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Digital Skills and the Impact of Digital Technologies in Secondary Education in the Era of Artificial Intelligence

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Abstract

This paper examines the availability and development of digital skills in the context of an increasing diffusion of Artificial Intelligence (AI) and other digital technologies within the economy and the wider society. The paper first assesses Ireland's performance with respect to digital skills relative to other EU countries, highlighting important gaps among the younger population. In this context, we place a particular focus on the role of secondary education in providing the skills needed for the digital economy. Drawing on in-depth data across secondary schools in Ireland, the paper examines students' perceptions that school benefits their digital skills and whether such technology positively impacts their school experience. Framed within a socio-cultural framework, the results highlight the complexity and interdependence of factors shaping digital skills development and the impact of technologies at school. The importance of teacher skills and adoption cannot be overstated. A culture of student democracy and a holistic, inclusive school ethos is also associated with better skills development. The results show the lasting impact of approaches during COVID-19 school building closures – with experiences during this period shaping skills perceptions several years later.

Keywords Digital technologies, digital skills, school ethos, school context, COVID-19

JEL Classification O33, I21, I25

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1 Introduction

Digital literacy is one of the most important factors driving the digital transformation taking place worldwide within the economy and the wider society. The availability of digital skills enables the adoption and diffusion of digital technologies such as Artificial Intelligence (AI) and enhances their effects on innovation and productivity. The rapid advances of AI and other digital technologies are reshaping the role of education in providing the digital skills that are needed in an increasingly digital economy and society.

Theoretical models have established a direct and positive relationship between human capital and the adoption of new technologies (Nelson and Phelps, 1966). A rich body of empirical evidence shows that the adoption of new advanced technologies requires highly skilled workers to fully exploit the potential of such tools (Doms et al., 1997). Chun (2003) finds that the use of information and communication technologies (ICT) is complementary with an educated workforce, and educated employees have a comparative advantage in the adoption of ICT. Enterprises employing a highly skilled workforce are better positioned to adopt new technologies (Fabiani et al., 2005; Haller and Siedschlag, 2011), and to innovate (Bayo-Moriones and Lera-López, 2007), and undergo organisational change (Falk, 2005).

Castellacci et al. (2020) provide evidence showing that digital skills (e-skills) enhanced the technological diversification of European regions. The analysis distinguished between e-skills of ICT-users and non-ICT users. Existing firm-level evidence indicates that digital skills foster firms' productivity while the shortage of digital skills limits the ability of firms to reap the productivity gains from digitalisation (Gal et al. 2019). Cette et al. (2020) use firm-level data from France and find that employing in-house ICT specialists enhanced firm-level productivity. The effect is stronger and larger than the effect of employing ICT external specialists. Borowiecki et al. (2021) find that the availability of ICT specialists and software specialists have positive and significant effects on firm-level productivity growth. The effects are larger in services firms.

Artificial Intelligence (AI) is a modern general-purpose technology (GPT) which has the potential to enhance productivity across enterprises, sectors, and the wider economy (Brynjolfsson et al., 2019). However, the effects of AI on productivity are likely to be delayed in time due to adjustment costs and additional complementary investments needed in other intangible assets such as skills, in particular digital skills, training, and organisational change (Brynjolfsson et al., 2021; Heimberger et al., 2024; McElheran et al., 2024).

The adoption of AI requires new digital skills with an increasing importance of skills such as advanced analytics, programming skills, cybersecurity skills (Kinkel et al., 2022) as well as new training concepts (Williams et al., 2022). A skilled workforce, as a factor influencing the adoption of AI, appears to be the most frequently cited in a recent literature review (Heimberger et al., 2024) while the lack of the

necessary digital skills is found to be a major barrier to adopting AI tools for production systems (Dohale et al., 2022).

AI impacts both the demand and supply of educational opportunities (National Academies of Sciences, Engineering and Medicine, 2024). Thus, on the demand side, rapid advances, in particular in the area of generative AI, are changing the demand for skills and therefore the demand for education and training. On the supply side, AI could be an input in education, providing new online learning opportunities for primary, secondary and continuing education. Recent advances in Large Language Models (LLM) have the potential to design more flexible and adaptive computer-based teaching environments and adapting to different learning needs and learning styles. As documented by research-based evidence, more personalised teaching and access to adaptive computer-assisted-learning (CAL) technologies lead to substantial learning gains (see for example, Banerjee et al., 2007; Escueta et al., 2020). Risks associated with AI, particularly in the context of educational assessment, are also increasingly emerging, as many countries grapple with the unique opportunities and challenges associated with AI in assessment. In the Irish context, Marcus-Quinn and McCoy (2024) highlight major gaps in schools' procedures around technology, with many relying on outdated policies that lack clear guidelines on recent technological advances, particularly AI.

Against this background, this research paper examines the availability of digital skills in the context of an increasing importance of AI and other digital technologies within the economy in Ireland and other EU economies. In this context, a particular focus is on the role of secondary education in developing the skills needed for the digital economy, given earlier research highlighting the importance of digital exposure at school for adult digital literacy and literacy (Asongu et al., 2024). While further and higher education undoubtedly play a key role in specialised skills development, almost all young people participate in secondary education so exposure to digital technologies and development of digital skills while at school are critical in national digital skills levels.

This research paper includes an assessment of existing evidence on the use of digital technologies across secondary schools and the promotion of digital skills within and across schools. The focus is predominantly on the Irish context, placing trends within the wider European setting where possible. The paper includes a brief review of PISA 2018 data on secondary students' experiences in using digital technologies in learning before COVID-19. The data show that students in Ireland held a generally positive view on the use of digital devices compared to the EU average, but analyses suggest notable differences in students' access to digital technology both within and outside school, despite positive attitudes towards digital technology per se. The paper is then centred on primary research undertaken in secondary schools in Ireland in Spring 2023. Over 2,200 upper and lower secondary students completed a detailed survey across 21 schools selected to capture diversity in terms of gender mix, prevalence of additional educational needs and school social mix. Drawing on this large-scale

multilevel data the paper examines the perceived benefits of digital technologies (DTs) for learning, the role of school in digital skills development and the impact of school, teacher and family processes in shaping these. The data allow important insights into digital access and literacy for different groups of secondary students in Ireland and critically a unique opportunity to assess the extent to which school leavers are likely to have the requisite digital experience and skills as they embark on their post-school lives and careers. It places the discussion in the context of policy developments at both national and EU levels. The Digital Strategy for Schools to 2027 (Department of Education, 2022) seeks to embed digital technologies in teaching, learning, and assessment across the education system, to ensure (young) adults are equipped with essential digital skills for the modern world. It includes a range of capital and current investments to bolster technology access and usage within and across educational settings. At EU level, digital skills are recognised as increasingly important for navigating society and the labour market. Improving computer and internet skills and access is stated as a key policy goal to foster digital inclusion, educational access and life-long learning (e.g., EU's Digital Education Action Plan 2021-2027 adopted in 2020[2]). These national and EU policy developments serve as an important backdrop for the current study.

This evidence will help to better understand the opportunities and challenges associated with the adoption and diffusion of AI and other digital technologies and the potential economic contribution of digital skills and upskilling to competitiveness within the digital economy.

