyakorn *et al*., 2021), noting a preference towards visual versus textual information (Hernandez-de-Menendez *et al*., 2020). Other studies focusing on nursing students have reported differences in both everyday life digital activities, such as using daily social media (Vizcaya-Moreno and Pérez-Cañaveras, 2020) and preferences for specific learning approaches, such as experiential learning, independent learning and use of multimedia (Hampton and Keys, 2017).

Learning disabilities (neurodivergence) divides

The study also sought to explore potential first and second-level digital divides within the underrepresented 15-20% neurodivergent student population (Doyle, 2020). Despite the high incidence of neurodivergence in students attending universities internationally (which is growing), there appears a dearth of neurodivergent pedagogical literature (Hamilton and Petty 2023).

Neurodiversity "is an umbrella term that represents the neurological variability of the human brain" which includes many terms such as autism, attention-deficit/hyperactivity disorder (ADHD), dyslexia, dyspraxia, epilepsy, and obsessive-compulsive disorder (Lukava, *et al*., 2022 p.76) and can be formally diagnosed or a self-reported protected characteristic (Equality Act, 2010). Although there are various statistics, it is suggested that 15-20% of the population is reported as neurodivergent (Doyle, 2020).

Students were asked to first indicate if they had a neurodivergent condition (actual or suspected) in one or more of the following areas: autism, dyslexia, dyspraxia, dyscalculia, dysgraphia and Attention Deficit Hyperactivity Disorder (ADHD). Following that, the students were asked to explain if they encountered any problems, difficulties or barriers when completing digital tasks/using digital tools related to their study. Finally, students were asked to list any apps, programmes, or digital tools that helped them as a neurodivergent person or any other elements that supported their life or learning that they felt might also be useful to others (e.g., for accessibility, time management, study organisation/prioritisation, visualisation).

Divides related to rural/urban experiences of growing up

The presence of a "urban/rural digital divide" is "widely acknowledged" in previous research (Philip *et al*. 2017, p.386) and policy (ITU, 2020) as a determining factor for digital skills development. For example, the Organisation for Economic Co-operation and Development (2021) has described the term "digital divide" as "different levels of access and use of information and communication technologies (ICTs) and, most often, to the gaps in access and use of Internet-based digital services" which can "vary in terms of geography (e.g. as urban and rural areas), by gender, by age, by skill level, by firm size, and in general, by different vulnerable groups in society, among others" (pp. 4-5). The European Network for Rural Development (2017) refers to rural areas based on facing the risk of a "double digital divide", lacking access to modern infrastructure which leads to "lack the basic skills and knowledge of the potential of digital technology so that even if the 'digital highways' are in place, they may remain under-exploited" (p.1).

To explore experiences of rurality, students were asked to report on the area they mostly lived in when they were a child up to finishing school as this is a time when fundamental digital gaps based on unequal access to technology and the internet would have been created to impact students' digital skills development, disparities, which could be further amplified in students' transitions into Higher Education.

Validity and rigour

The self-assessment survey tool has been through different rounds of quality assurance and peer review by subject experts in a way that reflects disciplinary needs in the context of both learning and nursing professional practice, which can "facilitate increased reproducibility of statistical design and reporting" (Hildebrandt and Peroneal (2020, p.1). The conceptual framework and the evidence-building processes that underly the methods used in assessing students' self-perceived digital competencies, have been previously reported in different empirical studies with students from diverse subject areas (such as Law, Library and Information Science and Nursing) (Martzoukou, 2020; 2021; 2023). The strengths of the process of self-assessment have also been extensively discussed in previous research on students' Internet skills development (Van Deursen *et al*., 2014) highlighting its value in improving students' learning (Klenowski, 1995; Ross, 2006; JISC, nd). However, within a fast-developing technological environment, iterative changes of the questionnaire were necessary for the purpose of this study, addressing emerging digital skills areas, such as artificial intelligence.

The reliability of the amended survey instrument was tested using Cronbach's alpha. The results showed that all item groups in the questionnaire had a Cronbach's alpha index much higher than 0.7, with almost all the values above 0.9. The lowest value was 0.897 for information literacy (identification of different information types) and the highest was for digital wellbeing (0.980) (Table 3). As the sample

size was small with ordinal scale data, non-parametric tests were employed in the analysis (Corder and Foreman, 2014).

Sampling

The research design followed a total population sampling approach with email invitations sent to all the population of Undergraduate (UG) and Postgraduate (PG) students studying at the School of Nursing, Midwifery and Paramedic Practice at the Robert Gordon University in Aberdeen, Scotland. The students were recruited following a targeted approach which involved meeting them online, during planned 'stage meetings' sessions, designed as part of their preparation for practice at the NHS. An hourly online meeting was organised with each stage group (i.e., Stage 1, 2 and 3, which is equivalent to Year 1, 2, and 3) as well with MSc students. During the meeting the students were briefed on the purposes, objectives and procedures of the research project and they were then asked to fill in an online questionnaire survey. The sample consisted of 555 students out of the potential population of 964 UG students and 32 PG registered students in the school, representing a total response rate of 55.5% (two respondents, however, were removed from this sample due to insufficient data). The rationale for inviting all students was that they attended diverse courses covering adult, mental health, and children and young people's nursing and it was important to ensure adequate representation from all groups and capture, in a holistic way, different perspectives on digital competencies development and experiences that related to digital divide barriers. Detailed demographic characteristics are provided in Table 1. The survey was administered in June 2023 with student voluntary and anonymous participation and informed online consent.

Ethical considerations

The research project was approved by the ethics committee of the school in the participating institution in the UK with GDPR (2018) compliance. The ethical procedure followed the school research ethics policy, addressing anonymity, confidentiality, informed consent, the right to withdraw, data handling, privacy, and potential risks, for example, reassuring students that the results of the survey would not be linked to their academic progress and that none of the students would be identifiable via the questionnaire outcome.

Data Analysis

IBM SPSS Statistics (v28) was employed for the statistical analysis of the survey data (IBM Corp, 2022) to explore correlations between age and study year demographic data, digital competencies and digital divides. Cronbach's alpha was used to assess the internal consistency reliability of the survey tool. The results were reported through descriptive statistical analysis (frequencies, valid percentages and median values). Following Kolmogorov–Smirnov and Shapiro–Wilk normality tests, the questionnaire items did not follow a normal distribution and therefore, Mann–Whitney (U-test) non-parametric statistical test was used to identify significant statistical differences between different groups. A p value of <.05 was followed to indicate statistical significance for all the tests. Principal components analysis (PCA) following the varimax orthogonal rotation method was used to identify groups of digital competencies in (Supplementary_material_appendix_B, Tables B1-13). We considered factors reaching eigenvalue 1 as a factor extraction method following Kaiser's criterion. The results of Bartlett's sphericity test at $p < 0.05$ and the Kaiser Meyer–Olkin (value of 0.6 or above) confirmed the suitability of our dataset for structure detection. Bivariate correlation statistics between all clustered variables reported the statistical associations between the different items of the research instrument (Supplementary_material_appendix_B, Table B14).

Thematic analysis and manual coding (Kiger and Varpio, 2020) was applied to the survey qualitative open data identifying key themes reflected in the questions with subthemes.

Limitations

The main limitation of the study comprises of a potential narrow perspective of a group of students studying within a single university and country. Therefore, the results of the survey should be generalized with caution. However, the approach followed presents a replicable process that can offer a more holistic framework to study the digital competencies development of students in a discipline focused way and design subject related learning interventions in nursing curricula.

Survey results

Demographics

The majority of the participants were female (91.3%, n=505), undergraduate students studying BSc Nursing (96,9%, n=536), with almost an equal split between those born on or after the year 2000 (Generation Z) (51.1%, n=282) and those before (49%, n=271). The female gender demographic composition of students in this study is not surprising as it reflects a gender imbalance that is evident in the nursing profession overall (RCN, 2018). Most of the students were born in Great Britain (73.6%, n=407) with the next larger group being Nigerian students (8.9%, n=49). Approximately a third of students studied in Year 1 (35.8%, n=198), in Year 2 (29.1%, n=161) and in Year 3 (35.1%, n=194) and most had a part-time job while studying at university (Table 1).

{insert Table 1 Demographic characteristics around here}

Self-assessed digital competencies results

Tables B1-B13 (in Supplementary_material_appendix_B) summarize the descriptive statistics in all the survey digital competencies items using frequencies and median values. In addition, subgroup test statistics for all demographic variables are reported through Mann–Whitney U test and Kruskal-Wallis H tests. The strongest area reported was 'Digital wellbeing' with all the items at median 4.0 ('advanced'). This was followed by 'Everyday life as a digital citizen', were most of the items were at 'advanced' level (median 4.0), while three items were at 'intermediate' level: 'e-democracy', 'e-government' and 'e-employment' (median 3.0) and 'ICT Proficiency' were two items were found at 'intermediate' (median 3.0) level: 'University management systems' and 'Communication platforms' while the rest were all at 'advanced' level. 'Digital communication' was also a strong area for the group with the majority of items reported at 'advanced' (median 4.0) level, while three directions were found to be at intermediate level.

