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Abstract

This working paper presents findings from a literature review on the impact of digital tools on student learning and motivation in education. Overall, digital tools can enhance engagement and personalise learning, but their effectiveness is not guaranteed and depends on strategic implementation. Teachers play a central role here, whilst the review also identifies risks such as digital distraction, equity issues and cyberbullying that must be thoughtfully addressed for effective and safe digital learning environments.

This working paper was prepared as part of the *Resourcing school education: Policies for the digital transformation of education and future-readiness of teachers* project, which is included in the 2025-26 Programme of Work of the OECD's Education Policy Committee. It was commissioned by the Irish Department of Education and Youth to the OECD to investigate the impact of digital tools on education. It was developed by the University of Stavanger, under the guidance of the OECD Secretariat.

Acknowledgements

This working paper is one of two companion working papers focused on the impact of digital technologies on students' learning. It synthesises key findings of a comprehensive review of the impact of various categories of digital tools on student learning and motivation in primary and secondary education and looks across these categories to explore integration strategies more holistically. Its companion working paper ("Overview of the integration of digital tools in primary and secondary education: Results from a literature review on the impact of digital technologies on students' learning" (Försström et al., 2025) delivers the granular review of the impact of various categories of digital tools on which this working paper draws. The working papers were prepared as part of the *Resourcing school education: Policies for the digital transformation of education and future-readiness of teachers* project, which is included in the 2025-26 Programme of Work of OECD's Education Policy Committee, and developed thanks to the financial support of Ireland's Department of Education and Youth.

The development of this working paper was undertaken by the Knowledge Centre for Education (KCE) of the University of Stavanger, Norway, and guided by the OECD Secretariat. Sanna Forsström, Morten Njå and Elaine Munthe (University of Stavanger) led the drafting of the working paper, and Serap Keles (University of Stavanger) provided support with quality control.

Jose-Luis Alvarez-Galvan (OECD) guided the paper's development and Lawrence Houldsworth (OECD) provided analytical support to the paper's final development. Karine Tremblay (OECD) led the initial stages of this work, including the definition of its scope. The overall guidance and feedback on drafts provided by Andreas Schleicher (Director of Education and Skills) and Paulo Santiago (Head of Division, Policy Advice and Implementation) are gratefully acknowledged. Christina Mitrakos (OECD) supported the paper's preparation for publication, supported by Rachel Linden (OECD) who also oversaw communication efforts. Beatrice Bottura (OECD) provided additional technical assistance. Susan Mulhall, Clare Connolly, and Edel Martin (Digital Policy for Schools, Department of Education and Youth, Ireland) provided valuable input throughout the paper's conceptualisation and development. The paper has also benefited from the valuable input from delegates to the OECD Group of National Experts on School Resources (GNE-SR), which oversees the OECD project.

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Executive summary

This working paper provides a synthesis of research on the integration of digital tools in primary and secondary education, examining their impact on student learning, motivation, and well-being. It moves beyond the polarised debate over screen time to offer a nuanced, evidence-based analysis of how, when and for what purposes digital technologies can be used to realise the benefits of digital technology in education.

This synthesis is built upon the findings of its companion working paper, "The impact of digital technologies on student learning: Results from a literature review" (Forsström et al., 2025[1]), which provides a detailed systematic review of the international research literature, examining the effects of specific categories of digital tools on student learning and motivation in primary and secondary education.

The Potential and the practice

The synthesis confirms that a wide range of digital tools have considerable potential to enhance students' learning and motivation. When used thoughtfully, technologies such as programming environments, digital games, media production tools, simulations and Artificial Intelligence (AI) can foster engagement, deepen understanding and support interdisciplinary learning.

- In mathematics, tools like Dynamic Geometry Software (e.g. GeoGebra) and programming environments (e.g. Scratch) make abstract concepts tangible, fostering deeper conceptual understanding and computational thinking.
- In science, immersive technologies like virtual and augmented reality (VR/AR) and simulations allow students to safely explore complex phenomena that are otherwise inaccessible, from molecular structures to ecosystems.
- For language and literacy, digital storytelling, multimedia storybooks and adaptive computer-assisted instruction can improve comprehension and vocabulary, particularly when they provide personalised feedback. Across disciplines, educational games are shown to boost motivation and develop critical skills like problem-solving and collaboration.

Persistent challenges in digital integration

While the potential is clear, the findings reveal that not all uses of technology yield strong or consistent benefits. The effectiveness of these tools is inextricably linked to the quality of their implementation. Realising the benefits depends on careful consideration of when, where and how these tools are integrated into practice.

A recurring theme across all findings is the paramount role of the teacher in facilitating successful integration. The evidence strongly suggests that the effective use of digital tools is associated with well-structured tasks and robust teacher support. The teacher's role is not diminished by technology but is, in fact, more critical than ever. Teachers must act as pedagogical designers who strategically select tools, scaffold learning to manage cognitive load, guide students in developing digital literacy, and thoughtfully balance digital and analogue methods.

This working paper highlights persistent challenges that can undermine the effectiveness of digital tools and, in some cases, cause harm.

- Cognitive overload and distraction are common issues, as many digital environments, particularly immersive ones such as virtual reality (VR) or complex games, can overwhelm students if they are not designed and scaffolded properly. Extraneous features, poorly designed interfaces and multitasking can increase cognitive load, ultimately hindering rather than supporting learning. Moreover, the very interactivity that makes digital tools engaging can also introduce new sources of distraction, requiring structured tasks and clear classroom management strategies to keep students focused.
- Equity and access remain significant barriers to effective digital integration. Unequal access to high-quality devices, reliable internet and adequate technical support can exacerbate existing educational inequalities. Students from less-resourced backgrounds may also lack foundational digital skills, making it difficult to benefit from advanced tools like Artificial Intelligence (AI) or learning analytics and potentially widening achievement gaps.
- Sustaining engagement and supporting the transfer of learning present further challenges. While tools such as educational games can generate high initial engagement, this motivation does not always persist over time or lead to deep, transferable learning. Skills acquired in a game-based environment, for example, may not automatically transfer to traditional academic contexts without explicit bridging and reflection guided by the teacher.

Cyberbullying

Given its significance in digital educational settings, this working paper dedicates a chapter to cyberbullying. It is highlighted as a serious consequence of digitalisation, with significant negative effects on students' mental health, self-esteem and well-being. Research links cyberbullying to low empathy among perpetrators, while pro-social bystander behaviour is an important protective factor. The most effective interventions are multi-component, combining technology-based solutions (e.g. AI tools to detect harmful language) with school-based programmes that foster a supportive climate through digital safety, empathy and bystander training.