The paper is structured as follows. Section 2 presents descriptive evidence on digital skills across EU countries. Section 3 presents an in-depth analysis of the role of secondary education in providing digital skills in Ireland. The paper concludes with a discussion and implications for policy.

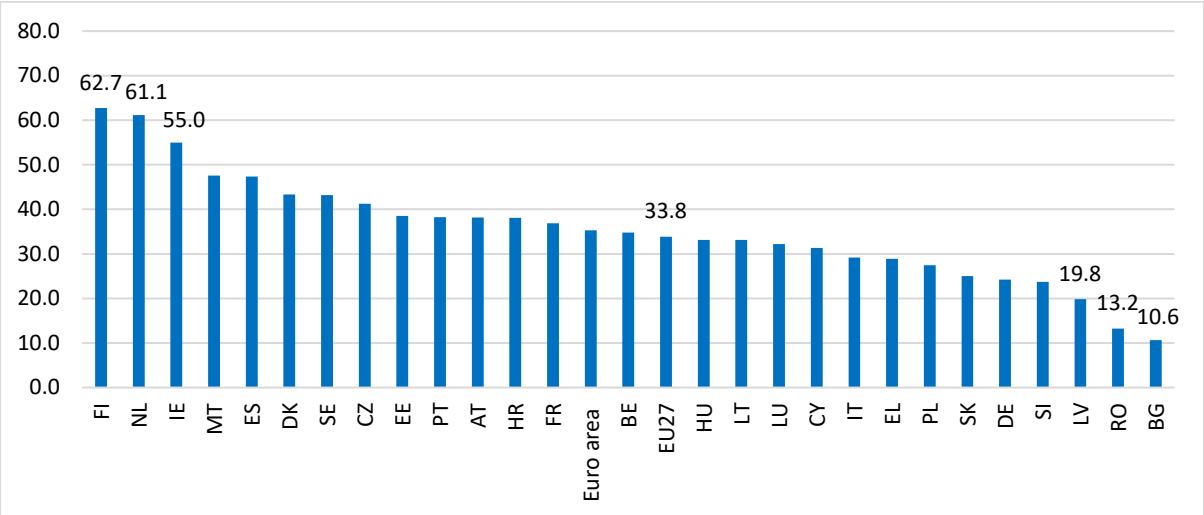
[2] The Digital Education Action Plan (2021-2027) is an EU policy initiative aimed at promoting high-quality, inclusive digital education across Europe and assisting Member States in adapting their education systems to the digital era. Adopted on 30 September 2020, it seeks to foster greater collaboration at the European level to address challenges and opportunities presented by the COVID-19 pandemic, offering opportunities for various stakeholders, including teachers, students, policymakers, academia, and researchers, at national, EU, and international levels. https://education.ec.europa.eu/focus-topics/digital-education/action-plan.

2 Digital Skills Across EU Countries: Descriptive Evidence

In this section we draw on data on digital skills available for EU countries collected with the EU Survey on the Use of Information and Communication Technologies (ICT) in Households and by Individuals. The survey is carried out every year by National Statistics Offices using the Eurostat's Model Questionnaire.[3] Digital skills are measured based on selected activities performed by individuals aged 16 to 74 when using the internet during the previous 3 months in the following areas: information, communication, problem solving, content creation. The key indicator we use across EU countries is overall digital skills, a composite indicator encompassing the following skills: information and data literacy skills; communications and collaboration skills; online and communication skills. For this analysis, we focus on the above basic overall digital skills[4] for all individuals by age groups and for employees and assess Ireland's performance relative to other EU countries.

Figure 1 shows Ireland's performance with respect to the share of employees with above basic overall digital skills relative to other EU countries in 2023. At 55%, the share of employees with above basic overall digital skills is the third highest in the EU. The two EU countries ahead of Ireland are Finland and the Netherlands with 63% and 61% of employees with above basic overall digital skills, respectively.

Figure 1: Employees with above basic overall digital skills, % of employees, EU countries, 2023



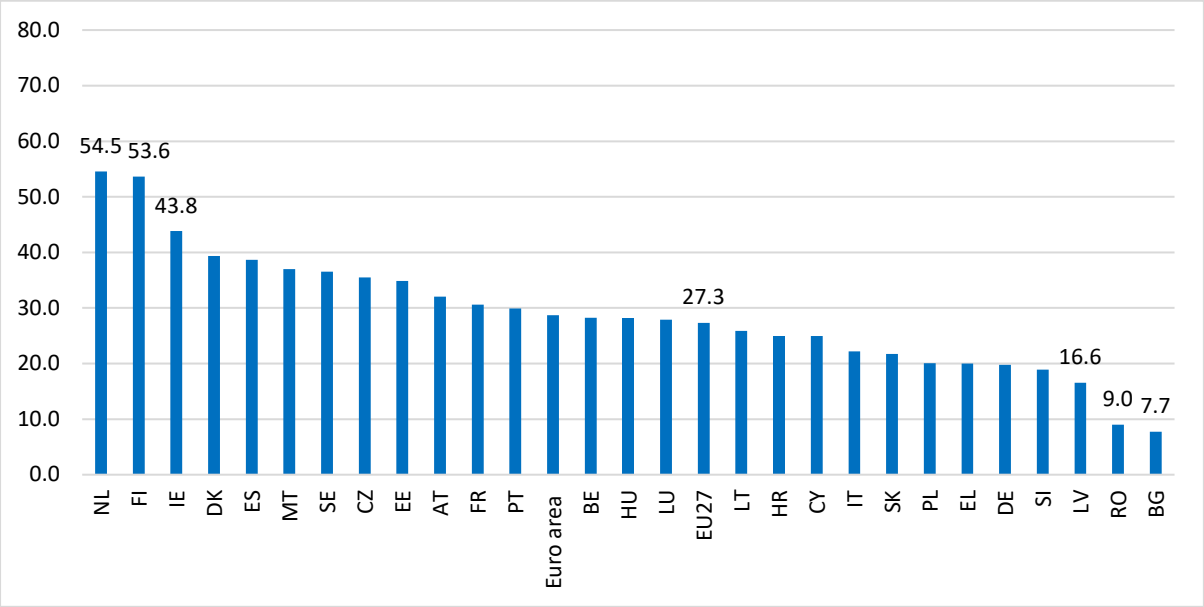
Source: Authors' elaboration based on data from Eurostat.

[3] The survey questionnaire is updated each year to reflect developments in information and communication technologies. The survey is conducted every year in all EU countries, Iceland, Norway, Switzerland and candidate countries and potential candidate countries. It covers households with at least one member aged between 16 and 74 years and individuals between 16 and 74 years. The survey is based on representative samples obtained using a stratified sampling method. The data collected refer to the first quarter of the survey year. More details on the survey are available from the following web page: https://ec.europa.eu/eurostat/cache/metadata/fr/isoc_i_esms.htm

[4] The above basic overall digital skills level implies that an individual has an above basic level in each of the skill areas considered: information and data literacy skills; communications and collaboration skills; online and communication skills.