'Digital identity management' was mainly at 'intermediate' level with two areas at 'advanced' (median 4.0) level: 'Being aware of the potential positive or negative impact of what you communicate online on your online reputation' and 'Understanding the impact of your online interactions'. 'Information literacy', was found at 'intermediate' level, with only a single item performing at 'advanced' level: 'Popular information' (median 4.0). 'ICT productivity', 'Digital Innovation' and Digital Learning and Development' were found to be at 'intermediate' level in all items. 'Digital creation' and 'Digital research skills', were both at 'intermediate' level throughout, expect for the creation of 'infographics' in the former category and 'Using a Critical Appraisal Tool' in the latter category, that were both reported at 'basic' level (median 2.0). Overall, nursing students assessed themselves at "intermediate" level (median 3.0) in most of the survey constructs and in relation to their digital ability to complete academic work.

Age demographics significant differences were identified in several areas (Supplementary_material _appendix_B), including 'Digital Learning and Development' (Table B10), 'Digital Identity Management' (Table B11) and 'Digital Wellbeing' (Table B12). In addition, significant differences were identified in five items within 'ICT Proficiency' (Table B2), three items in 'Digital Innovation' (Table B9), seven items in 'Digital Communication' skills (Table B8), five items in 'Digital creation skills' (Table B6) and three items in 'Everyday participation as digital citizens". There were also other individual items, where significant differences were observed: 'Sharing securely your digital files with others' (ICT Productivity) (Table B3), 'Finding digital information relevant to your academic studies, using databases' (Information

Literacy) (Table B5) as well as 'Organising and storing research raw/open data online' and 'Using a survey tool' (Digital Research) (Table B7). It is interesting to note that the direction of the mean rank values of the non-parametric (Man Whitney) test indicated that students who were born in year 2000 or after self-assessed higher overall based on their digital competencies.

In addition, significant differences were observed between first year and continuing students in the following digital competencies items, where the former group self-assessed higher: 'Digital Creation' (one item: 'Vlog/Podcasts') (Table B6), 'ICT Proficiency' (one item: 'Search engines') (Table B2), 'Digital Innovation' (one item: 'Working collaboratively on different aspects of a creative/innovative project/service design & managing the process as a team') (Table B9) and 'Digital learning and development' (one item: 'Using online tools to record learning events/outcomes and use them for self-analysis, reflection, and showcasing of achievement') (Table B10). Continuing students, on the other hand, only self-assessed higher in two items in 'Information Literacy' ('Scholarly Academic Literature' and 'Professional Literature') (Table B5) and in one item in 'Everyday participation as digital citizen' ('e-democracy') (Table B1).

In relation to the overarching academic outcomes question 'Which level best describes your digital abilities to complete your academic work' (B13), significant differences were found on the basis of: a) age demographics, b) digital challenges experienced in the area in which students mostly lived (e.g., rural/urban before joining the university (e.g., access to electricity, computer, laptop, mobile more, tablet, broadband, basic computer training), c) digital barriers students had experienced in relation to proactively developing their digital skills and d) year of study.

Grouping Variables

Furthermore, the study employed PCA (Principal Component Analysis) to reduce the number of digital competencies variables in the dataset and Exploratory Factor Analysis (EFA) for the purposes of assessing whether they were representative of each of the of each of the underlying construct. PCA transforms a set of variables into a smaller set of variables, called "principal components", which account for most of the variance in the original variables (Comrey and Lee, 1992). PCA with Varimax rotation was employed for grouping the digital competencies constructs. The output of this process is presented in Supplementary_material_appendix_C, Tables C1-C12. The use of KMO and Bartlett Test of Sphericity indicated that it was possible to proceed with principal components factor analysis (Tabachnick and Fidell, 2007). Each of the survey constructs were grouped into a single component, while the single-item factor loadings were quite high.

The descriptive statistics (mean and standard deviation) of the examined constructs for the entire sample are presented in the last two rows of Tables C1-C12. As it can be observed that higher digital competencies were reported for 'Digital Wellbeing' (mean=3.68) and for 'ICT Proficiency' (mean = 3.64). Low competencies were reported for 'Digital Creation' skills *(*mean = 2.77) and 'Digital Research' skill*s* (mean = 2.87).

Correlation Statistics

Pearson correlation coefficients and the corresponding significance levels for all the construct components are presented in Table C13 with Pearson's test (2-tailed) at significance level $p < 0.05$(*) and significance level $p < 0.01$(**). It is worth noting that strong statistically significant correlations at level $p < 0.01$(**) were identified between almost all the self-reported dimensions of digital competencies, encompassing digital skills that were related to everyday life digital activities to ICT proficiency and productivity, information literacy, and digital creation, research communication, innovation, identity management and wellbeing.

What would empower students to further develop their digital skills

In the survey, students answered an open-ended question which helped to contextualize the above findings. The question centered on ways that would empower them to further develop their digital skills.

Students mentioned several digital skills areas they would need further support with or training on, including learning new software/tools and understanding university systems (e.g., Moodle). Digital skills development was centred on completing coursework, such as preparing online posters and presentations (PowerPoint) and formatting information, using referencing tools (such as RefWorks), developing online database searching skills/library searching, data analysis (e.g. Microsoft Excel), digital productivity tools for note-taking and time management. In relation to digital creativity tasks, several skills mentioned addressed blogs, podcasts and creating videos, while in relation to digital communication, students referred to skills for using social media and for digital learning and development (e.g., e-portfolio).

Respondents also offered ideas for different preferred types of training including workbooks/tutorials, presentations, bitesize guides, video guides and tutorials, as well as online training and courses, in-person sessions and one-to-one support. Whatever the method proposed, students preferred clear explanations, "consistent information", and "accessible interfaces", while several respondents mentioned tailored support that is relevant to their careers. In addition, students' comments indicated that digital skills should be taught early in a course and in collaboration: "Taught earlier and in collaboration with study skills and the library", "Teach more in first year to help us build every year we study more sessions when beginning uni to go over how to use the systems", "Incorporating structured digital skills education and identification of beneficial skills from the beginning of the course", "Study skills and library support to teach a class at the start of each academic year as a reminder". In addition, more time dedicated to digital skills development was necessary: "What would empower me would be more time to do digital skills", "More time - life/study balance", "More time to practice". Personal motivation to develop digital skills was equally deemed important. As one student explained: "I decide what I feel is relevant for me to know and the things that I have self-assessed as lower are not important or useful to me", indicating that a low score on certain digital skills could mean that students were not engaged with the particular skills, or they deemed them necessary or unimportant:

"I don't know I don't use certain things or have interest in doing blogs or podcasts etc so that's why I score low in sections related to that not sure really not interested in using many online tools I like pen and paper".

"It's down to priorities. When content isn't so engaging or urgent I don't feel the need to reach out for help so much".

"Motivation for using these tools is lacking for me. I'm not sure how this can be supported by academic staff but perhaps if more coursework demanded the use of these digital skills".

Students required an "interest to learn" which could be triggered by connecting these skills to their course related experiences together with reassurance and guidance that they were "in the right direction". As students also explained, digital skills classes could be part of a course: "Incorporate these classes into our timetable" and, in that way, students could be "given time within the module to learn that skill", especially if "an assignment was in line with a digital literacy skill that I'm lacking". In addition, teaching staff could use more advanced and interactive tools that would "inspire" them to "develop digital skills in these areas" and "actively involve" students "in digital learning and collaboration initiatives - e.g., sharing project results online". Interestingly, beyond embedding digital skills into the study programme, students' perspectives overall, conveyed a sense of connecting the significance of digital skills to the purposes of academic study rather than to digitally-enabled nursing practice.

Digital Divides

Urban/Rural Digital Divides

Students had experiences of growing up in both urban (44.7%, n=247) and rural (46.5%, n=257) geographical areas (Table 2). First level digital divides were identified in 17% (n=97) of the study population, who reported having experienced digital challenges prior to joining the university (such as access to electricity, computer, laptop, mobile more, tablet, broadband, basic computer training), while 77.9% (n=431) reported experiences of at least one second-level barrier to developing their digital skills (e.g., lack of time, training, interest, urgency, confidence, task complexity) (Table 2).