Policy implications

The integration of digital technology into education is a complex, multifaceted process. The potential to create more engaging, personalised and effective learning environments is considerable, but so are the risks. This working paper concludes that a successful path forward requires moving away from a tool-centric approach towards a holistic, human-centred one. The central question is not *what* technology to use, but *how* it can be used to support core pedagogical principles and student well-being.

This requires a coordinated effort from all stakeholders. Policymakers must invest in equitable infrastructure, support high-quality professional development and promote evidence-based practices. School leaders must foster a collaborative culture where teachers are given the time, resources and autonomy to innovate responsibly. Teachers must be empowered as pedagogical designers who can critically evaluate and strategically integrate digital tools. Finally, the educational system as a whole must prioritise the development of digital literacy and citizenship for all students, equipping them with the skills to learn, create and thrive safely and ethically in a digital world.

1 Introduction

Digitalisation in education is a multi-level transformation involving individual, organisational and societal change, with the goal of integrating digital solutions to enhance both learning and well-being (Ministry of Local Government and Modernisation, 2021[2]). In schools, this process extends beyond the introduction of digital devices to require a broader transformation of teaching, learning and administrative practices.

Despite widespread adoption, the digitalisation of schools remains a widely debated issue in many countries. Public discourse is often polarised, with debates focusing on concerns such as screen time and the potential impact on students' learning and well-being. For example, some parents worry about the amount of time students spend on devices. However, these discussions frequently lack direct links to research evidence. Recent reports call for a more nuanced, evidence-informed dialogue (NOU 2024: 20[3]). The central issue is not whether devices are present, but how digital tools are selected, in what contexts they are used, for which purposes, and how they are integrated into curricular and pedagogical practices.

This working paper provides a research-based synthesis addressing these questions. It examines how different types of digital tools affect student learning and motivation in primary and secondary education, analysing the challenges of integration and the conditions necessary for success.

The central questions guiding this synthesis are:

- What is the educational potential of using different types of digital tools in primary and secondary education across various subjects?
- What challenges have been identified across their use, and how can this potential be realised in practice?

This working paper builds on the accompanying working paper, "The impact of digital technologies on students' learning: Results from a literature review" (Forsström et al., 2025[1]), which provided a granular discussion of five broad themes (programming and robotics, media production and literacy, gaming, extended reality and simulations, and artificial intelligence and learning analytics), outlining the research literature on their impact, effective practices and implementation challenges. This working paper synthesises key findings and looks across all five themes to explore integration strategies more holistically. It considers how these technologies interact with themes of particular relevance to policymakers and practitioners, such as variations by student age and school subject. It also delves into the processes of teaching and learning to consider what, when and how digital tools can be used successfully.

Engaging with the possibilities of digital tools also means acknowledging some of the challenges that increased exposure to and use of digital tools may yield, such as increased cognitive load through unnecessary stimulation or presenting a distraction. A further challenge is how digital tools present a risk in terms of cyberbullying. This paper dedicates a specific chapter to exploring cyberbullying in more detail as an important hindering factor in the safe and effective use of digital tools.

How to read this document

This document can be read as a stand-alone resource. However, those who wish to gain a more detailed understanding of the methods, included studies and conceptual framing may benefit from starting with the accompanying working paper ("The impact of digital technologies on students' learning: Results from a literature review", Forsström et al., 2025[3]) or consulting specific sections of interest there.

- **Policymakers** may find this paper useful as a synthesis of key findings across studies, offering insights into how different technologies are used in schools, what challenges are identified and how these challenges might be addressed at policy, school and classroom levels.
- **Teachers, school leaders and practitioners** can use this paper to better understand when and how digital tools may support student learning and motivation, as well as which conditions and teaching strategies have been found to promote successful integration and what is needed at the school level.
- **Researchers** may use this paper to locate patterns, identify promising practices and find relevant studies and ideas for future studies.

2 Benefits and challenges of the use of digital tools in primary and secondary education

This chapter explores both the benefits and the ongoing challenges of digitalisation in schools, focusing on how digital tools shape teaching and learning across subjects, grade levels and diverse student needs. Drawing on insights from the accompanying working paper, "The impact of digital technologies on students' learning: Results from a literature review" (Forsström et al., 2025[1]), and the wider research literature, it offers a nuanced perspective on how digitalisation creates new opportunities while also introducing complexities in today's classrooms.

We examine the impact of a broad range of technologies – including programming environments, educational games, media production tools, augmented and virtual reality, artificial intelligence and learning analytics – on learning outcomes, motivation and inclusion. The effectiveness of these tools is shaped by factors such as subject requirements, student age, teacher competence and access to infrastructure. Digital tools have the potential to foster engagement, support personalised learning, promote collaboration and develop 21st-century skills. At the same time, we also consider challenges such as increased cognitive demands, difficulties in maintaining motivation, digital inequality and risks of distraction or exclusion.

Learning across subjects and grades

Digital tools are not limited to a single subject or grade level. Their influence extends across the curriculum, affecting learning in mathematics, science, languages, physical education, special education and more. This section examines how different categories of digital technology shape learning and engagement throughout students' school years, from early primary through secondary education.

By reviewing evidence across a wide range of subjects and age groups, we highlight the unique benefits of specific tools and the broader principles that emerge when digital resources are integrated into teaching and learning. As outlined in the aforementioned accompanying working paper, the effectiveness of digital tools depends on their alignment with subject-specific needs, students' developmental stages and contextual factors such as infrastructure and support (Forsström et al., 2025[1]). This chapter explores these cross-cutting themes, illustrating how various digital tools affect learning and engagement across subjects and grade levels. A summary of key findings is presented in Table 2.1.

Table 2.1. School subjects and digital technologies: Tools used and key outcomes

Subject	Technologies/Tools discussed	Studies show for instance
Mathematics	Programming, Robotics, Simulation tools, Dynamic geometry software (DGS) (e.g. GeoGebra), computer algebra systems (CAS), Digital games (e.g. Strategy, Simulation), Scratch, Python	Enhanced engagement, understanding and performance in math, especially with smaller classes and short interventions.
Science	AR, VR, Simulations, Animations, Virtual labs, Simulation games	Improvements in understanding complex science concepts and support for individualised learning.
Language	Digital storytelling, Multimedia storybooks, Computer-assisted instruction (CAI) (e.g. Headsprout), GraphoGame, Video games (RPGs, commercial off-the-shelf (COTS))	That interactive and personalised tools can support literacy, with effectiveness depending on features and context.
Physical education	Exergames (e.g. Dance Dance Revolution, Cyber Cycling)	Benefits for cognitive development and academic performance through active engagement.
Special education	AR, Digital games (e.g. GraphoGame), Digital writing tools	Improved focus, comprehension and social skills for students with special educational needs.
Interdisciplinary skill development	Programming, digital games (e.g. RPGs)	Development in creativity, computational thinking and critical decision-making skills.