Ireland ranks also the third among EU countries with respect to the share of all individuals with above basic overall digital skills (Figure 2).

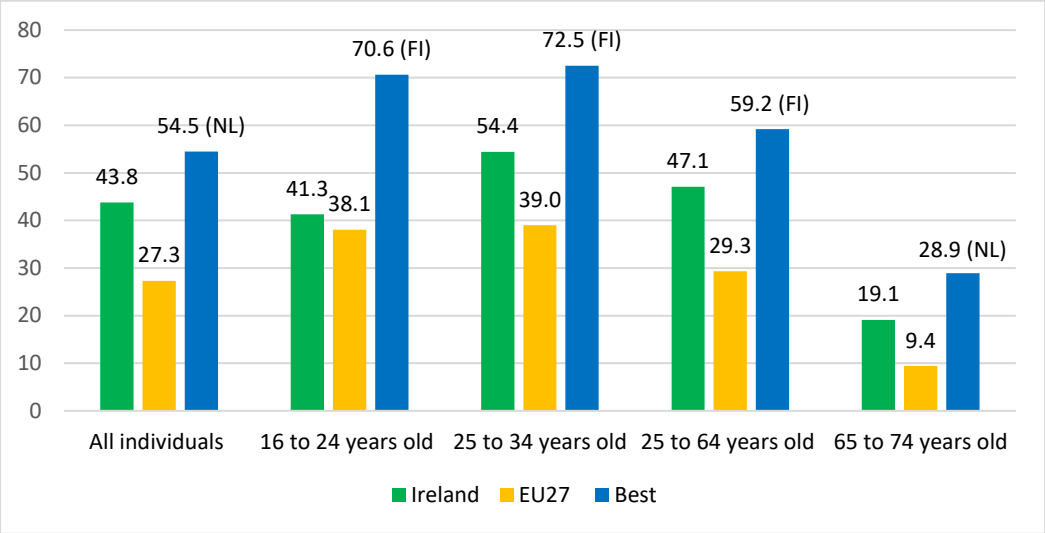
Figure 2: Individuals with above basic overall digital skills, % of individuals, 2023



Source: Authors' elaboration based on data from Eurostat.

Examining further Ireland's performance on digital skills for all individuals and by age group, Figure 3 below shows that the gap between Ireland's performance and the EU country with the best performance is the largest for the 16-24 age group. The share of individuals aged 16-24 years in Ireland in 2023 is just 3 percentage points above the EU average and substantially lower, by 29 percentage points relative to Finland, the EU country with the best performance. The second largest gap is for the age group 25-34: the share of individuals with above basic overall digital skills in Ireland is 18 percentage points lower relative to the EU country with the best performance, Finland.

Figure 3: Individuals with above basic overall digital skills, % of individuals, EU countries 2023



Source: Authors' elaboration based on data from Eurostat.

3 The Role of Education in Providing Digital Skills: Empirical Evidence from Irish Schools

Given the gap in digital skills among younger cohorts in Ireland identified in Section 2 above, understanding which students feel supported in their digital skills development and the school contexts and processes enabling such skills development is critical in addressing skills shortfalls in Ireland. Drawing on in-depth data across secondary schools in Ireland, this is a key focus of this paper. In considering earlier work, the paper builds on an important body of research examining the relationship between digital technologies (DT)[5] usage and actual skills development (Claro et al. 2012; Hatlevik et al. 2015), skill perceptions (Schmid & Petko 2019) and academic achievement (Agasisti et al. 2020; Zhang, Liu 2016). A second strand of work examines how digital skill is related to self-efficacy (Hatlevik et al. 2018; Rohatgi, et al. 2016) and attitudes (Erdogdu & Erdogdu 2022). There is also growing focus on not just access to DTs but also how they are used. Several studies suggest that the use of technology in schools is still often superficial and not meeting the potential of technology (Niederhauser et al., 2018) and the core challenge around effective implementation across different contexts remains.

An area that is relatively underexplored relates to students' perceptions that school benefits their computer/digital skills – school-acquired digital skills belief. Given the importance of self-efficacy and academic self-concept across a range of outcomes (Chamundeswari et al., 2014), digital skills belief may be important in shaping decision-making and perceived digital competency post-school. Drawing on longitudinal data on students born in 1998, Griffin et al. (forthcoming) show variation in students' perceptions of digital skill learning across school types in Ireland and crucially the interplay with home DT usage. Schools from less well-resourced families and girls were more likely to attribute digital skills development to their school setting. Taking a similar approach, examining perceptions of school developed DT skills as well as perceived benefits in their learning, this study provides a more timely and richer analysis of student experiences across 21 distinct secondary school settings in Ireland. We examine:

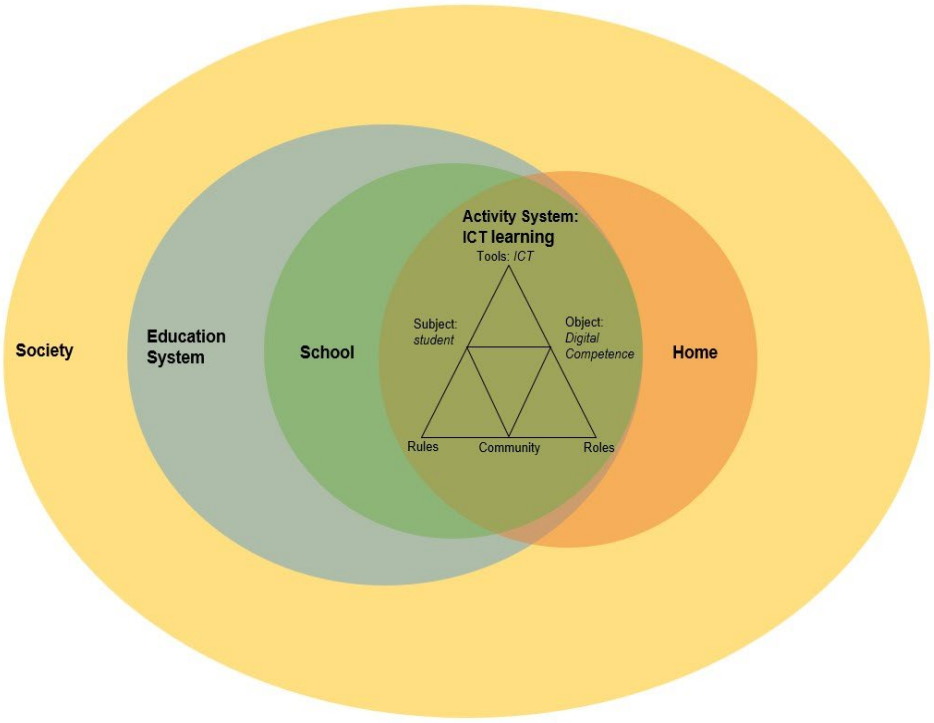
- To what extent do students feel DTs in teaching and learning positively impact their school experience?
- Which students reflect positively on school benefiting their digital skills?
- How do school context (including social and gender mix) and school process variables (like value emphasis, democratic principles and social relations) shape such reflections?