Geographical location was not found to directly play a role in the way in which students self-assessed specific digital competencies, although they had an impact on the digital abilities self-assessment of students for overall completing academic work. Significant statistical differences were identified between students who experienced at least one of the listed first level digital divides (e.g., lack of continuous access to electricity, access to a desktop computer, smart mobile phone, tablet broadband, or basic computer training) and self-assessed digital competencies. Students who encountered digital challenges/divides were more likely to self-report lower digital competencies than students who did not. The most notable differences were in 'Everyday participation as digital citizens' (Supplementary_material_appendix_B, Table B1), 'Digital Creation' (Table B6) and 'Digital Innovation' (Table B9), where statistically significant correlations were found across all question items. These were followed by 'ICT Proficiency' (Table B2) and 'Digital Identity Management' (Table B11), where all question items, except for one, were found significant. Additionally, there were three items identified in 'ICT Productivity' (Table B3), 'Digital Research' (Table B7), and 'Digital Communication (Table B8), two items in 'Information Literacy' (Table B5) and 'Digital Learning and Development' (Table B10) and one item in 'Digital wellbeing' (Table B12).

Significant statistical differences were also found in second level digital barriers and self-assessed digital competences, indicating that students who had experienced at least one of the listed barriers in that category (e.g., lack of time, training, interest, confidence) were more likely to self-report lower digital competencies than students who did not encounter any challenges.

{Insert Table 2 Digital challenges and barriers}

Learning Disability (neurodivergence) Divides

A total of 89 students (16.1%) self-reported a neurodiverse condition, while 82 (14.8%) indicated that they may be neurodivergent, but they are not sure, or they have not been formally diagnosed. The high potential incidence of neurodivergent students in this study (total of 30.9%, n=171) is in par with previous studies where a percentage as high as 33% has been reported (HESA 2021) (Table2).

Learning disabilities (neurodivergence) were not found to play a role in students' digital competencies self-assessments as no significant differences were identified based on that variable, although transitions are reported as a significant issue for neurodivergent students in previous research (Bakker *et al*. 2023). However, students shared additional ideas, which helped to further contextualize the findings in the area of digital divides connected to learning disabilities. For example, different challenges they experienced with ICT proficiency and productivity, such as keeping focused on tasks and avoiding distractions and reading on screen (Supplementary_material_appendix_D, Table D1):

> "Struggle to focus on one thing at a time, easily distracted, always need to be doing something else at same time as doing digital tasks".

Students with Dyspraxia, who typically have difficulty with motor skills in their learning ability to write, type, draw and grasp small objects, also mentioned that the design of the keyboard tools with smaller objects can become an issue for them:

"I find it hard to find the correct keys when typing".

In addition, students mentioned challenges which could create problems with feeling overwhelmed due to information overload that could have a negative impact on processing information from multiple online sources or complex tools which could be a barrier to information literacy and digital research skills development:

> "Being presented with large amounts of information at once makes it difficult to comprehend instructions or maintain focus without feeling overwhelmed".

Students required more support in navigating different technologies and assistive tools available to them and they preferred solutions considering the unique challenges of their specific conditions, especially dyslexia:

> "Try to use systems available but would be interested to see more specific for dyslexia".

Several students also shared different methods and strategies for overcoming these challenges, with the most popular being using assistive technologies (which were popular with dyslexic students) and audio-visual strategies (Supplementary_material_appendix_D, Table D2):

> "I have found apps such as Read & Write Gold extremely helpful. Grammarly has also helped".

Besides the use of videos, students with autism specifically, highlighted the use of time-management memory-improving tools to address a need for structured learning actions:

> "Good routine helps me, so things like a calendar and well-organised meetings".

Students with dyscalculia mentioned the need for "Numeracy tools would be helpful to enhance my numeracy skills", referring to "Websites calculators and British National Formulary (BNF) app" and to the of "dyscalculia-friendly fonts and coloured backgrounds to help the numbers stand out".

Students with dyspraxia revealed the use of multiple tools to overcome challenges around a set of skills known as transcription and writing. Again, students used Grammarly, Dragon, Read and Write Gold and Dragon:

> "An app that converts my handwriting into text. Also, dragon that turns speech into text".

However, students also highlighted that some students can have multiple disabilities.

Several students with ADHD mentioned challenges related to lack of attention to detail and continually starting new tasks before finishing old ones, also reporting that they were unaware of tools available to them, highlighting a need for the development of a toolkit considering apps, programmes and digital tools to support them:

> "There are none that I have found or know about".

However, some students mentioned using various assistive technology tools to manage their workload such as "Speechify app", "Google Calendar for planning". As another student explained:

"I need to make sure I am very organised, and I write everything down. Lately, I put tasks I don't want to forget in my calendar on my iPad because that gives me the best overview of everything. I colour-code everything as well, which is very helpful".

Students mentioned the effective role of the university's support services in supplying these assistive learning technology tools: "I have many tools on my laptop provided by the learning team now" and "The university has supplied me with a laptop with various apps on to help with this". They also mentioned several approaches that bring structure into their learning process, such as listening to music, taking small "breaks little and often", and advised that making "lectures more interactive or

prerecorded so we can pause and take breaks when necessary to stay focused" and "Videos and visualisation" are beneficial for their comprehension.

Discussion

This study sought to explore how nursing students self-assess based on their digital competencies and to further understand any existing obstacles to digital literacy development they encountered. Digital exclusion in Higher Education has been examined in previous research, however, most frequently, at the level of technological infrastructure and internet connectivity and in relation global geographical divisions created between the Global North and the Global South countries (Thomas-Slayter, 2003), where people are more likely to experience poverty and limited access to resources or educational opportunities (ACU, 2020, Lembani et. al., 2020). At EU level, it has been reported that digital divides based on accessibility have been reduced over the last years, however, there is still a fundamental need for upskilling, with one of the four key goals of the European Commission (2021) focusing on "a digitally skilled population and highly-skilled digital professionals".

This need for upskilling was also prevalent in this study in which nursing students self-assessed their digital competencies at intermediate level in most digital skills areas. This research also offered a better understanding of how students may transfer into HE existing digital divides from everyday life in a way that may have an impact on their follow up digital literacy development; these highlight the need for further learning opportunities to develop digital skills that meet the expectations of the nursing profession, particularly with the emergence of new innovative technologies and AI related transformations that require advanced digital skills (Rony, Parvin and Ferdousi, 2024).

Significant differences were also observed in relation to age demographics, with younger students self-assessing their digital competencies at a higher level overall. In addition, first year students self-assessed higher than continuing students in certain digital skills areas, which required digital creation, ICT proficiency and innovation skills, while continuing students were stronger in information literacy, which presents a fundamental academic skill, especially in nursing education and practice, where evidence-based practice is a core direction in clinical decision making and for the delivery of quality healthcare (Majid *et al*., 2011). On the other hand, research skills did not appear to be an area of strength of students, possibly because most of the students were UG and in their first year of study. This signifies a need to develop more robust strategies for supporting students at early levels to excel in digital research foundational skills. Further research replicating this methodology could further explore this outcome with diverse students at different study levels.

This research also offered a deeper contextual understanding of the diverse range of digital skills challenges and the variability of strategies followed by neurodivergent students which signifies the need for a universal design to nursing education to accommodate diverse needs and requirements of all learners (Halligan *et al.,* 2019). In this study students' existing neurodiverse conditions did not appear to play a role in the way in which they self-assessed their digital competencies. This adds some additional evidence to the position that people with neurodiverse conditions do not necessarily encounter challenges in their development of digital skills more broadly and may instead be presented with unique opportunities in digital tech employment environments that require digital innovation and creativity (Autism Network Scotland, n.d.). Despite this result, neurodivergent students described different barriers they experienced particularly within the areas of 'ICT proficiency' and 'ICT productivity', where they recommended available tools and strategies that can assist in keeping focused on tasks and avoiding distractions. These suggestions can assist in developing more tailored and informed digital skills support. They also offered personal strategies for overcoming these barriers, which provide helpful insights and directions for digital skills programme development. It is important to cater for these challenges in a way that is different according to the individual neurodivergent conditions of students.

Overall, the strong statistical correlations between the self-reported digital competencies dimensions in this study, offered empirical evidence of the interplay between everyday life, learning and work-related digital competencies, putting forward the need for a more holistic approach to the teaching of digital skills in nursing education. Previous research with nursing students has mainly placed emphasis on individual digital skills, such as "digital professionalism" (Mather *et al*, 2018), electronic health literacy (Anderberg *et al*. 2019, p. 5), or information literacy (Aylward *et al*. (2020), centred on "the reliability and validity of online health care information" (Blakemore *et al*., 2020). Other research has explored the socio-emotional factors on students' digital literacy, such their awareness of digital issues in the online environment (Erdat, 2023; Okumus and Atılgan, 2021; Park, 2013).

The above findings offer important directions for the nature of support that academic libraries can provide for nursing students' development of digital competencies. The most important recommendation addresses the need to design tailored digital literacy programmes which focus on specific digital skills, such as digital creation and digital research and in a way that carers for the needs of different students (e.g., first year and continuing students). Digital literacy programs should not only be offered at an appropriate knowledge level, but also support nursing students to develop awareness of state-of-the art knowledge of digital tools and methodologies for healthcare, such as evidence-based practice, predictive analytics and artificial intelligence for patient care and clinical decision-making (Agnew, 2022). Finally, more emphasis is necessary in promoting the importance of continuous learning and upskilling in digital competencies and the relevance of advanced digital skills in the context of emerging technologies and transformations in healthcare. Current research points to evidence that library support has a positive impact on nursing students' information literacy skill development (Purnell, Royal and Warton (2020). However, information literacy skills development takes place within the context of developing a range of digital skills that involve other interrelated skills, such as ICT proficiency, digital communication and digital learning and development, among others. Approaching the development of digital skills holistically means working synergistically with students and adopting a learner-centered approach that identifies and addresses existing gaps in information and digital literacy. This approach necessitates nurturing a lifelong learning mindset in students to ensure continuous skills development.