Mathematics

Integrating digital tools into mathematics education can enrich learning environments and foster deeper understanding and engagement. As outlined in the accompanying working paper, digital technologies offer interactive experiences – such as simulation and modelling – that help make abstract mathematical concepts more concrete and accessible (Forsström et al., 2025[1]).

Dynamic geometry software (DGS) and computer algebra systems (CAS) have demonstrated positive impacts on students' mathematical skills (Juandi et al., 2021a[4]) (Juandi et al., 2021b[5]). Tools like GeoGebra enable students to explore geometric figures and algebraic expressions interactively, manipulating variables and immediately observing the results. This hands-on exploration supports conceptual understanding and can bridge the gap between abstract ideas and practical application.

Programming tools play a key role in mathematics learning, especially as students' progress through grade levels. Block-based programming environments, such as Scratch, offer accessible introductions for younger students by reducing cognitive load and making programming concepts tangible (Hu, Chen and Su, 2021[6]). In secondary education, text-based languages like Python are more appropriate for sustaining motivation and managing complex mathematical tasks (Scherer, Siddiq and Sánchez Viveros, 2020[7]).

The transition from block-based to text-based programming, however, presents challenges, as it requires students to move from intuitive visual interfaces to more abstract and syntactically demanding environments (Vinueza-Morales et al., 2021[8]). Collaborative learning and metacognitive strategies further support student success, particularly in programming education (Scherer, Siddiq and Sánchez Viveros, 2019[9]).

Integrating programming and robotics within mathematics classrooms can also enhance students' computational thinking and problem-solving abilities (Forsström et al., 2025[1]). Computational thinking involves skills such as decomposing problems, recognising patterns, identifying relevant information, and formulating step-by-step solutions – core competencies in mathematics.

The effectiveness of digital tools in mathematics varies depending on several contextual factors. Research suggests that digital tools yield better results when used in smaller classes, during shorter interventions and when students have individual access to computers (Juandi et al., 2021a[4]; Juandi et al., 2021b[5]; Hillmayr et al., 2020[10]). Other factors, such as class size, duration of exposure and educational level, also

influence outcomes. Successful integration is typically characterised by active experimentation, immediate feedback and opportunities for collaborative problem-solving.

Digital games represent a promising strategy for enhancing both engagement and learning outcomes in mathematics. Different types of games serve distinct purposes: strategy and simulation games help students develop problem-solving skills through interactive scenarios, while serious games promote active and personalised learning. By adapting to students' progress and providing real-time feedback, these games foster motivation and address individual learning needs. Incorporating games into mathematics instruction can create engaging, student-centred environments that support deeper understanding and sustained interest in the subject.

Science

Integrating digital tools into science education offers unique opportunities to deepen students' understanding of abstract and complex phenomena. Technologies such as augmented reality (AR), virtual reality (VR), simulations and animations provide visual and interactive experiences that make scientific concepts more accessible.

A central advantage of these technologies is their ability to simulate environments and processes that would otherwise be inaccessible or unsafe in traditional classrooms. For example, simulation tools allow students to explore the ocean floor, journey through outer space, or observe atoms and molecules – experiences that are particularly relevant in biology, physics and chemistry (Yakubova et al., 2023[11]; Pellas, Kazanidis and Palaigeorgiou, 2020[12]). By engaging with complex scientific ideas in a visual and interactive manner, students can develop deeper conceptual understanding and strengthen their scientific reasoning skills.

Digital tools also support individualised learning, allowing students to progress at their own pace and approach scientific questions from new perspectives. This flexibility can boost motivation and engagement, particularly for students who benefit from repeated exploration or self-directed inquiry.

AR and VR applications enable students to visualise cell structures, ecosystems and animal behaviours through 3D models, providing hands-on opportunities for virtual experimentation (Pellas, Kazanidis and Palaigeorgiou, 2020[12]). Simulation-based technologies, such as virtual laboratories, facilitate hands-on experimentation in a controlled virtual environment. These tools are especially valuable when real-life experiments are constrained by safety, cost or logistical barriers (Hillmayr et al., 2020[10]). Effective use of virtual labs is characterised by iterative experimentation, real-time feedback and opportunities for collaborative inquiry.

Simulation games further enrich science learning by enabling students to explore cause-and-effect relationships in dynamic systems. For instance, ecosystem simulation games allow students to manipulate variables such as pollution or resource use, helping them understand complex interdependencies and the practical implications of scientific principles.

Language

Research on digital tools for language and literacy development highlights the importance of adaptive feedback and content-relevant multimedia. These features create interactive and engaging learning experiences for young students. Studies focusing on early grades (McTigue et al., 2020[13]; Takacs, Swart and Bus, 2015[14]) consistently find that adaptive interventions and mechanisms for feedback, coupled with active adult involvement, can enhance learning outcomes. Longer-term interventions, especially those spanning several months, also appear more effective (McTigue et al., 2020[13]).

Computer-assisted instruction (CAI) programmes, such as Headsprout and educational games like GraphoGame exemplify this approach by offering adaptive feedback and personalised learning pathways. These digital tools allow students to progress at their own pace and benefit from immediate, structured feedback (Rigney, Hixson and Drevon, 2020[15]). However, the effectiveness of such programmes is shaped by contextual factors, including adult guidance, language transparency and the duration of the intervention (Silverman et al., 2024[16]; McTigue et al., 2020[13]). GraphoGame, for example, is suitable for early reading acquisition, especially for students at risk of dyslexia, yet some studies report limited impact on word-reading outcomes compared to alternative interventions or control groups (McTigue et al., 2020[13]). Results tend to improve when interventions feature adult support, transparent orthographies and extended durations (McTigue et al., 2020[13]).

Digital storytelling tools have proven effective in improving students' literacy skills by integrating traditional narratives with multimedia elements – such as images, sound and video – to create engaging and interactive experiences (Akgün and Akgün, 2020[17]; Sahin and Coban, 2020[18]). Successful learning with these tools involves active content creation, collaborative authoring and opportunities for self-expression. Studies indicate that digital storytelling can positively affect academic achievement across subjects, particularly in science and language education (Akgün and Akgün, 2020[17]).

The study by Takacs, Swart and Bus (2015[14]) on multimedia-enhanced storybooks highlights the potential of animations, sound effects and music to improve comprehension and vocabulary acquisition, provided these features are well-aligned with the narrative. However, interactive elements unrelated to the story may distract learners and reduce the tools' effectiveness, pointing to the importance of thoughtful design.

For older students, especially in upper primary and secondary education, game-based instruction has shown particular promise for vocabulary acquisition (Thompson and Von Gillern, 2020[19]). This benefit is often attributed to adolescents' higher cognitive development and intrinsic motivation. Video games and role-playing games (RPGs) immerse students in interactive contexts where they practice dialogue creation, decision-making and problem-solving, supporting both language proficiency and creative thinking (Hainey et al., 2016[20]).