[5] While the term 'information and communication technologies' or 'ICT' has been the preferred term of the OECD, Ireland has tended to use the term 'digital technologies' or 'DT', so we use this term in the paper.

3.1 Theoretical Framework

Given the focus on students, families, schools and school contexts, our paper is underpinned by a socio-cultural approach, where a school is an environment of collaborative, social activities of teachers, students and others; and their activities shape and transform its culture, values, practices and other specific characteristics (John-Steiner & Mann, 1996; Ilomäki & Lakkala, 2018). The paper adapts Lim's (2002) socio-cultural approach to digital learning at school, placing the spotlight on the social and school context in digital skills and learning beliefs. As portrayed in Figure 4, learning and (perceived) skills development are socially situated, with digital technologies as mediators within broader ecological circles (home, school/teachers, education system, and society). Digital learning is potentially shaped by infrastructure, ethos and values, as well as student characteristics, school social mix and teacher skills and orientation. Availability of DTs tells an incomplete story, with socio-cultural factors relating to school leadership and ethos, teacher skills, parenting and family resources, and student interest and engagement, potentially important in shaping digital skills development (Marcus-Quinn et al., 2019; Schmid & Petko, 2019; Carroll et al., 2024). The effectiveness of technology in teaching and learning depends on how it is used and the skills of those using it. Excessive use of certain media, like slide shows, insufficient interaction during (online) classes or inappropriate pace of instruction, can mean DTs are not having the impact on learning or skills development they might have (Carroll et al, 2024, Dunne et al., 2020). Teachers' digital proficiency may be important in understanding students' skills development. While many teachers engaged in a steep learning curve in relation to technology adoption in the context of COVID-19 (Mac Domhnaill et al., 2021), that may not translate into usage now. Or it may create challenges for teachers in blurring their school and home lives (the school and home ecological circles), with additional burden around creating digital resources; see for example (Marcus-Quinn and Hourigan, 2022).

Figure 4: A theoretical framework from the study of DT in school



Source: Adapted from Lim 2002 & Griffin et al., forthcoming.

3.2 Use of Digital Technologies in Schools in Ireland

Ireland was traditionally considered comparatively weak in the integration of technologies in the classroom and in terms of digital skills development among students (see OECD, 2019). Beblavý et al. (2019) constructed an index of readiness for digital lifelong learning (IRDLL) and compared scores across EU countries. Ireland ranked 12th of the 27 countries on the overall index, slightly above the EU average. Examining the components of the index, Ireland's overall ranking of 12th was characterised by relatively strong performance in learning participation and outcomes, and relatively weak performance in institutions and policies for digital learning as well as availability of digital learning. These findings are mirrored in PISA 2018 results which show that the average score on a scale measuring schools' capacity to integrate DTs in the classroom, according to school leaders, was notably lower in Ireland than across the EU and OECD (Cosgrove et al., 2022). 15-year-olds in Ireland spent considerably less time on the internet during school time (4 hours per week) than the OECD average (8 hours per week), with the gap widening over time (Cosgrove et al., 2022). Results show that teenagers used computers in school less frequently than on average across the OECD, and at times considerably so, for each of a range of 10 educational activities such as browsing the internet for schoolwork, using computers for group work or communication, and practising or drilling (OECD, 2021, Table B6.14). Butler and Leahy (2022) similarly reported that in 38% of secondary schools and 45% of

primary schools assessed by Department of Education inspectors in 2019 (DES, 2020), DT did not feature in teaching and learning. They conclude "… digital technologies are still underutilised in many schools and classrooms" (Butler & Leahy, 2022, p. 77).

The pandemic had a profound impact on digital engagement in schools, creating a steep learning curve for more traditional schools (Mohan et al., 2020). Essentially, it forced schools with very little experience of using technology into upskilling and refocusing very quickly – although it is not clear whether it evened the playing field or whether earlier adopters continue to fare better. The limited evidence in Ireland suggests that the impact of COVID-19 on student learning and engagement varied considerably across school contexts, to some extent reflecting different levels of online teaching and wider infrastructural barriers (Mac Domhnaill et al., 2021).

To address inequalities and weaknesses in the effective adaptation of education and training systems of EU member states to the digital age, the European Commission published a Digital Education Action Plan (DEAP) 2021-2027. The plan has two aims: (i) fostering the development of a high-performing digital education ecosystem[6]; and (ii) enhancing digital skills and competences for the digital transformation[7] (Beblavý et al., 2019, pp. 25-34). While late starters, there is also a stronger policy focus now in Ireland with an ambitious *Digital Strategy for Schools 2027* (Department of Education, 2022) aiming to:

> *"empower schools to harness the opportunities of digital transformation to build digital competence and an effective digital education ecosystem so as to develop competent, critically engaged, active learners while supporting them to reach their potential and participate fully as global citizens in a digital world" (Department of Education, 2022, p.11.).*

There has been a central focus on digital skills development and investment in infrastructure as part of the EU Recovery and Resilience Facility for Ireland (European Commission, 2024). However, schools continue to have considerable autonomy in setting DT policies and in their orientation towards innovative approaches, creating wide school-level variation in DT exposure and skills among secondary students (McCoy et al., forthcoming).

[6] Digital education ecosystems cover infrastructure, connectivity and digital equipment; effective digital capacity planning and development, including up-to-date organisational capabilities; digitally competent and confident teachers and education and training staff; high-quality learning content, user-friendly tools and secure platforms which respect e-privacy rules and ethical standards.

[7] This objective encompasses basic digital skills and competences from an early age; digital literacy, including tackling disinformation; computing education; good knowledge and understanding of data-intensive technologies, such as artificial intelligence (AI); advanced digital skills, which produce more digital specialists; and ensuring that girls and young women are equally represented in digital studies and careers.

3.3 Methodology and Measures

Participants

While the PISA study is designed to measure population-level contexts, it is less useful for estimating differences between subgroups of a population, so provides limited insight into how different groups of secondary students in Ireland fare in terms of digital literacy and digital usage (Cosgrove et al., 2022). However, a large-scale study of secondary student experience was conducted by the authors in 2023, providing rich insights on digital access and skills developed across different groups of students in Ireland (Carroll et al., 2024). Participants were recruited from 21 Irish secondary schools identified from administrative data to capture a diversity of school locations, gender mix, social class mix and school size. Within each school, all second (13-14-year-olds) and fifth year (16-17-year-olds) students were invited to participate. The total response rate from the 21 schools was 59% (range: 23% - 87%). A total of 2,243 students responded, just over half of whom were female (54% female). The achieved sample is broadly in line with the national population, providing strong diversity across key characteristics: 22% of students reported they experience an impairment, disability or educational difficulty; 13% of students reported speaking a language other than English at home; and 29% reported one parent and 57% reported both parents hold a higher education degree.

Procedure

Study procedures were approved by the ESRI Research Ethics Committee. Prior to data collection, parent and student written consent was obtained for all participants. In March/April 2023 in-person school visits by the research team provided details on the study to the school community, followed by administration of the surveys with students, in paper or online format, typically taking one class period to complete (40-60 minutes). Students also had the option of completing a shorter and more accessible version of the questionnaire. Respondents provided anonymised demographic information, reported on their experiences of their school and outside school lives and aspirations for the future (see Carroll et al., 2024 for full details). Neither schools nor students received any compensation for participating in the study. All descriptive and multivariate analyses were conducted in SPSS.