Conclusion

There is not a one-fits-all approach to digital competencies development, as not one student is similar because of their individual characteristics and life experiences. However, developing a more informed understanding of students' digital competencies gaps and the multiple shapes that digital exclusion may take is important for the design of meaningful digital skills enhancement programmes in Higher Education. As this study showed, digital competencies were not only multidimensional, complex and interrelated, but also influenced by diverse digital challenges and barriers. The results of this study put forward the importance of libraries collaborating with schools for offering a discipline-based and tailored scaffolding approach to the development of nursing students' digital competencies, as opposed to a 'one fits-all', generic or baseline direction. Higher Education should focus on equipping students with discipline related digital skills and knowledge in a way that relates to students' future professional trajectories and ensure a "digitally fluent workforce" (Lokmic-Tomkins, *et al*., 2021), not only a digitally fluent student. It should also develop increased awareness of the digital barriers and experiences that students encounter within their everyday lives. This involves a continuous engagement with evolving digital skills needs in the profession and a focus on students' learning and development for life. Future research should explore the parameters of interrelated digital skills withing everyday life and work environments and examine how experiences within different settings influence strategies for students' ongoing learning and professional growth.

Finally, it is important to note that, although this study explored nursing students, its design and findings are relevant and applicable to digital divides that may be present in other student populations. Digital competencies is a critical skillset for students across different disciplines and not unique to nursing, and, as changing digital technologies become integral to different aspects of learning and diverse professional practice, it is important to develop tailored digital literacy support, informed by detailed understanding of students' development needs, in a way that relates meaningfully to their study directions, their future professional trajectories and their individual

knowledge levels and skills. The research methodology applied in this study has already been tested with other student populations with the aim to explore pockets of digital inequalities across different discipline areas, such as Law (Martzoukou et al., 2022) and Information Science (Martzoukou et al. 2020), with the input of academic staff/students and with the aim to offer digital literacy training and support and enhance students' digital capacity as future professionals. In addition, the study's novel insights into the digital challenges that neurodivergent students encounter demonstrates the necessity for inclusive educational strategies, in a way that can be applied to other fields beyond nursing, to ensure that all students, regardless of their learning needs, have equal opportunities to develop essential digital competencies.

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Demographic Characteristics		
Variables	**Frequency**	**Valid %**
Gender		
Female	505	91.3%
Male	45	8.1%
Binary	3	0.5%
Missing	5	0.9%
Birth year		
Born before 2000	271	49.0%
Born on or after 2000	282	51.0%
BSc Nursing	536	96.9%
MSc Nursing	17	3.1%
Year of Study		
1st year	198	35.8%
2nd year	161	29.1%
3rd year	194	35.1%
Country of Birth		
Great Brittain	407	73.6%
Nigeria	49	8.9%
Ireland	14	2.5%
Poland	10	1.8%
United States	9	1.6%
Other countries (e.g., Ghana, Philippines, Lithuania, British Virgin Islands, India)	64	11.6%
Employment status		
Full-time	18	3.3%
Part-time	343	62.0%
Other (e.g., ad hoc health care nurse bank staff/student nurse)	34	6.1%
Unemployed/Students	158	28.5%

Table 1. Demographic characteristics

Area mostly lived in		
Urban	247	44.7%
Rural	257	46.5%
Mixed	49	8.9%
Self-reported neurodiverse condition		
Yes	89	16.1%
Maybe/Not diagnosed	82	14.8%
No	382	69.1%
Digital challenges prior to joining the university		
At least one challenge before arriving to university (e.g., access to electricity, computer, laptop, mobile more, tablet, broadband, basic computer training)	94	17.0%
No challenges	459	83.0%
Barriers experienced in relation to proactively developing digital skills		
At least one barrier (e.g., lack of time, training, interest, urgency, confidence, task complexity)	431	77.9%
No barriers	122	22.1%

Table 2. Digital challenges and barriers

Supplementary Material Appendix A

Table A1. Structure and dimensions of the questionnaire survey

Questionnaire Dimensions	Dimension study items
Q.1 Demographics (Items N=5)	Gender, birth year, year of study, country of birth, current course, employment status.
Q.2 Everyday participation as a digital citizen (Items N=9)	e-democracy (e.g., accessing voting information and political information online; taking an active role in democratic processes online) e-government (e.g., obtaining knowledge about current laws, legislation and government, accessing and using government online services, such as legal information) e-finance (e.g., online banking, price comparison websites, managing personal/student finance); e-commerce (e.g., online shopping, buying & swap apps) e-commerce (e.g., online shopping, buying & swap apps) e-health (e.g., accessing and using health services online, e-consult with doctors, NHS 24 online services) e-wellbeing (e.g. personal health tracking, e-fitness, e-mental health self-management) e-leisure (e.g., playing online games, socialising online) e-learning (e.g., looking for new digital opportunities to grow as a person such as online webinars, online training, watching YouTube videos and following an active approach to sourcing information) e-employment (e.g., working remotely, using digital content and tools for work purposes).
Q.3 ICT proficiency with completing different tasks (Items N=6)	Technological devices (e.g., laptops, tablets, smartphones, desktop computers; connecting to the Internet/wi-fi) Web browsers (e.g., Chrome, Explorer, Firefox, Safari etc.) Search engines (e.g., Google, Bing etc.); University digital administrative services (e.g., email, student data portal) University digital administrative services (e.g., email, student data portal)

	University learning management systems (e.g. Moodle, Blackboard, Brightspace) Communication Platforms (e.g. Zoom, Skype, Microsoft Teams, Google Hangouts)
Q.4 ICT productivity (Items N=5)	Organising/ managing/ storing your digital files effectively for your learning (e.g., using filenames and through folders) Sharing securely your digital files with others (e.g., sharing files on Moodle, via email) Using productivity tools, such as calendars, task lists, project and time management apps, to make learning more efficient (e.g., Microsoft Project, Outlook/Google calendar, Trello, Toggl) Proof reading /spell-checking your work Creating formatting styles (e.g., Table of Contents, report-writing styles)
Q.5 Information literacy (identification of information types) (Items N=3)	Scholarly/academic literature (e.g., journal articles, conference papers, book chapters, other publications written and vetted by subject experts); professional literature (e.g., Professional organisations such as Nursing and Midwifery Council publications, Royal College of Nursing Publications, Royal College of Midwives Publications, Health Professional Blogs, The Royal College of Paramedics, Scottish Government publications/policy) Popular information (e.g., general discussions on social media, websites and blogs)
Q.6 Information literacy skills (Items N=9)	Finding digital information relevant to your academic studies, using informal Web sources (e.g. Google, Google Scholar, Bing or other search engines) Finding digital information relevant to your academic studies, using databases (e.g. CINAHL, Medline, Science Direct, Cochrane Library) Using online collection tools for gathering digital information together in new ways (e.g., Slideshare, List.ly, Pinterest, Quora, Scoop.it, etc.) Evaluating whether digital information is trustworthy and relevant; organising the digital information you find for your learning through folders, bookmarks, reference management software, and tagging