Both commercial off-the-shelf (COTS) and serious games appear effective in supporting vocabulary growth, with some studies showing stronger results for COTS games, though evidence is limited (Thompson and Von Gillern, 2020[19]). The success of game-based approaches depends on the type of game, the platform and the broader learning context.

Research comparing digital and paper-based reading points to a 'screen inferiority effect', where reading on paper leads to greater comprehension and metacognitive engagement – particularly for complex or informational texts (Clinton, 2019[21]; Delgado et al., 2018[22]). The PIRLS 2021 study found a significant mode effect, with students scoring higher on paper-based reading tests than on digital versions, especially with informational content (Støle, Mangen and Foldnes, 2024[23]). Hakemulder and Mangen (2024[24]) further report that habitual digital reading may be associated with reduced eudaimonic engagement: those who regularly read shorter texts on screens reported lower levels of meaningful involvement and insight compared to those who read on paper. This suggests that frequent screen reading could reduce readers' capacity for deep, meaningful literary engagement.

Across these domains, the effectiveness of digital tools for language development depends not only on the technology itself but also on factors such as adult involvement, language transparency, intervention duration and thoughtful alignment between multimedia features and learning goals. For early literacy, adaptive feedback and structured guidance are crucial, while for older students, immersive and game-based contexts may better support vocabulary growth and engagement. However, the medium of reading remains important, with paper often providing advantages for comprehension and deeper engagement, especially with complex materials.

Physical education

Physical education received limited attention in the included studies; however, one study examined the use of exergames – interactive video games that combine physical activity with cognitive tasks. Examples include Dance Dance Revolution and Cyber Cycling, which integrate movement and problem-solving to support executive functions such as attention and memory. López-Serrano et al. (2021[25]) found that exergames can enhance cognitive and academic performance when incorporated into physical education lessons or used as active breaks. Regular use was associated with improvements in executive functions, classroom behaviour, self-concept and peer relationships across age groups. Key challenges include ensuring adequate infrastructure, providing inclusive opportunities for students with disabilities and offering teacher training for effective integration.

Special education

The studies included in the accompanying working paper, "The impact of digital technologies on students' learning: Results from a literature review" (Forsström et al., 2025[1]), highlight the potential of digital technology in special education.

Digital technologies can potentially support students with special educational needs. Augmented reality (AR) has been found to be a valuable tool for enhancing academic and developmental outcomes in students with autism spectrum disorder (ASD) and intellectual and developmental disabilities (IDD) (Yakubova et al., 2023[11]; Baragash et al., 2020[26]). Augmented reality (AR) appears to make learning more accessible and engaging for students with cognitive, sensory, or physical disabilities by catering to their unique needs and improving focus, comprehension and motivation. Based on the included studies, AR applications can be highly effective in enhancing various skills across the domains of learning, social, physical and living skills (Baragash et al., 2020[26]). However, challenges include the need for specialised teacher training, the risk of sensory overload and the importance of balancing AR experiences with real-world interactions.

Additionally, the content must align with learning goals and address the specific needs of students. For instance, students who are sensitive to visual and auditory stimuli may find AR technology overwhelming. Therefore, the content should be carefully designed to accommodate these sensitivities while maintaining a strong connection to the intended learning objectives.

When it comes to writing skills, the results of an included study suggest that digital writing instruction can provide essential scaffolding and support, particularly for students facing learning challenges (Little et al., 2018[27]). This kind of support enables them to improve their spelling, grammar and ideation skills more effectively.

Interdisciplinary skill development and benefits with digital tools

Programming activities enhance students' computational thinking through problem-solving tasks and activities that require algorithmic reasoning. Furthermore, programming can foster creativity, particularly when students are encouraged to explore and experiment with open-ended tasks, where the opportunity for originality plays a key role. It was also found that studies measuring the transfer of skills in tasks closely related to programming, such as mathematics or algorithms, demonstrated positive outcomes (Scherer, Siddiq and Sánchez Viveros, 2019[9]). The studies also indicate that programming education fosters students' creative thinking, mathematical skills and metacognition. Programming also has the potential to enhance spatial skills and reasoning abilities, although the results regarding reasoning skills were not statistically significant (Scherer, Siddiq and Sánchez Viveros, 2019[9]).

Different digital games, such as digital role-playing games, are also seen as having the potential to enhance students' critical thinking, decision-making and social skills (Hainey et al., 2016[20]; Mao et al., 2022[28]). In subjects where students are required to think critically about historical events, social dynamics, or literary narratives, digital role-playing games can provide opportunities by placing students in decision-making roles (Hainey et al., 2016[20]). This allows students, for instance, to explore different perspectives and consider the consequences of their actions.

The potential of the use of different types of digital tools to support student learning and motivation

Digital tools serve a variety of educational purposes in primary and secondary education, extending beyond individual subjects to support engagement, personalisation, feedback, collaboration and self-regulation. This section discusses how different technologies – including programming environments, educational games, media production tools, extended reality (XR), AI and learning analytics – can contribute to student learning and motivation when thoughtfully integrated into teaching practice. The evidence highlights that benefits such as increased engagement and collaboration are most likely when digital tools are aligned with pedagogical goals and supported by effective teaching. This overview sets the stage for a more detailed discussion of ongoing challenges and considerations for implementation.

Table 2.2. Key benefits of different types of digital tools to support student learning and motivation

Digital tool/Technology	Key benefits	Example studies/Findings
Block-based programming (e.g. Scratch)	Increased engagement; accessible introduction to logic and problem-solving	Zhang et al., 2021[28]; Scherer, Siddiq and Sánchez Viveros, 2020[6]
Educational games	Behavioural and emotional engagement; motivation; personalised learning	Bai, Hew and Huang, 2020[29]; Hainey et al., 2016[19]
Extended reality (AR/VR)	Immersive engagement; conceptual understanding; individualised learning	Pellas, Kazanidis and Palaigeorgiou, 2020[11]; Yakubova et al., 2023[10]
AI-based tools (e.g. Writing Evaluation, Chatbots)	Personalised feedback; scaffolding; autonomy	Martínez-Comesaña et al., 2023[28]; Xu, 2024[29]
Learning analytics systems	Progress monitoring; goal-setting; self-regulation	Elmoazen et al., 2023[28]
Media production (e.g. Podcasting, Digital Storytelling)	Collaboration; creativity; authentic communication	Acosta and Garza, 2011[28]; Akgün and Akgün, 2020[16]
Robotics	Hands-on, embodied learning; spatial reasoning	Zhang et al., 2021[28]
Multimedia storybooks	Comprehension; vocabulary development	Takacs, Swart and Bus, 2015[13]