Student-level demographic information

Students reported on their gender, any additional learning need/disability, parental education and economic vulnerability. Responses were recoded into the following variables: gender (0 = female, 1 = male), special educational needs (SEN) (SEN, no SEN, not sure about SEN status), parental education (0 'neither parent with higher education (HE) ', 1 'one or both with HE') and socio-economic difficulties (0 = answered 'not sure', 'fairly easy', 'easy' or 'very easy'; 1 = answered 'fairly difficult', 'difficult' or 'very difficult' to pay the bills at home). Earlier research suggests that girls might be less likely engage/enrol in DT activities given stereotypes (Master et al., 2024), while students with additional

needs may benefit from assistive technologies, and those from more affluent families may benefit from greater DT resources at home and at school (Mac Domhnaill et al., 2021). We also differentiate students in lower and upper secondary years for the model on DTs positively shaping school experiences, as one might expect more positive reflections from lower secondary students given more innovative teaching and learning approaches prior to the high stakes upper secondary years (Carroll et al., 2024).

School-level demographic information

Data was obtained from the Department of Education regarding each of the 21 schools on location (rural, town, urban), gender mix (co-educational, all girls or all boys), whether the school is part of the priority education programme 'DEIS', serving socio-economically disadvantaged populations (disadvantaged school) and whether the school is fee-charging (selective school).

DT Variables

Students reported on a range of aspects of their DT access and usage within and outside school, allowing us to assess how such access shapes perceptions of digital skill development. They reported on the frequency of usage of personal devices (tablets, laptop, smartphone) in school and the nature of usage (use for various purposes for designing oral presentations, in collaborative tasks like groupwork, to source useful material for class, to reflect on their learning as part of portfolio work etc.). We classify schools based on the frequency of DT usage by students, with student average DT (personal devices, laptops or computers) usage greater than three times weekly classed as 'high tech schools'. Respondents were also asked about their home DT usage and the time they spent online at home (>3 hours per day or less). Students were also asked to reflect on their teachers and the extent to which they felt their teachers were enthusiastic about using technologies in the classroom and whether they need 'more ICT-related training'. Finally, they report on their experiences during COVID-19 school building closures, including whether they 'had a chance to attend lessons on the internet', 'had regular problems with my internet connection' and 'had problems accessing help or support from teachers' ('always true', 'sometimes true', 'not true'). They also reflected on any enduring impact on their overall learning, grades/ academic performance, wellbeing, social and leisure activities and plans for the future ('yes, to a great extent', 'yes, a little', 'no, not at all').

We identify two key outcome variables for the analysis. The first is based on whether students feel school has benefited their computer or digital skills development ('yes, a lot', 'yes, a little', 'no benefit' and 'negative impact'). As noted earlier, few studies have examined school acquired digital skills beliefs. Our second outcome measure relates to whether students reflect positively on DTs enriching their school experiences. Students were asked their perceptions on the value of DTs: whether ICT use positively impacts on their school experience, on their motivation and on their achievement (5-point

likert scale ‘strongly agree’ to ‘strongly disagree’). The first question on school experience is used comparing those who reflect positively with all others in a logistic model.

School Culture

There is a large body of research about DTs use in schools and classrooms, but often these studies concentrate on only one or two phenomena of education and technology (e.g. classroom cases, or technical competence of teachers and students), thus isolating the object of study from the broader context of a school (Ilomäki and Lakkala, 2018). Research suggests that unless a more comprehensive view is adopted in the efforts of developing a school, there is little chance of innovation programmes having any lasting effect (Ilomäki and Lakkala, 2018; Wikeley et al. 2005). This study places a central focus on how school characteristics like gender and social mix shape DT skills orientation of schools. In addition, a unique feature of the current study stems from the opportunity to assess how school process characteristics relate to reflections on digital skills opportunities at school. We assess whether schools with stronger value emphasis, more democratic principles and more positive social relations are also more likely to support DT skills development. We use several scale variables to capture aspects of school ethos. Students responded to a five-item measure of their engagement at school, including ‘school work is worth doing’, ‘the subjects I study interest me’, and ‘I get all the support I need to learn’, forming a scale ranging 5 to 25 ($\alpha = 0.87$).Students also reported on how well their school promoted a list of values, including ‘achieving quality in teaching and learning’, ‘creating community’, and ‘encouraging different types of achievement’. Scores range from ‘very badly’ to ‘very well’ and are summed to create a total score ranging from 6 to 30 ($\alpha = 0.87$). The measure has previously shown to correlate with student ratings of the value of education, innovative approaches and student-teacher interaction quality (Carroll et al., 2024). Students answered questions on the extent to which their school embodied democratic principles and created a student-led ethos, including ‘encouraged to make up my own mind’, ‘encouraged to express my opinions’ and ‘encouraged to discuss the issues with people having different opinions’. Responses range from ‘very often’ to ‘never’, giving a total score ranging from 3 to 12 ($\alpha = 0.73$). The measure has previously been shown to be important in student engagement and has been prominent in more innovative school contexts (Mihut and McCoy, 2020). New digital media has also been important in allowing students to take a more participative role in education and in creating a space for student voice (Manca at el., 2017). Students also reported on the extent to which their school embodied a strong ethos, with 6 statements including my school promoted ‘showing respect’, ‘encouraging different types of achievement’, and ‘being just and responsible’ ($\alpha = 0.87$). Finally, students reported on the extent of positive social engagement in their school culture, including ‘I learn to get along with other people’, ‘other students accept me as I am’. ‘I feel respected’ and ‘I feel that I belong’. Scores range from ‘strongly disagree’ to ‘strongly agree’ and sum to 4 to 20 ($\alpha = 0.82$).