	Understanding academic integrity/honesty when accessing & using information online (e.g., plagiarism, collusion) Understanding how to share information publicly online, respecting and acknowledging the work of others (e.g., using creative commons licensing, providing references/citations to original works) Using artificial intelligence generated content ethically, following academic integrity values (e.g. using ChatGPT, Google Bard) Referencing digital information sources, adhering to a referencing style (e.g., Harvard referencing style).
Q.7 Digital creation skills (Items N=8)	Creation and editing of videos Infographics (e.g., Canva) Online posters Blogs/Wikis Vlogs/Podcasts Creation of audio files (e.g. using Audacity, Voice-over presentations) Using Simulation/Virtual Reality Tools (e.g. virtual hospital/community) Data visualisation (e.g., Excel, SPSS)
Q.8 Digital research skills (Items N=8)	Finding research raw/open data online (e.g. open health data, national statistics sources such as the Scottish Public Health Observatory, Information Services Division Scotland, The World Health Statistics) Organising and storing research raw/open data online (e.g., using tools such as RefWorks or Microsoft Word to annotate or summarise findings) Using a Critical Appraisal Tool (e.g., CASP) Using a survey tool (e.g., Online Surveys, Mentimeter) Analysing digital research data using simple tools (e.g., spreadsheets, textual data analysis software, visual tools) Using methodologies to cleaning, transforming and preparing open data sets (e.g., available on

	the Internet, via different organisations, research institutions) Understanding how evidence-based research are used to construct arguments, make decisions, and/or solve problems Following ethical, legal, and security guidelines when using research data (e.g., Social, Ethical and Professional Guidelines, personal data protection regulations such as GDPR).
Q.9 Digital communication skills (Items N=9)	Participating professionally (e.g., reviews, comments, likes) in a range of digital networks (e.g., social and professional networks) related to your interests, work, and/or academic subject Understanding expected behaviour/code of practice in online environments (e.g., NMC/HCPC Social Media guidance) Communicating respectfully, inclusively & confidentially, recognising that digital media can be used to intimidate, shame, and harass other people Communicating professionally via email with others (e.g., peers, tutors, mentors) Actively participating in online learning environments (e.g., discussion forums) Recognising false or damaging online communications (e.g., fake news, misinformation) Actively sharing your specialist ideas (e.g., academic or professional) in a range of online communication media (e.g., social media such as LinkedIn, Twitter, Facebook) Sharing information using external communication tools (e.g., WhatsApp, Viber, Skype) Designing online communications for different purposes (e.g., online discussions, blog messages, X (Twitter) threads to persuade, inform, entertain, guide, and support).
Q.10 Digital innovation (Items N=4)	Developing new ideas and projects using online tools and technologies (e.g., using tools in innovative ways to create presentations, projects, apps, video resources and designs) Engaging with professional digital innovations (e.g., telehealth initiatives, the use of

	smartphones and health online applications for consultations and patient care) Working collaboratively on different aspects of a creative/innovative project/service design & managing the process as a team Promoting new online tools and opportunities to others (e.g. proactively promoting creative ideas and projects)
Q.11 Digital learning and development (Items N=8)	Participating in online learning opportunities and resources (e.g., online courses, podcasts, global conversations on X (Twitter), quizzes, online tutorials, simulations, or open lectures) Adopting new ways of learning online (e.g., online workshops, virtual labs, video-tutorials, webinars) Working collaboratively and supportively with other learners, using online technologies where appropriate (e.g., via your university's online education system (Moodle), Office 365, other apps and online environments or via your previous working experiences) Using online tools to take notes, annotate, and collate learning materials, review, and revise learning (e.g., Evernote, Notion, Google Apps, Scribble) Using online tools to record learning events/outcomes and use them for self-analysis, reflection, and showcasing of achievement (e.g., in an e-portfolio or learning blogs) Receiving and responding to online feedback about your academic work Using learning management systems (e.g., BlackBoard Collaborate, Zoom, Teams) to learn collaboratively Sharing your online knowledge and skills, helping other learners (e.g., mentoring others)
Q.12 Digital identity management (Items N=7)	Managing your online profiles on different digital media (e.g., social media) in a way that is suitable for personal, professional, and academic purposes Understanding how your online personal data are collected and used in different systems and use privacy settings appropriately Being aware of the potential positive or negative impact of what you communicate online on your online reputation

	Making sure outcomes of learning and other achievements are accessible in online forms (e.g., via an e-portfolio, digital CV, personal website) Understanding the impact of your online interactions (e.g., how you project yourself to others online) Using online analytics to explore your impact and influence on others Establishing healthy boundaries/habits in using social media (e.g. monitoring time spent online).
Q.13 Digital wellbeing (Items N=6)	Feeling comfortable, in control, and safe when using digital technologies Recognising that digital information and media can cause distraction, overload, and stress, and disconnecting when necessary Considering the rights and wrongs and the possible consequences of your online behaviour Acting positively against cyberbullying and other damaging online behaviours Managing online and real-world interactions in ways that support healthy relationships Using digital media to access wellbeing services, monitor health conditions (e.g., student support services)
Q.14 Digital abilities to complete academic work (Items N=1)	Which level best describes your digital abilities to complete your academic work (e.g., using digital tools and processes as set in your course)?

Table A2. Likert scale digital competence levels

Level 1: Novice The digital task is new to me. I am currently developing basic knowledge and skills in this area, but I need help either to complete or to learn how to complete this sort of task.

Level 2: Basic I have foundational knowledge in this area. I can perform simple digital tasks with help from others.

Level 3: *Intermediate* I have more than foundational knowledge, but I am not yet advanced in this area. I can usually complete complex digital tasks independently, although I sometimes need help from someone more advanced than I am.

Level 4*: Advanced* I have advanced knowledge in this area, though I am not an expert. I can perform complex digital tasks without assistance. I adapt easily to learning new knowledge and skills. Others sometimes ask me for help.

***Level 5**: Expert* I have mastered the knowledge and skills for this area. I apply my knowledge and skills to create and redesign processes, tools, and/or technologies appropriately and effectively. As an expert in this area, I frequently show others how to complete these tasks.

Table A3. Cronbach's Alpha Reliability of Questionnaire Dimensions

Questionnaire Dimensions	Reliability -Cronbach's Alpha
Q.2 Everyday participation as a digital citizen (Items N=9)	0.924
Q.3 ICT proficiency with completing different tasks (Items N=6)	0.959
Q.4 ICT productivity (Items N=5)	0.922
Q.5 Information literacy (identification of information types) (Items N=3)	0.897
Q.6 Information literacy skills (Items N=9)	0.938
Q.7 Digital creation skills (Items N=8)	0.949
Q.8 Digital research skills (Items N=8)	0.940
Q.9 Digital communication skills (Items N=9)	0.945
Q.10 Digital innovation (Items N=4)	0.945
Q.11 Digital learning and development (Items N=8)	0.952
Q.12 Digital identity management (Items N=7)	0.946
Q.13 Digital wellbeing (Items N=6)	0.980

Supplementary Material Appendix B

Mann-Whitney U test and Kruskal Wallis H-test / Bivariate correlations of the survey factors

Table B1. Everyday participation as digital citizens (Items N=9)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
Valid *N* =553	1	2	3	4	5	Median
e-democracy μ, ε, δ	49 (8.9%)	142 (25.7%)	218 (39.4%)	115 (20.8%)	29 (5.2%)	3.00
e-government η, μ, δ	23 (4.2%)	123 (22.2%)	220 (39.8%)	146 (26.4%)	41 (7.4%)	3.00
e-finance μ, δ	13 (2.4%)	55 (9.9%)	179 (32.4%)	197 (35.6%)	109 (19.7%)	4.00
e-commerce η, μ, δ	6 (1.1%)	40 (7.2%)	104 (18.8%)	196 (35.4%)	207 (37.4%)	4.00
e-health μ, δ	15 (2.7%)	49 (8.9%)	160 (28.9%)	206 (37.3%)	123 (22.2%)	4.00
e-wellbeing μ, δ	14 (2.5%)	69 (12.5%)	192 (34.7%)	186 (33.6%)	92 (16.6%)	4.00
e-leisure η, μ, δ	17 (3.1%)	56 (10.1%)	149 (26.9%)	165 (29.8%)	166 (30.0%)	4.00
e-learning π, μ, δ	11 (2.0%)	66 (11.9%)	196 (35.4%)	173 (31.3%)	107 (19.3%)	4.00
e-employment μ, δ	20 (3.6%)	84 (15.2%)	188 (34.0%)	178 (32.2%)	83 (15.0%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B2. ICT proficiency with completing different tasks (Items N=6)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
Valid *N* =553	1	2	3	4	5	Median
Technological devices η, μ, δ (valid *N* =553)	5 (0.9%)	42 (7.6%)	166 (30.0%)	222 (40.1%)	118 (21.3%)	4.00
Web browsers η, μ, δ	3 (0.5%)	56 (10.1%)	156 (28.2%)	224 (40.5%)	114 (20.6%)	4.00
Search engines η, μ, ε, δ	3 (0.5%)	40 (7.2%)	149 (26.9%)	224 (40.5%)	137 (24.8%)	4.00
University digital administrative services η, μ, δ	4 (0.7%)	53 (9.6%)	195 (35.3%)	214 (38.7%)	87 (15.7%)	4.00
University learning management systems μ, δ	5 (0.9%)	59 (10.7%)	224 (40.5%)	182 (32.9%)	83 (15.0%)	3.00
Communication Platforms η, δ	8 (1.4%)	54 (9.8%)	218 (39.4%)	196 (35.4%)	77 (13.0%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B3. ICT productivity (Items N=5)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
Valid *N* =553	1	2	3	4	5	Median
Organising/ managing/ storing your digital files δ (valid N =)	13 (2.4%)	84 (15.2%)	212 (38.9%)	154 (27.8%)	90 (16.3%)	3.00
Sharing securely your digital files with others η, δ	15 (2.7%)	87 (15.7%)	234 (42.3%)	149 (26.9%)	68 (11.3%)	3.00
Using productivity tools η, μ, δ	20 (3.6%)	108 (19.5%)	220 (39.8%)	142 (25.7%)	63 (11.4%)	3.00
Proof reading /spell-checking your work μ, δ	11 (2.0%)	78 (14.1%)	209 (37.8%)	168 (30.4%)	87 (15.7%)	3.00
Creating formatting styles μ, δ	22 (4.0%)	118 (21.3%)	229 (41.4%)	125 (22.6%)	59 (10.7%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: p < 0.05 birth year; π: p < 0.05 type of area mostly lived in; μ: p < 0.05 challenges; ε: p < 0.05 year of study (first vs continuous); δ: p < 0.05; barriers experienced overall)