A key potential of digital tools lies in supporting student engagement, as highlighted in numerous studies. Interactive and immersive technologies – such as block-based programming environments (e.g. Scratch), educational games and extended reality (XR) – have been shown to increase student interest and time-on-task. For example, block-based tools engage younger learners through intuitive interfaces that allow focus on logic rather than syntax (Zhang et al., 2021[29]; Scherer, Siddiq and Sánchez Viveros, 2020[7]). Game-based learning is associated with behavioural and emotional engagement, leveraging features such as immediate feedback, goal-setting and student autonomy to promote persistence and a sense of mastery (Bai, Hew and Huang, 2020[30]; Hainey et al., 2016[20]; Lopez et al., 2023[31]). XR applications further engage students by allowing exploration of abstract or inaccessible phenomena through 3D models and simulations and immersive environments (Pellas, Mystakidis and Christopoulos, 2021[32]; Zhang and Wang, 2021[33]; Yakubova et al., 2023[11]).

Digital tools also contribute to personalised learning and feedback. AI-based technologies and learning analytics systems are increasingly designed to offer individualised support. For instance, automated writing evaluation tools and empathic conversational agents can provide timely, tailored feedback, helping

students identify misconceptions and adjust their learning strategies (Martínez-Comesaña et al., 2023[34]; Ortega-Ochoa, Arguedas and Daradoumis, 2024[35]). Learning analytics can further support goal-setting and progress monitoring, particularly when combined with teacher guidance (Elmoazen et al., 2023[36]). Adaptive features in AI-enhanced tools and formative assessment platforms help maintain appropriate levels of challenge for diverse learners (See et al., 2022[37]; Xu, 2024[38]).

The use of digital tools to support self-regulated learning is another promising area. Programming environments, AI-supported applications and learning analytics can facilitate planning, monitoring and reflection. For example, immediate feedback in programming tasks fosters iterative problem-solving and development of metacognitive skills (Scherer, Siddiq and Sánchez Viveros, 2019[9]; Vinueza-Morales et al., 2021[8]). In virtual laboratories, learning analytics can assist students in setting goals, tracking progress and adjusting strategies in real time (Elmoazen et al., 2023[36]). AI tools such as ChatGPT may also prompt self-reflection and autonomy by offering personalised feedback and supporting learner ownership (Xu, 2024[38]). However, these benefits rely heavily on effective teacher facilitation, as AI systems may not fully address the emotional, social or contextual dimensions of learning (Ouyang, Dinh and Xu, 2023[39]).

Digital technologies can support cognitive development and domain-specific skills, including spatial reasoning, logical thinking and mathematical modelling. XR and simulation technologies – such as augmented and virtual reality, dynamic geometry software (DGS) and computer algebra systems (CAS) – allow students to visualise and interact with complex phenomena, thereby improving conceptual understanding in mathematics and science (Juandi et al., 2021a[4]; Juandi et al., 2021b[5]; Hillmayr et al., 2020[10]). Virtual laboratories and AR-based simulations can support deeper engagement with scientific processes by enabling real-time variable manipulation and immediate feedback (Hillmayr et al., 2020[10]; Yakubova et al., 2023[11]). Educational robotics can further promote hands-on learning and help ground abstract concepts through physical interaction, particularly in early years (Zhang et al., 2021[29]). In addition, other programming environments can enhance computational thinking by guiding students to break down problems, identify patterns and apply algorithmic reasoning (Zhang et al., 2021[29]; Scherer, Siddiq and Sánchez Viveros, 2020[7]).

Collaboration and teamwork are also supported through digital tools. Collaborative programming projects foster peer learning, creativity and mutual support as students work together to develop solutions and share strategies (Vinueza-Morales et al., 2021[8]; Sun and Zhou, 2023[40]). Participatory media activities – such as podcasting and digital storytelling – promote collaboration by engaging students in shared content creation and authentic communication (Acosta and Garza, 2011[41]; Akgün and Akgün, 2020[17]).

Finally, certain digital tools may offer particular benefits for inclusive and equitable learning. Media production tools and AI applications can provide multiple modes of expression and engagement, supporting inclusion when thoughtfully integrated into teaching practice. For example, multimedia storybooks have been found to benefit students from disadvantaged backgrounds, as well-designed features like animations and sound effects can improve comprehension and vocabulary (Takacs, Swart and Bus, 2015[14]). These tools may help compensate for limited language exposure outside school, but effectiveness depends on careful alignment with learning objectives, as unrelated interactive elements may distract from learning (Takacs, Swart and Bus, 2015[14]).

Challenges related to digitalisation of primary and secondary education

The rapid growth of digital technology in schools has brought new opportunities, but also a complex set of challenges for educators and students. The accompanying working paper, “The impact of digital technologies on students’ learning: Results from a literature review” (Forsström et al., 2025[1]), identifies a range of challenges relevant across digital tools and educational contexts (see Table 2.3).

Cognitive load is a central concern, particularly when students face complex interfaces, immersive environments, or multi-step tasks without sufficient guidance. For instance, VR-based learning environments may overwhelm students if tasks are not broken down or if too many elements compete for attention (Albus, Vogt and Seufert, 2021[42]). Similarly, game-based and open-ended programming activities can place high demands on learners, especially younger students, if motivational and narrative elements are not aligned with learning goals. The key issue is not the tools themselves, but whether their complexity and interactivity match students' developmental levels and prior knowledge. Tools such as AI-based writing support, robotics kits and learning analytics dashboards must be adapted to students' cognitive and emotional capacities to be effective; otherwise, they may become sources of frustration rather than support (Khalil, Slade and Prinsloo, 2023[43]). Even multimedia storybooks can hinder learning if they include distracting features unrelated to instructional objectives (Takacs, Swart and Bus, 2015[14]).

Table 2.3. Identified challenges related to different digital tools

Challenge	Tools/Contexts most affected	Key considerations / Mitigation	Example studies
Cognitive overload	AR/VR, complex simulations, games	Align complexity with age and skills; scaffold tasks	Albus, Vogt and Seufert, 2021[41]; Takacs, Swart and Bus, 2015[13]
Sustaining engagement	Educational games, open-ended platforms	Monitor long-term motivation; link to curriculum	Fadda et al., 2022[43]
Digital equity and access	All, especially XR, AI, analytics	Address infrastructure gaps; support disadvantaged students	Casal-Otero et al., 2023[43]
Teacher competence and training	All	Ongoing professional learning; align tech use with pedagogy	General synthesis, see Forsström et al., 2025[3]
Distraction and multitasking	Mobile devices, open web, VR	Structure digital tasks; set clear boundaries	Astatke, Weng and Chen, 2023[43]
Ethical/safety concerns	Social media, AI, analytics	Privacy protection; digital citizenship education	John and Yunus, 2021[43]
Transferability of learning	Open worlds, games	Align with academic content; scaffold transfer	Alawajee and Delafield-Butt, 2021[43]

While digital tools offer unique possibilities – real-time feedback, multimodal expression, immersive simulations and personalised learning pathways – they also present new obstacles. As the accompanying working paper, shows, such tools can both enhance learning and create barriers depending on how they are used, underscoring the need for age-appropriate design, continuous support and balanced implementation (Forsström et al., 2025[1]). As Table 2.3 indicates, these challenges cut across both technical and pedagogical dimensions, requiring careful implementation rather than reliance on the tools alone.