3.4 Descriptive Results

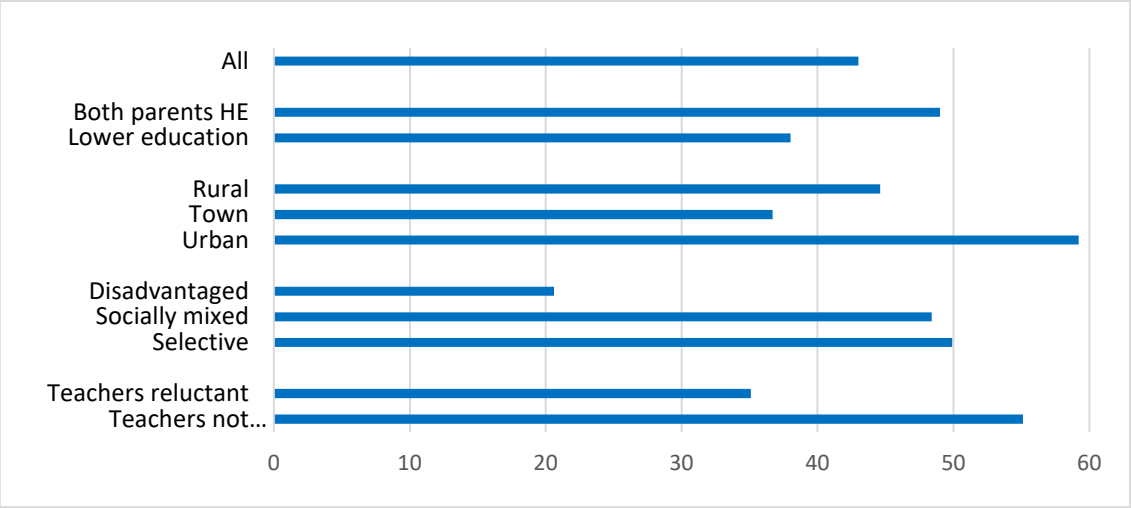
Overall, results suggest a relatively low level of DT usage by students across all 21 schools. Taking a relatively low benchmark of using DTs at least three times weekly in class, Figure 5 shows just 40% of students report this 'higher' level of usage, with wide variation across school contexts. Students whose parents have lower levels of education are less likely to attend more technologically oriented schools, as are students attending socially disadvantaged school contexts. Such schools are more likely to be located in urban areas. Students attending schools with greater technology usage are also more likely to report teachers are not reluctant about adopting new technology. Figure 6 further illustrates wide variation in perceived teacher reluctance in using DTs in class – such variation is not particularly structured by school type. Within each school sector, there is wide variation in the percentage reporting a DT reluctant teaching body – ranging from 21% to 70% across the socially-mixed school settings, for example. It is interesting that perceived deficits in teacher professional development do not track perceived teacher reluctance, although wide school level variation is again observed (Figure 7). While 21% of students in one socio-economically disadvantaged school feel teachers require training, this compares to over two-thirds in one of the selective schools; overall students in selective schools are more likely to identify training needs.

Students largely agree that it is important to learn about safe use of the internet (83%) and nearly two-thirds see the importance of DTs to prepare for life and work (62%) (Figure 8). Students are generally positive about the perceived impact of DT usage in their learning: 71% feel it positively impacts their school experience, 55% see a positive impact on their achievement and 52% a positive impact on their motivation at school. Again, wide variation can be observed across school contexts: the percentage indicating a positive impact on their school experience, for example, ranges from 42% in one disadvantaged school context to 95% in one of the socially mixed schools (Figure 9).

Finally, we consider the extent to which students feel school has benefited ('a lot') their computer/digital skills development (Figure 10). There appears to be little variation across student characteristics (gender, SEN status, parental education and economic vulnerability), and school social mix differences are negligible. However, subjective measures are seemingly related to perceptions of skill development – students who are more engaged at school are far more likely to report benefits in terms of DT skills. Perceptions in terms of teacher reluctance in using DTs are also strongly related to perceived benefits: 16% of students who felt their teachers were reluctant in adopting new DTs reported positive school benefits in DT skills development, compared to 31% of students who disagree that teachers were reluctant to adopt new technologies.

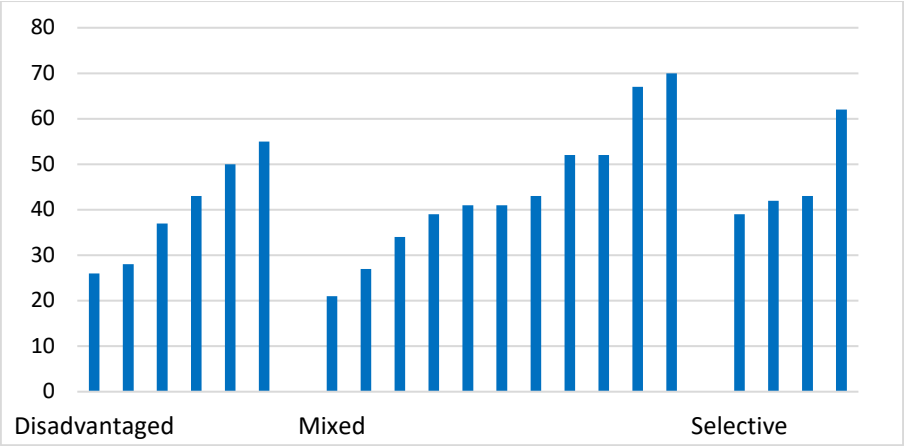
In the next section we assess student and school characteristics associated with positive reflections on the benefits of DTs at school and school acquired digital skills belief.

Figure 5: Percentage of students reporting higher digital technology use in school



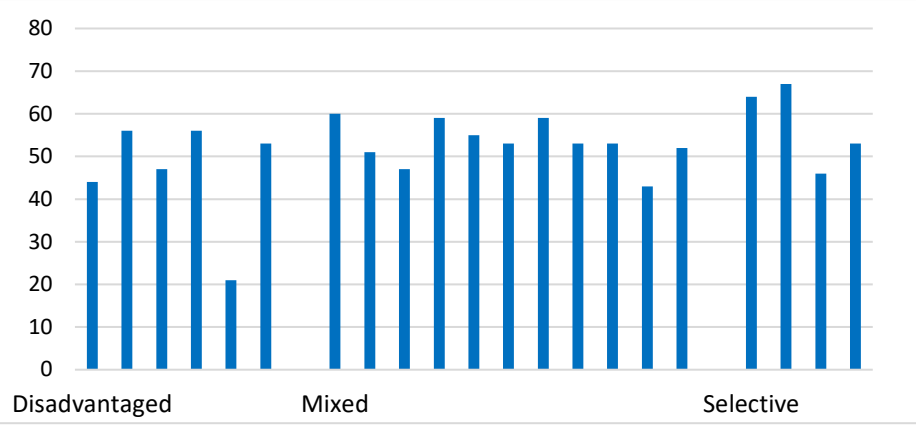
Source: Authors' analysis of 2023 Secondary Student Survey (Carroll et al., 2024).

Figure 6: Percentage of students who perceive their teachers are reluctant to adopt new technologies across 21 schools



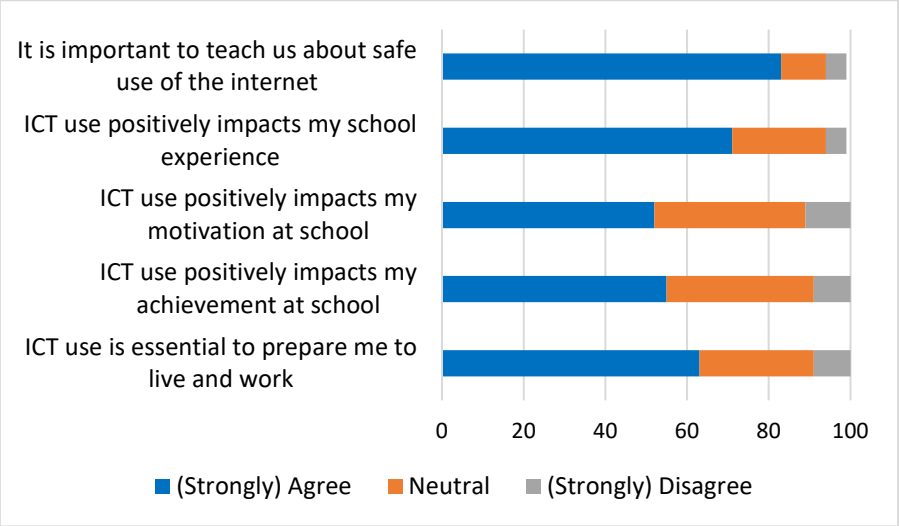
Source: Authors' analysis of 2023 Secondary Student Survey (Carroll et al., 2024).