Table B4. Information literacy (identification of information types) (Items N=3)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
Valid *N* =553	1	2	3	4	5	Median
Scholarly/academic literature ε δ	11 (2.0%)	120 (21.7%)	233 (42.1%)	150 (27.1%)	39 (7.1%)	3.00
Professional literature ε δ	13 (2.4%)	98 (17.7%)	233 (42.1%)	158 (28.6%)	51 (9.2%)	3.00
Popular information η, δ	5 (0.9%)	69 (12.5%)	197 (35.6%)	181 (32.7%)	101 (18.3%)	4.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: p < 0.05 birth year; π: p < 0.05 type of area mostly lived in; μ: p < 0.05 challenges; ε: p < 0.05 year of study (first vs continuous); δ: p < 0.05; barriers experienced overall)

Table B5. Information literacy skills (Items N=9)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
Valid *N* =553	1	2	3	4	5	Median
Finding digital information relevant to your academic studies, using informal Web sources δ	4 (0.7%)	70 (12.7%)	227 (41.0%)	181 (32.7%)	71 (12.8%)	3.00
Finding digital information relevant to your academic studies, using databases η, δ	14 (2.5%)	110 (19.9%)	234 (42.3%)	151 (27.3%)	44 (8.0%)	3.00
Using online collection tools for gathering digital information together in new ways μ, δ	42 (7.6%)	144 (26.0%)	220 (39.8%)	104 (18.8%)	43 (7.8%)	3.00
Evaluating whether digital information is trustworthy and relevant μ, δ	15 (2.7%)	97 (17.5%)	221 (40.0%)	167 (30.2%)	53 (9.6%)	3.00
Organising the digital information you find for your learning through folders, bookmarks, reference management software, and tagging δ	33 (6.0%)	130 (23.5%)	232 (42.0%)	115 (20.8%)	43 (7.8%)	3.00
Understanding academic integrity/honesty when accessing & using information online δ	10 (1.8%)	78 (14.1%)	202 (36.5%)	178 (32.2%)	85 (15.4%)	3.00

Understanding how to share information publicly online, respecting and acknowledging the work of others [δ]	15 (2.7%)	99 (17.9%)	234 (42.3%)	148 (26.8%)	57 (10.3%)	3.00
Using artificial intelligence generated content ethically, following academic integrity values [δ]	93 (16.8%)	138 (25.0%)	194 (35.1%)	96 (17.4%)	32 (5.8%)	3.00
Referencing digital information sources, adhering to a referencing style [δ]	10 (1.8%)	88 (15.9%)	238 (43.0%)	160 (28. 9%)	57 (10.3%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B6. Digital creation skills (Items N=8)

	Measurement scale (1 “Novice”, 2 “Basic”, 3 “Intermediate”, 4 “Advanced”, 5 “Expert”)					
Valid *N* =553	1	2	3	4	5	Median
Creation and editing of videos [η, μ, δ]	69 (12.5%)	147 (26.6%)	201 (36.3%)	88 (15.9%)	48 (8.7%)	3.00
Infographics [μ, δ]	114 (20.6%)	175 (31.6%)	154 (27.8%)	73 (13.2%)	37 (6.7%)	2.00
Online posters [η, μ, δ]	64 (11.6%)	128 (23.1%)	194 (35.1%)	111 (20.1%)	56 (10.1%)	3.00
Blogs/Wikis [η, μ, δ]	97 (17.5%)	156 (28.2%)	184 (33.3%)	75 (13.6%)	41 (7.4%)	3.00
Vlogs/Podcasts [η, μ, ε, δ]	108 (19.5%)	142 (25.7%)	173 (31.3%)	88 (15.9%)	42 (7.6%)	3.00
Creation of audio files [μ, ε, δ]	76 (13.7%)	139 (25.1%)	202 (36.5%)	90 (16.3%)	46 (8.3%)	3.00
Using Simulation/Virtual Reality Tools [η, μ, δ]	56 (10.1%)	130 (23.5%)	209 (37.8%)	103 (18.6%)	55 (9.9%)	3.00
Data visualisation [μ, δ]	68 (12.3%)	145 (26.2%)	209 (37.8%)	87 (15.7%)	44 (9.0%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B7. Digital research skills (Items N=8)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
Valid *N* =553	1	2	3	4	5	Median
Finding research raw/open data online [δ]	19 (3.4%)	104 (18.8%)	258 (46.7%)	128 (23.1%)	44 (8.0%)	3.00
Organising and storing research raw/open data online [η, δ]	37 (6.7%)	143 (25.9%)	237 (42.9%)	97 (17.5%)	39 (7.1%)	3.00
Using a Critical Appraisal Tool [δ]	153 (27.7%)	161 (29.1%)	174 (31.5%)	45 (8.1%)	20 (3.6%)	2.00
Using a survey tool [η, δ]	36 (6.5%)	114 (20.6%)	214 (38.7%)	128 (23.1%)	61 (11.0%)	3.00
Analysing digital research data using simple tools [μ, δ]	52 (9.4%)	156 (28.2%)	220 (39.8%)	88 (16.1%)	36 (6.5%)	3.00
Using methodologies to cleaning, transforming and preparing open data sets [μ, δ]	108 (19.5%)	163 (29.5%)	191 (34.5%)	63 (11.4%)	28 (5.1%)	3.00
Understanding how evidence-based research are used to construct arguments, make decisions, and/or solve problems [δ]	27 (4.9%)	123 (22.2%)	234 (42.3%)	125 (22.6%)	44 (8.0%)	3.00
Following ethical, legal, and security guidelines when using research data [μ, δ]	27 (4.9%)	124 (22.4%)	222 (40.1%)	124 (22.4%)	56 (10.1%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B8. Digital communication skills (Items N=9)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
Valid *N* =553	1	2	3	4	5	Median
Participating professionally in a range of digital networks related to your interests, work, and/or academic subject [η, μ, δ]	29 (5.2%)	99 (17.9%)	224 (40.5%)	135 (24.4%)	66 (11.9%)	3.00
Understanding expected behaviour/code of practice in online environments [η, μ, δ]	10 (1.8%)	56 (10.1%)	190 (34.4%)	181 (32.7%)	116 (21.0%)	4.00
Communicating respectfully, inclusively & confidentially, recognising that digital media	8 (1.4%)	46 (8.3%)	184 (33.3%)	177 (32.0%)	138 (25.0%)	4.00