Teacher competence and role is a critical factor mentioned across all digital tools examined in the aforementioned accompanying working paper (Forsström et al., 2025[1]). Successful integration requires that teachers align technology use with pedagogical goals, manage cognitive load and balance digital and analogue methods. Scaffolding, pacing and guidance are highlighted in programming activities, while media production and digital storytelling benefit when teachers help students navigate multimedia complexity and support collaboration. In game-based learning, teachers need to select and frame games so that they support curricular aims and promote focus and inclusion. With extended reality tools, teachers must scaffold immersive tasks and manage potential overload – particularly for younger students – so that the technology complements rather than overwhelms learning. In the case of AI and learning analytics, the teacher's role includes interpreting data, ensuring ethical use and supporting students in acting on feedback; these tools supplement but do not replace pedagogical judgment.

The accompanying working paper also stresses the importance of balancing digital and analogue tools. While digital tools can enhance engagement and provide new opportunities, excessive or uncritical use

may undermine the benefits of traditional instruction (Forsström et al., 2025[1]). Without adequate digital competence or support, implementation risks becoming superficial or fragmented.

Sustaining student engagement over time is another challenge. While digital tools, especially games, can initially boost motivation through features like autonomy, feedback and interactivity (Bai, Hew and Huang, 2020[30]; Hainey et al., 2016[20]), this effect is not always sustained. Some studies indicate that longer interventions may show diminishing motivational effects, and it is unclear to what extent increased motivation leads to deeper learning. For example, skills gained in open-ended environments like Minecraft may not always transfer to academic contexts (Alawajee and Delafield-Butt, 2021[44]), and extended interventions may lead to reduced engagement over time (Fadda et al., 2022[45]), indicating that sustained engagement cannot be assumed.

Access to digital devices and infrastructure remains a significant challenge, particularly in under-resourced settings (Casal-Otero et al., 2023[46]). Försström et al. (2025[1]) underscore how unequal access to reliable internet, high-quality devices and quiet learning spaces can exacerbate educational inequalities and hinder meaningful engagement with digital tools. Equity concerns extend to the use of AI and learning analytics: while personalised dashboards and automated feedback can support self-regulated learning, these benefits are not equally distributed. Students lacking foundational digital skills or access may struggle to engage, potentially widening existing disparities (Khalil, Slade and Prinsloo, 2023[43]).

Digitalisation also brings risks related to harmful use, such as cyberbullying (see Cyberbullying below) and online exclusion. The widespread use of social media and mobile devices exposes students to harassment, privacy breaches and exclusion from peer communication, with negative impacts on mental health, self-esteem and academic engagement (Astatke, Weng and Chen, 2023[47]; John and Yunus, 2021[48]). These risks are compounded by unequal access, which can further limit participation and increase vulnerability.

Finally, everyday classroom challenges – such as digital distractions, multitasking and cognitive fatigue – are common across tools and subjects. Non-academic content competes for attention, reducing time on task, and technical glitches or delayed feedback in VR/AR can fragment attention and induce ‘immersion fatigue’. Similarly, poorly designed digital interfaces can overload learners or encourage superficial multitasking when digital literacy is low. These findings show that many of the challenges described earlier ultimately manifest in classroom practice, where weak task design or limited competence amplifies distraction and overload.

3 Realising the benefits of digital tools in education

Having outlined the challenges in the previous chapter, we now address integration: how, when and why digital tools can support learning in primary and secondary education.

Drawing upon the accompanying working paper, "The impact of digital technologies on students' learning: Results from a literature review" (Forsström et al., 2025[1]), and key studies (see Box 3.1), the chapter shows how with clear aims, well-designed tasks and alignment with educational aims, digital tools may support self-regulation, enable personalised learning, foster collaboration and extend connections beyond the classroom, while mitigating digital distractions, cognitive overload, fragmented personalisation and uneven digital competence.

In particular, effective integration requires digital literacy among students and teachers, including the capacity to navigate, evaluate and create digital content, to discern reliable sources, to practise self-regulation and to address digital ethics. Intentional planning and teaching practices are important too, coupled with building understanding of the cognitive processes related to digital learning.

Planning and conducting teaching

Teachers are responsible for determining the purpose, timing and method of digital tool use; they must evaluate and understand the tools available. The learning process begins with careful planning, focusing on curriculum goals, task design, tool selection and alignment with learning objectives and student needs to foster motivation and connect tasks to subject content. The subsequent phase requires strategies to sustain motivation, manage distractions and address individual learning goals throughout the learning process.

Task design and choosing the right tool for the job

Task design is a central consideration for teachers when aligning digital tools with learning goals and individual student needs. This process involves managing content, task complexity and relevance to ensure tasks remain engaging and meaningful. For example, Olsson and Granberg (2024[49]) found that project-based learning with tools like Scratch can make abstract concepts more accessible, supporting deeper understanding.

Scherer, Siddiq and Sánchez Viveros (2020[7]) and Hu, Chen and Su (2021[6]) emphasise the importance of scaffolding tasks to build on students' prior knowledge. Gradually increasing complexity – such as moving from block-based to text-based programming – helps manage cognitive load and fosters student confidence.

Box 3.1. Summary of key studies

The **EDUCATE project** (Evaluation of the new curriculum reform) (Gudmundsdottir et al., 2024[50]) is a comprehensive research initiative conducted in Norway to examine the integration of digital tools in education under the new curriculum framework. The project investigates the practices of teachers and students, focusing on how digital technologies can be effectively incorporated into teaching and learning processes to improve educational outcomes such as independent learning, critical thinking and responsible digital engagement. It concentrates on 10th-grade lower secondary and third-year upper secondary students across subjects including mathematics, science, social studies, languages and ethics. By exploring how digital tools can enhance digital competence, independent learning and critical thinking, the project provides insights into effective teaching practices and student engagement with technology.