Figure 7: Percentage of students who perceive teachers require more ICT-related training across 21 schools



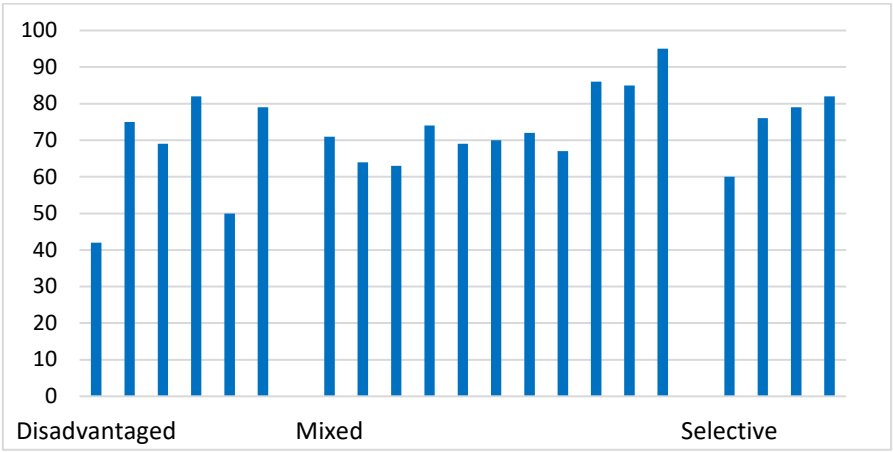
Source: Authors' analysis of 2023 Secondary Student Survey (Carroll et al., 2024).

Figure 8: Perceived value of computer/digital use



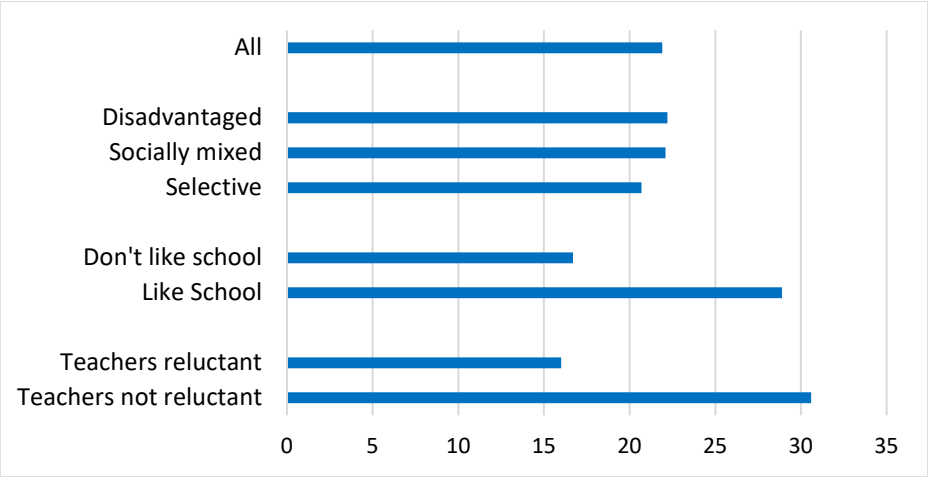
Source: Authors' analysis of 2023 Secondary Student Survey (Carroll et al., 2024).

Figure 9: Percentage indicating ICT use positively impacts their school experience



Source: Authors' analysis of 2023 Secondary Student Survey (Carroll et al., 2024).

Figure 10: Percentage indicating that school has benefitted their computer/digital skills ('a lot')



Source: Authors' analysis of 2023 Secondary Student Survey (Carroll et al., 2024).

3.5 Model Results

The first model examines student and school factors predicting school benefiting students' digital skills (Table 1). The results show no effect of gender and social background on school-acquired digital skills belief, in contrast to research with young adults who are now 27 years old (Griffin et al., forthcoming). Students in selective schools are more critical as are students in towns and particularly rural areas. In Model 2 we additionally consider actual DT usage at school and perceptions of teacher reluctance to adopt new DTs, both of which significantly shape perceived DT skills developed at school. COVID-19 experiences also matter – students reporting regular online classes and not having internet problems during this time fare better in terms of perceived skills development. Finally, in Model 3 we consider climate and ethos aspects of the school environment. These are highly associated with digital skills assessments – schools with a stronger school ethos, promoting strong values and social engagement, as well as those with greater student democracy are all associated with positive DT skill reflections among students.

The second model considers the role of student and school characteristics in students seeing DTs as having a positive impact on their school experiences. Boys and those not experiencing economic difficulty are more positive, but boys attending single sex schools are less likely to report DTs are impacting positively on their school experience. Students in selective schools are more positive. Teacher willingness to adopt new technologies also impacts positively. Actual DT usage at the school again impacts with students enrolled in schools with greater technology usage more likely to reflect positively on DTs impacting their school experiences. Again COVID-19 has an enduring impact: students benefiting from regular online classes during school building closures are more positive about DTs positively impacting on school experiences. Finally, in model 3 school climate and ethos has less impact, although students in schools which promote student democracy and inclusive values reflect more positively.

Overall, the results suggest that schools have been somewhat effective in countering inequalities in DT access and skills development, but challenges remain in terms of equity of access to personal devices in learning and teacher competencies/openness to new innovations. COVID-19 exacerbated challenges around internet access (particularly in rural areas) and in terms of accessing support from teachers; the results show differential access to online classes and the impact. In particular, students reflect an enduring impact on their achievement and motivation (Carroll, et al., 2024), but also in terms of their DT skills development.

The results point to (infra)structural and process factors at play. Schools reported as stronger on providing DT skills include city schools, schools where teachers are not seen as reluctant regarding DTs, schools that were effective in providing online classes during COVID, are stronger in supporting student engagement, stronger on student democracy, supporting social engagement and have an inclusive

ethos. Further, DTs are seen to have a positive impact on school achievement- particularly for male students (but not in single sex schools), more affluent families, those in schools with DTs more embedded and where teachers are seen as enthusiastic, where students benefitted from online classes during COVID and in schools which are stronger on student democracy and inclusive values.

4 Discussion

As with any other resource, technology in education can be susceptible to the Matthew principle such that already resourced schools/families are better placed to adopt technology to the maximum and to expect more from it. While there is some evidence to support this, differences in skills perceptions found across school settings do not particularly reflect school social mix or the relative affluence of the student body. Students attending schools in the priority education programme (DEIS) reflect as positively on school supporting their digital skills development as their peers in socially mixed settings. This suggests policy interventions to support digital technology availability and skills development in DEIS schools have been effective. However, there can be little doubt that if technology is to tackle rather than reinforce educational inequality schools/families need to be supported in adopting it to fullest potential, particularly in relation to access to costly digital devices (Marcus-Quinn, 2022). The results also show the lasting impact of approaches during COVID-19 school building closures – with experiences during this period shaping skills perceptions several years later.