can be used to intimidate, shame, and harass other people [δ]						
Communicating professionally via email with others [η, δ]	6 (1.1%)	38 (6.9%)	179 (32.4%)	188 (34.0%)	142 (25.7%)	4.00
Actively participating in online learning environments [δ]	8 (1.4%)	53 (9.6%)	209 (37.8%)	181 (32.7%)	102 (18.4%)	4.00
Recognising false or damaging online communications [η, δ]	7 (1.3%)	62 (11.2%)	205 (37.1%)	191 (34.5%)	88 (15.9%)	4.00
Actively sharing your specialist ideas (e.g., academic or professional) in a range of online communication media (e.g. social media such as LinkedIn, Twitter, Facebook) [η, δ]	20 (3.9%)	93 (16.8%)	234 (42.3%)	142 (25.7%)	64 (11.6%)	3.00
Sharing information using external communication tools [η, δ]	11 (2.0%)	60 (10.8%)	188 (34.0%)	186 (33.6%)	108 (19.5%)	4.00
Designing online communications for different purposes [η, μ, δ]	58 (10.5%)	113 (20.4%)	214 (38.7%)	112 (20.3%)	56 (10.1%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B9. Digital innovation (Items N=4)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
	1	2	3	4	5	Median
Developing new ideas and projects using online tools and technologies [η, μ, δ]	50 (9.0%)	135 (24.4%)	232 (42.0%)	92 (16.6%)	44 (8.0%)	3.00
Engaging with professional digital innovations [μ, δ]	33 (6.0%)	112 (20.3%)	237 (42.9%)	128 (23.1%)	43 (7.8%)	3.00
Working collaboratively on different aspects of a creative/innovative project/service design & managing the process as a team [η, μ, ε, δ]	49 (8.9%)	129 (23.3%)	225 (40.7%)	104 (18.8%)	46 (8.3%)	3.00
Promoting new online tools and opportunities to others [η, μ, δ]	68 (12.3%)	139 (25.1%)	218 (39.4%)	89 (16.1%)	39 (7.1%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B10. Digital learning and development (Items N=8)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
	1	2	3	4	5	Median
Participating in online learning opportunities and resources η, δ	13 (2.4%)	76 (13.7%)	242 (43.8%)	148 (26.8%)	74 (13.4%)	3.00
Adopting new ways of learning online η, δ	13 (2.4%)	85 (15.4%)	241 (43.6%)	157 (28.4%)	57 (10.3%)	3.00
Working collaboratively and supportively with other learners, using online technologies where appropriate η, δ	7 (1.3%)	72 (13.0%)	231 (41.8%)	168 (30.4%)	75 (13.6%)	3.00
Using online tools to take notes, annotate, and collate learning materials, review, and revise learning η, μ, δ	50 (9.0%)	128 (23.1%)	216 (39.1%)	106 (19.2%)	53 (9.6%)	3.00
Using online tools to record learning events/outcomes and use them for self-analysis, reflection, and showcasing of achievement η, ε, δ	30 (5.4%)	124 (22.4%)	235 (42.5%)	117 (21.2%)	47 (8.5%)	3.00
Receiving and responding to online feedback about your academic work η, δ	8 (1.4%)	83 (15.0%)	228 (41.2%)	157 (28.4%)	77 (13.9%)	3.00
Using learning management systems (e.g., Blackboard Collaborate, Zoom, Teams) to learn collaboratively η, μ, δ	8 (1.4%)	66 (11.9%)	243 (43.9%)	165 (29.8%)	71 (12.8%)	3.00
Sharing your online knowledge and skills, helping other learners η, δ	23 (4.2%)	96 (17.4%)	229 (41.4%)	147 (26.6%)	56 (10.5%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B11. Digital identity management (Items N=7)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
	1	2	3	4	5	Median
Managing your online profiles on different digital media (e.g. social media) in a way that is suitable for personal, professional, and academic purposes η, μ, δ	8 (1.4%)	74 (13.4%)	206 (37.3%)	169 (30.6%)	96 (17.4%)	3.00
Understanding how your online personal data are collected and used in different systems and use privacy settings appropriately η, μ, δ	16 (2.9%)	79 (14.3%)	224 (40.5%)	150 (27.1%)	84 (15.2%)	3.00
Being aware of the potential positive or negative impact of what you communicate online on your online reputation η, μ, δ	5 (0.9%)	55 (9.9%)	197 (35.6%)	178 (32.2%)	118 (21.3%)	4.00
Making sure outcomes of learning and other achievements are accessible in online forms η, μ, δ	13 (2.4%)	90 (16.3%)	219 (39.6%)	151 (27.3%)	80 (14.5%)	3.00
Understanding the impact of your online interactions η, μ, δ	8 (1.4%)	56 (10.1%)	192 (34.7%)	182 (32.9%)	115 (20.8%)	4.00
Using online analytics to explore your impact and influence on others η, μ, δ	42 (7.6%)	109 (19.7%)	219 (39.6%)	114 (20.6%)	69 (12.5%)	3.00
Establishing healthy boundaries/habits in using social media η, δ	13 (2.4%)	59 (10.7%)	218 (39.4%)	159 (28.8%)	104 (18.8%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B12. Digital wellbeing (Items N=6)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
	1	2	3	4	5	Median
Feeling comfortable, in control, and safe when using digital technologies η, μ, δ	5 (0.9%)	51 (9.2%)	199 (36.0%)	206 (37.3%)	92 (16.6%)	4.00
Recognizing that digital information and media can cause distraction, overload,	6 (1.1%)	44 (8.0%)	190 (34.4%)	198 (35.8%)	115 (20.8%)	4.00

and stress, and disconnecting when necessary η, δ						
Considering the rights and wrongs and the possible consequences of your online behaviour η, δ	3 (0.5%)	35 (6.3%)	167 (30.2%)	208 (37.6%)	140 (25.3%)	4.00
Acting positively against cyberbullying and other damaging online behaviours η, δ	6 (1.1%)	44 (8.0%)	166 (30.0%)	202 (36.5%)	135 (24.4%)	4.00
Managing online and real-world interactions in ways that support healthy relationships η, δ	5 (0.9%)	43 (7.8%)	186 (33.6%)	200 (36.2%)	119 (21.5%)	4.00
Managing online and real-world interactions in ways that support healthy relationships η, δ	8 (1.4%)	50 (9.0%)	198 (35.8%)	197 (35.6%)	100 (18.1%)	4.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall)

Table B13. Which level best describes your digital abilities to complete your academic work (e.g., using digital tools and processes as set in your course)? (Items N=1)

	Measurement scale (1 "Novice", 2 "Basic", 3 "Intermediate", 4 "Advanced", 5 "Expert")					
	1	2	3	4	5	Median
Which level best describes your digital abilities to complete your academic work η, μ, δ	3 (0.5%)	69 (12.5%)	262 (47.4%)	180 (32.5%)	39 (7.1%)	3.00

Note(s): Mann–Whitney U test and Kruskal–Wallis H-test (η: $p < 0.05$ birth year; π: $p < 0.05$ type of area mostly lived in; μ: $p < 0.05$ challenges; ε: $p < 0.05$ year of study (first vs continuous); δ: $p < 0.05$; barriers experienced overall).

Supplementary Material Appendix C.

Exploratory Factor Analysis (EFA) Results

Table C1. EFA results for everyday participation as digital citizens (Items N=9)

Items	*Component 1*
e-finance	.850
e-wellbeing	.845
e-health	.833
e-commerce	.805
e-learning	.794
e-employment	.792
e-government	.770
e-leisure	.760
e-democracy	.661
Cronbach's alpha	0.924
Mean value	3.494
Standard dev	0.794
Note(s): Extraction Method: Principal Component Analysis. 1 component extracted	

Table C2. EFA results for ICT proficiency with completing different tasks (Items N=6)

Items	*Component 1*
Search engines	.926
University digital administrative services	.922
Technological devices	.912
Web browsers	.907
Communication Platforms	.901
University learning management systems	.900
Cronbach's alpha	0.959
Mean value	3.643
Standard dev	0.794
Note(s): Extraction Method: Principal Component Analysis. 1 component extracted	

Table C3. EFA results for ICT productivity (Items N=5)

Items	*Component 1*
Sharing securely your digital files with others	.903
Creating formatting styles	.891
Using productivity tools	.874
Organizing/ managing/ storing your digital files	.864
Proof reading /spell-checking your work	.836
Cronbach's alpha	0.922
Mean value	3.302
Standard dev	0.867
Note(s): Extraction Method: Principal Component Analysis. 1 component extracted	

Table C4. EFA results for Information literacy (identification of information types) (Items N=3)

Items	*Component 1*
Professional literature	.944
Scholarly/academic literature	.929
Popular information	.861
Cronbach's alpha	0.897
Mean value	3.317
Standard dev	0.849
Note(s): Extraction Method: Principal Component Analysis. 1 component extracted	

Table C5. EFA results for Information literacy skills (Items N=9)

Items	*Component 1*
Evaluating whether digital information is trustworthy and relevant	.866
Understanding how to share information publicly online, respecting and acknowledging the work of others	.858
Finding digital information relevant to your academic studies, using databases	.845
Understanding academic integrity/honesty when accessing & using information online	.843
Organizing the digital information you find for your learning through folders, bookmarks, reference management software, and tagging	.836
Finding digital information relevant to your academic studies, using informal Web sources	.830
Referencing digital information sources, adhering to a referencing style	.829
Using online collection tools for gathering digital information together in new ways	.795
Using artificial intelligence generated content ethically, following academic integrity values	.688
Cronbach's alpha	0.938
Mean value	3.167
Standard dev	0.792
Note(s): Extraction Method: Principal Component Analysis. 1 component extracted	

Table C6. EFA results for Digital creation skills (Items N=8)

Items	*Component 1*
Blogs/Wikis	.914
Vlogs/Podcasts	.899
Online posters	.878
Creation of audio files	.858
Infographics	.854
Creation and editing of videos	.850
Data visualization	.811
Using Simulation/Virtual Reality Tools	.809
Cronbach's alpha	0.949
Mean value	2.771
Standard dev	0.973
Note(s): Extraction Method: Principal Component Analysis. 1 component extracted	

Table C7. EFA results for Digital research skills (Items N=8)

Items	*Component 1*

Analyzing digital research data using simple tools	.870
Understanding how evidence-based research are used to construct arguments, make decisions, and/or solve problems	.865
Organizing and storing research raw/open data online	.863
Using methodologies to cleaning, transforming and preparing open data sets	.853
Following ethical, legal, and security guidelines when using research data	.852
Finding research raw/open data online	.837
Using a survey tool	.803
Using a Critical Appraisal Tool	.778
Cronbach's alpha	0.940
Mean value	2.876
Standard dev	0.866
Note(s): Extraction Method: Principal Component Analysis. 1 component extracted	

Table C8. EFA results for Digital communication skills (Items N=9)