Forsström and Amdam (under review) conducted **a review of reviews** examining the relational aspects of teachers' professional digital competence. Their research presents a model that highlights the interconnected ecosystems in which teachers operate, emphasising relational factors such as interactions with students, colleagues, leadership and the broader educational context. This perspective underscores that teachers' ability to integrate digital tools effectively is influenced not only by their individual competencies but also by the support and structures within their professional environments.

Amdam et al. (2024[51]) analysed a survey that gathered responses from 1,505 Norwegian teachers regarding effective practices in 1:1 computing classrooms, focusing on classroom management and digital teaching competence.

The **Norwegian Official Report** (NOU 2024: 20[3]) titled (translated from Norwegian) "The Digital (in) Life: A Balanced Childhood in the Age of Screens" is a government-commissioned investigation conducted in Norway to examine how children's and adolescents' screen use impacts their health, well-being, learning and development across various contexts, including kindergartens, schools and leisure activities. The report synthesises existing research, expert input and perspectives from young people to provide a nuanced understanding of both the opportunities and challenges associated with digital technologies. By exploring topics such as digital competence, the role of screen use in learning environments and strategies for mitigating distractions and promoting balanced use, the report offers evidence-based recommendations to inform policies that support healthy, inclusive and effective digital practices in education and beyond.

Mathematics offers examples of digital tools tailored to specific content areas, such as geometry. Dynamic geometry software, for instance, has potential to help students manipulate and visualise geometric figures, and enhance their understanding of complex concepts (Juandi et al., 2021b[5]).

However, as seen in the accompanying working paper, some studies conclude that the use of digital tools has not consistently yielded results across all types of learning content (Forsström et al., 2025[1]). There are cases where digital tools have not demonstrated significant effects on learning outcomes. For instance, research on reading comprehension has shown that reading on screens does not always lead to improved performance compared to reading on paper (Clinton, 2019[21]; Delgado et al., 2018[22]). Findings from Norway echoes the conclusion that not all digital tools lead to effective learning outcomes and highlights the critical role of teachers in selecting appropriate tools for specific tasks (NOU 2024: 20[3]). The report emphasises that digital technologies should not be adopted indiscriminately but rather integrated thoughtfully to align with pedagogical goals and the needs of individual students. Task design, as the report points out, is central to this process, requiring careful consideration of the strengths and limitations of each tool in the context of the curriculum.

While some digital tools, such as simulations or dynamic geometry software, offer clear benefits in facilitating visualisation and exploration, the NOU warns against assuming all digital tools will yield positive outcomes. For instance, tools that are overly complex or poorly aligned with student needs can increase cognitive load and reduce engagement. The report underscores the importance of teachers' professional digital competence, as their ability to evaluate and adapt tools to different learning contexts directly influences the effectiveness of digital integration.

It has been argued that effective task design involves not only choosing the right tools but also determining when and how to use them (NOU 2024: 20[3]). Teachers must consider factors such as the students' developmental stage, prior knowledge and the complexity of the content to ensure that the chosen tools support learning rather than hinder it. Moreover, the report highlights the importance of combining digital tools with other methods, such as collaborative discussions or hands-on activities, to create richer and more meaningful learning experiences. This balanced approach helps ensure that digital tools are used as enablers rather than replacements for sound pedagogical practices. This is also noted in Gudmundsdottir et al. (2024[50]), who concluded that relying solely on digital tools is insufficient; a variety of resources is necessary. The key lies in combining different tools for diverse purposes and achieving the right balance. This approach provides varied learning experiences that keep students engaged and ensures digital tools complement, rather than replace, traditional teaching methods.

For instance, studies highlighting the advantages of tools like dynamic geometry software or programming environments such as Scratch can guide teachers in selecting tools that align with their learning objectives. At the same time, research can also reveal limitations, such as increased cognitive load associated with overly complex platforms or tools that lack clear alignment with pedagogical goals. Equipping teachers with this knowledge, combined with ongoing professional development, ensures that they can critically evaluate and adapt tools to meet the diverse needs of their students, fostering both engagement and meaningful learning experiences (NOU 2024: 20[3]).

Combination of digital and analogue resources

Gudmundsdottir et al. (2024[50]) and the aforementioned government-commissioned report from Norway (NOU 2024: 20[3]) suggest that combining digital and analogue tools often leads to more effective learning outcomes than relying on a single approach. Studies underscore this blended strategy, showing how integration can enhance engagement and deepen understanding. For example, Hillmayr et al. (2020[10]) demonstrate that digital simulations in science education, such as virtual laboratories for exploring chemical reactions and physical forces, are particularly effective when paired with hands-on experiments (e.g. chemical reactions, physical forces). This combination allows students to validate digital findings through practical activities, linking theory to practice and reinforcing understanding through multiple modalities. Similarly, Gudmundsdottir et al. (2024[50]) highlight the benefits of integrating virtual labs with physical experiments, enabling students to explore complex scientific concepts interactively and confirm abstract theories through tangible experiences.

The Norwegian Official Report underscores similar conclusions regarding the integration of digital and analogue tools, emphasising the importance of balance and strategic use to optimise learning outcomes (NOU 2024: 20[3]). The report highlights that while digital technologies offer unique opportunities for personalised and interactive learning, they must be complemented by traditional methods to ensure a well-rounded educational experience. This aligns with the argument that combining resources deepens understanding and enhances engagement across diverse subjects. For instance, the report emphasises that digital tools should be used intentionally, tailored to specific pedagogical goals and balanced with analogue practices to support cognitive development and minimise distractions.

Gudmundsdottir et al. (2024[50]) also discuss the value of digital tools in subjects such as languages, social studies and ethics, where digital platforms facilitate collaborative research and efficient access to

information. However, traditional methods – such as handwritten notes and group discussions – remain essential for developing critical thinking and synthesis skills. Similarly, Norwegian Official Report highlights that combining digital visualisations with manual tasks, such as written reflections or collaborative discussions, strengthens both analytical and collaborative abilities, ensuring digital tools complement traditional practices (NOU 2024: 20[3]).

In mathematics, the effectiveness of using digital tools alongside traditional methods. As discussed by Juandi et al. (2021a[4]), Juandi et al. (2021b[5]) and Hillmayr et al. (2020[10]), technologies like dynamic geometry software enable students to manipulate and visualise mathematical figures, enhancing their grasp of abstract concepts. However, this digital manipulation is most impactful when combined with conventional approaches, such as paper-based exercises or classroom discussions. This blended strategy supports a comprehensive understanding of mathematical principles, facilitating both individualised problem-solving and collaborative exploration. Gudmundsdottir et al. (2024[50]) further emphasise that combining digital graphing tools with traditional exercises helps students visualise problems digitally while exploring solutions through manual calculations. The Norwegian Official Report further supports this approach, emphasising that blending digital graphing tools with paper-based exercises allows students to visualise problems digitally while solving them manually, fostering both conceptual understanding and procedural fluency (NOU 2024: 20[3]).