The evidence highlights the complexity and interdependence of factors shaping digital skills development and the impact of technologies at school. The importance of teacher skills and adoption cannot be overstated. Teachers' openness to new innovations is key, perhaps reflecting cultural factors at the school level as much as professional development. The findings point to the importance of technological pedagogy in teacher education programmes (both initial and continuous professional development), as well as supportive school climates. This has been highlighted across many contexts, including in Finland, a leader in technology integration in schools. Here teachers' digital competence, related to pedagogical understanding of using technology in education, is argued to be the cornerstone of supporting students' digital competence (Hakkarainen et al. 2000, 2001).

Infrastructural barriers also persist, stemming from school design constraints, the physical condition of school buildings and connectivity difficulties, all creating inequalities in technology access (McCoy et al., 2016; Carroll et al., 2024). More funding is needed for appropriate devices for both teachers and students to achieve equity of the digital experience (also noted by Marcus-Quinn, 2022). Technical support is still a pressing issue in the Irish context, particularly for schools in the voluntary secondary sector who don't have centralised technical support services (Carroll, et al., 2024).

In keeping with the socio-cultural framework, the results show that school context and ethos matter - embedding DT learning in education requires more than infrastructure and is heavily dependent on the socio-cultural context, and leadership. A culture of student democracy and a holistic, inclusive school ethos is associated with better digital skills development. While the data do not speak to causality, one might conclude that more inclusive environments better meet student leaning needs and support more collaborative, innovative student-centred approaches. Inclusive digital environments are important, to ensure equitable learning opportunities for all students, with particular attention to those who are vulnerable, such as learners with disabilities, facilitating their engagement. To accomplish this goal, it is imperative for both school leaders and teachers to collaborate in identifying the unique needs of their schools and establishing conducive environments for inclusive digital development (Bešić et al., 2024). This entails enhancing the digital infrastructure, bolstering support systems, and empowering teachers to foster digital inclusion within their schools (Kim et al., 2021). In terms of gender, motivating girls and young women to enrol in computer science courses and digital skills opportunities at school is also critically important for their digital skills development (see also Master et al, 2024).

Returning to the starting point of the paper and the digital skill gaps among younger cohorts in Ireland, Beblavý et al. (2019) highlighted that Ireland's "performance is undermined by a lack of up-skilling initiatives to respond to digital transformation and the absence of a sustainable, long-term vision" (p. 57). Since then, the policy response has been notable, including two digital strategies for schools, which importantly saw a shift towards a learner-centred vision of technology integration (McGarr and Johnston, 2021). Recent policy recognises the complex and contextually bound nature of the change process suggesting a maturation of understanding in respect of the intersection between technology and education. The recognition of how DT policy can augment and facilitate the realisation of other school-based reforms such as the revision of the lower secondary level curricula marks a significant shift from previous policy where DT policy appeared to stand alone from other school-based reforms and from other education reforms at national level (McGarr and Johnston, 2021). There is some evidence of a growing embedding of DTs within primary and secondary education in Ireland, and through provision of online blended learning approaches to enable access to particular subjects, or to support at risk or vulnerable students to partake in, or in many cases reconnect with, education through for example alternative programmes like iScoil (see Hallissy et al., 2023). However, achieving inclusive, student-centred learning and skills development will need further evolution of the pedagogical agenda within which the potential of technology can be realised, "so that Ireland's young people become engaged thinkers, active learners, knowledge constructors and global citizens to participate fully in society and the economy" (Department of Education, 2022, p. 5).

Table 1: Model Results: Probability School Benefits DT Skills Development ('a lot')

	Model 1	Model 2	Model 3
Girls (ref: boys & other)	0.01	0.01	0.02
University-educated parents (ref: lower education)	0.16	0.13	0.03
School Type (ref: socially mixed schools)			
Socially disadvantaged (DEIS) schools	-0.31	0.21	0.03
Selective (fee-charging) schools	-0.71**	-0.44	-0.72**
School Gender Mix (ref: coeducational schools)			
Girls Schools	0.05	-0.02	-0.10
Boys Schools	0.04	0.36	0.22
Region (ref: Urban)			
Town	-0.63***	-0.22	-0.37
Rural	-0.48*	-0.38	-0.44
Technology use at school (ref: high technology use)			
Medium technology use		-0.47***	-0.46**
Low technology use		-1.10***	-1.01***
Teachers not reluctant to adopt DT (ref: reluctant)		0.72***	0.48***
I had online classes during COVID		0.25**	0.06
I had regular problems with internet during COVID		0.25**	0.30
Positive school engagement			0.477***
Positive social engagement			0.45***
Student led ethos			0.50***
Strong value emphasis			0.70***
Stronger school ethos			0.28
Constant	0.09	0.94*	0.87*
Pseudo R^2	0.08	0.09	0.09
N	1915	1900	1807

Data Source: 2023 Secondary Student Survey (Carroll et al., 2024).

Note: ***p<0.001; ** p<0.01; *p<0.05.

Table 2: Model Results: Probability DT Use Positively Impacts School Experience

	Model 1	Model 2	Model 3
Stage Upper secondary (ref: lower secondary)	0.22*	0.08	0.06
Girls (ref: boys & other)	-0.58***	-0.68***	-0.76***
University-educated parents (ref: lower education)	0.14	0.12	0.08
SEN Yes (ref: No)	-0.19	-0.26*	0.29
SEN Unsure	-0.23	-0.32*	0.23
Economic Difficulties (ref: No)	0.21*	0.13	0.10
School Type (ref: socially mixed schools)			
Socially disadvantaged (DEIS) schools	0.13	0.27	0.19
Selective (fee-charging) schools	0.35	0.56**	0.43**
School Gender Mix (ref: coeducational schools)			
Girls Schools	-0.20	-0.16	-0.20
Boys Schools	-0.52**	-0.44*	-0.50**
Region (ref: Urban)			
Town	0.29	0.58	-0.52*
Rural	-0.05	0.05	-0.02
Technology use at school (ref: high technology use)			
Medium technology use		-0.11	-0.09
Low technology use		-0.30*	-0.27*
Teachers not reluctant to adopt DT (ref: reluctant)		1.33***	1.26***
Longer hours online at home (>3hrs) (ref: lower)		0.03	0.04
I had online classes during COVID		0.33**	0.25*
I didn't have problems with internet during COVID		0.22	0.24
Student likes school			0.12
Positive school engagement			0.15
Positive social engagement			0.25
Student led ethos			0.27*
Strong value emphasis			0.12
Stronger school ethos			0.27*
Constant	0.71	-0.15	-0.18
Pseudo R^2	0.03	0.14	0.15

N	2009	2009	2009

Data Source: 2023 Secondary Student Survey (Carroll et al., 2024).

Note: ***p<0.001; ** p<0.01; *p<0.05.

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