Items	*Component 1*
Communicating professionally via email with others	.868
Communicating respectfully, inclusively & confidentially, recognizing that digital media can be used to intimidate, shame, and harass other people	.864
Recognizing false or damaging online communications	.863
Actively participating in online learning environments	.860
Sharing information using external communication tools	.860
Understanding expected behaviour/code of practice in online environments	.858
Actively sharing your specialist ideas (e.g., academic or professional) in a range of online communication media (e.g. social media such as LinkedIn, Twitter, Facebook);	.835
Participating professionally in a range of digital networks related to your interests, work, and/or academic subject	.804
Designing online communications for different purposes	.716
Cronbach's alpha	0.945
Mean value	3.466
Standard dev	0.826
Note(s): Extraction Method: Principal Component Analysis. 1 component extracted	

Table C9. EFA results for Digital innovation (Items N=4)

Items	*Component 1*
Working collaboratively on different aspects of a creative/innovative project/service design & managing the process as a team	.936
Promoting new online tools and opportunities to others	.934
Developing new ideas and projects using online tools and technologies	.929
Engaging with professional digital innovations	.910
Cronbach's alpha	0.945
Mean value	2.929
Standard dev	0.963

Note(s): Extraction Method: Principal Component Analysis. 1 component extracted

Table C10. EFA results for Digital learning and development (Items N=8)

Items	*Component 1*
Working collaboratively and supportively with other learners, using online technologies where appropriate	.893
Adopting new ways of learning online	.888
Using learning management systems (e.g. BlackBoard Collaborate, Zoom, Teams) to learn collaboratively	.877
Sharing your online knowledge and skills, helping other learners	.876
Receiving and responding to online feedback about your academic work	.871
Participating in online learning opportunities and resources	.871
Using online tools to record learning events/outcomes and use them for self-analysis, reflection, and showcasing of achievement	.852
Using online tools to take notes, annotate, and collate learning materials, review, and revise learning	.814
Cronbach's alpha	0.952
Mean value	3.261
Standard dev	0.838

Note(s): Extraction Method: Principal Component Analysis. 1 component extracted

Table C11. EFA results for Digital identity management (Items N=7)

Items	*Component 1*
Making sure outcomes of learning and other achievements are accessible in online forms	.903
Being aware of the potential positive or negative impact of what you communicate online on your online reputation	.896
Understanding how your online personal data are collected and used in different systems and use privacy settings appropriately	.890
Understanding the impact of your online interactions	.890
Managing your online profiles on different digital media (e.g. social media) in a way that is suitable for personal, professional, and academic purposes	.886
Establishing healthy boundaries/habits in using social media	.852
Using online analytics to explore your impact and influence on others	.784
Cronbach's alpha	0.946
Mean value	3.440
Standard dev	0.868

Note(s): Extraction Method: Principal Component Analysis. 1 component extracted

Table C12. EFA results for Digital wellbeing (Items N=6)

Items	*Component 1*

Managing online and real-world interactions in ways that support healthy relationships	.934
Considering the rights and wrongs and the possible consequences of your online behaviour	.933
Acting positively against cyberbullying and other damaging online behaviour	.907
Recognizing that digital information and media can cause distraction, overload, and stress, and disconnecting when necessary	.906
Managing online and real-world interactions in ways that support healthy relationships	.901
Feeling comfortable, in control, and safe when using digital technologies	.893
Cronbach's alpha	0.960
Mean value	3.687
Standard dev	0.843

Note(s): Extraction Method: Principal Component Analysis. 1 component extracted

Table C13. Bivariate correlations of the survey factors

Factors/ Variables	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*
1	1.00												
2	0.760**	1.00											
3	0.728**	0.794**	1.00										
4	0.709**	0.685**	0.744**	1.00									
5	0.682**	0.709**	0.791**	0.825**	1.00								
6	0.544**	0.508**	0.707**	0.597**	0.740**	1.00							
7	0.586**	0.615**	0.723**	0.707**	0.827**	0.810**	1.00						
8	0.701**	0.706**	0.686**	0.718**	0.757**	0.631**	0.724**	1.00					
9	0.531**	0.549**	0.637**	0.575**	0.704**	0.748**	0.790**	0.689**	1.00				
10	0.671**	0.685**	0.736**	0.691**	0.766**	0.722**	0.801**	0.837**	0.776**	1.00			
11	0.667**	0.651**	0.674**	0.673**	0.712**	0.619**	0.704**	0.823**	0.685**	0.849**	1.00		
12	0.670**	0.657**	0.609**	0.619**	0.624**	0.485**	0.575**	0.792**	0.552**	0.759**	0.840**	1.00	
13	0.593**	0.648**	0.679**	0.659**	0.690**	0.576**	0.605*	0.652**	0.552**	0.700**	0.635**	0.619 **	1.00

Note(s): *$p < 0.05$ and **p < 0.001, 1. Everyday participation as a digital citizen ; 2. ICT proficiency with completing different tasks ; 3. ICT productivity; 4. Information literacy (identification of information types); 5. Information literacy skills; 6. Digital creation skills; 7. Digital research skills; 8. Digital communication skills; 9. Digital innovation; 10. Digital learning and development; 11. Digital identity management; 12. Digital wellbeing; 13. Digital abilities to complete academic work.

Supplementary Material Appendix D.

Open Data

Table D1. Neurodivergence related challenges

Digital competences area	Indicative Quotes
ICT Pproficiency & ICT productivity	"I find reading black on white hard, so I use coloured fonts. I also struggle with distractions, so I put my laptops on DND. "[Do Not Disturb] "Sitting and looking at a computer is difficult. while words move and lights appear it is hard to focus on words and actually take them in." "I have trouble keeping focussed for long". "If it is not enticing enough, or it is not something I particularly want to do then I will become distracted and do other things before coming back to it". "Struggle to focus on one thing at a time easily distracted always need to be doing something else at same time as doing digital tasks". "Yes - easily distracted with online writing. I find it difficult to read on a screen. I find it easier to read paper i.e., books. Although I enjoy using read-aloud when available". "I often find the screen causes my dyslexia to be worse. I prefer reading from paper". "I find it a bit harder to engage as my focus is impacted and I also struggle if there is a lot of reading". "I feel easily distracted and can't concentrate". "Yes, can't stay focused on a task for long".
Information literacy & digital research	"I find a lot of information online overwhelming. Therefore, need a lot of time to pick information out". "Being presented with large amounts of information at once makes it difficult to comprehend instructions or maintain focus without feeling overwhelmed". "May feel overwhelmed when attempting to use tools". "If the tools are overwhelming and have too much going on…that is also difficult". "Sometimes it's difficult to process the information and it can be quite an overload to navigate." "Being presented with large amounts of information at once makes it difficult to comprehend instructions or maintain focus without feeling overwhelmed". "May feel overwhelmed when attempting to use online tools".
Finding the right tools	"Struggle to understand how to get a coloured background for my laptop making it difficult for me to engage on the work", "Some of the generic tools are aimed at the "average" user finds black writing on a white background difficult to follow and it makes it difficult to focus. I also struggle to read smaller writing". "I am not sure what is available". "I know there are some out there, I just haven't found any that work for me". "An assumption that people are comfortable to use microphones and cameras - this is so much more anxiety producing for me and feels very inaccessible". "Never find an app that doesn't make me nervous so far".

	"Try to use systems available but would be interested to see more specific for dyslexia". "I do have a word checker that works specifically for dyslexia". "Try to use systems available but would be interested to see more specific for dyslexia".

Table D2. Neurodivergence strategies

	Indicative Quotes
Assistive technologies	"I have found apps such as Read & Write Gold extremely helpful. Grammarly has also helped". "Read-aloud systems when available". "Grammarly is something that I've recently invested in, and it has made a real difference in the quality of work". "I have found apps such as Read and Write Gold extremely helpful". "Global auto-correct, Read and Write Gold, Mindjet Mind Manager, recorded lecture". "Global autocorrect is helpful, being able to highlight text and it to be read out to me"
Audio-visual strategies	"Having videos to back to and re watch to take in helps." "Video how To's, forums where you can post questions". "Watching videos with visual teaching". "Screen tints. Screen ruler chrome add-ons to help keep track of sentences. Highlighter Chrome add-ons to track sources or important things to remember". "Change screen colour to make information easier to read and understand". "Using microphone on Word to turn my speech into words on a document".
Time-management and memory-improving tools	"Good routine helps me, so things like a calendar and well-organised meetings". "[helps]Time management and patience". "Using digital flashcards". "Outlook calendar and reminders allow me to not forget about important appointments" "Highlighter Chrome add-ons to track sources or important things to remember".
Using the University Support Services	"I have many tools on my laptop provided by the learning team now" "The university has supplied me with a laptop with various apps on to help with this". "I have a mentor with the inclusion team that supports me by collaboratively breaking down and reorganizing the information in a way I am more easily able to comprehend and interact with".