As Gudmundsdottir et al. (2024[50]) argue, the strategic use of digital tools is crucial, highlighting the importance of carefully selecting the context and timing for their deployment. For instance, digital resources are highly beneficial in research projects, where they allow students to gather and analyse data efficiently. Yet, pairing these activities with traditional practices – such as creating outlines or conducting peer reviews – supports the development of critical thinking and analytical skills, making the learning process more well-rounded. (Gudmundsdottir et al., 2024[50]) further advocate for a scaffolded approach to integrating digital tools with analogue resources, especially to accommodate students with varying levels of digital literacy. Starting with analogue resources helps students build foundational skills, and as they gain confidence, digital platforms can be gradually introduced. This gradual integration ensures that all students can fully benefit from digital technologies, promoting both competence and engagement.

Addressing distractions in digital learning environments

Distractions have emerged as a notable challenge in various digital learning contexts, particularly within multimedia learning environments and technologies like AR and VR. An overload of sensory input – characterised by excessive visual and auditory stimuli – can lead to disengagement, especially among students with heightened sensitivities or special educational needs. For example, Yakubova et al. (2023[11]) found that students with autism spectrum disorder may experience sensory overload when interacting with overly complex AR applications, resulting in distractions and reduced learning effectiveness.

Simplifying digital environments by reducing unnecessary elements is essential for minimising cognitive strain and decreasing the likelihood of distractions. As noted by Pellas, Kazanidis and Palaigeorgiou (2020[12]), effective learning with AR and VR technologies requires careful design to avoid overwhelming students, especially younger learners who may struggle to manage immersive environments, leading to reduced focus or cognitive overload.

Additionally, using social media platforms in educational contexts presents further challenges related to distraction. Students may easily deviate from academic tasks, engaging instead with non-academic content or social interactions. This issue is particularly evident on platforms such as YouTube and Facebook, where entertainment content can divert attention from learning activities. John and Yunus (2021[48]) highlight that while social media applications can enhance learning experiences, they also pose significant risks of distraction, which can reduce focus and the time allocated to actual learning.

Effective mitigation of distractions involves implementing strategies that help learners manage their attention. Alpizar, Adesope and Wong (2020[52]) found that incorporating signalling in multimedia learning environments – such as dynamic signals or annotations – assists students in focusing on essential content, thereby reducing cognitive load and enhancing retention. These attentional cues are particularly useful for directing students' focus to the most relevant parts of the material.

Addressing the issue of distractions requires a nuanced approach that considers various factors, including students' age and developmental stage. Younger learners may be more susceptible to distractions due to their limited capacity for self-regulation. According to Pellas, Kazanidis and Palaigeorgiou (2020[12]), strategies incorporating teacher guidance and support are essential for student engagement. Educators are encouraged to create structured environments that limit distractions, such as establishing clear guidelines for using digital tools and integrating strategies that foster focused learning.

Moreover, fostering digital literacy is crucial (see below). Students equipped with strong digital literacy skills are better able to navigate complex online environments, distinguish credible from non-credible content and self-regulate their engagement with digital tools (Olsson and Granberg, 2024[49]; Sahin and Coban, 2020[18]). This empowerment can mitigate distractions by enabling learners to make informed decisions about their online activities. For instance, Olsson and Granberg (2024[49]) demonstrate that, with appropriate teacher guidance, students using programming tools like Scratch can remain focused on creative mathematical reasoning tasks.

Ultimately, while digital tools offer promising opportunities for enhancing learning experiences, they also pose risks related to distraction. A balanced approach that includes designing user-friendly interfaces, incorporating attentional cues, providing teacher support and fostering digital literacy will be crucial in navigating these challenges and optimising learning outcomes across different educational contexts.

Selecting the right tools to design meaningful learning activities that address each student’s individual needs and learning goals while minimising distractions requires significant competence from teachers. Teachers’ professional digital competencies are a crucial factor in this process. Students' digital skills are also central to ensuring effective learning processes when using digital tools.

Students’ and teachers’ digital literacy and competence

Digital literacy plays a central role in fostering effective learning processes across a wide range of subjects and age groups. Digital tools have the potential to enhance skill development, motivation and engagement among students, supporting self-regulation and offering opportunities for deeper, more personalised learning experiences. However, to fully realise the potential of these tools in the classroom, both teachers and students must possess adequate digital literacy skills in order to maximise the benefits of digital technologies for learning, engagement and personal development. In this context, digital literacy refers to the ability to effectively and critically navigate, evaluate and create information using digital technologies.

The role of students’ digital literacy in their success

Students' digital literacy is a critical factor influencing their ability to use digital tools and platforms across various educational contexts effectively. Digital literacy encompasses not only technical skills but also the capacity to critically evaluate and interact with digital content, enhancing learning outcomes in areas such as programming, gaming, media production and social media engagement.

In the context of programming education, students with higher digital literacy are better equipped to navigate programming environments and tools. Vinueza-Morales et al. (2021[8]) emphasise that students with advanced digital skills can more easily transition from block-based to text-based programming languages. These students can effectively engage with hybrid programming environments, which blend

visual and textual coding and are less likely to experience frustration during this transition. Conversely, students with lower digital literacy may struggle with the complexity of text-based programming, highlighting the need for tailored instructional support to bridge this gap.

Similarly, with media production and literacy, digital literacy enables students to harness the full potential of multimedia tools for learning. Takacs, Swart and Bus (2015[14]) found that multimedia storybooks can significantly enhance literacy development when students are proficient in digital navigation and comprehension. Students who can effectively interact with digital story elements, such as animations and sounds, show improved reading comprehension and vocabulary acquisition. However, those lacking digital literacy may find these tools overwhelming or distracting, which can hinder their learning progress.

Digital literacy also plays a pivotal role in students' ability to critically engage with social media platforms for educational purposes. John and Yunus (2021[48]) highlight that students with strong digital literacy skills can effectively use social media applications like YouTube and WhatsApp to enhance their language learning and communication skills. They can discern educational content from non-academic material, enabling them to focus on resources that support their learning objectives. On the other hand, students with lower digital literacy may be more susceptible to distractions or may misuse these platforms, diminishing their educational value.

Moreover, digital literacy is essential for facilitating autonomous and self-regulated learning. Students who are digitally literate are more likely to engage in self-directed learning activities, using digital tools to access information, collaborate with peers and reflect on their learning processes. For instance, in game-based learning environments, students with higher digital literacy can navigate game mechanics more effectively, leading to enhanced engagement and learning outcomes (Hainey et al., 2016[20]). They can also leverage in-game feedback to make informed decisions and adapt their strategies, fostering a deeper understanding of the subject matter.

However, teacher guidance is central to developing students' digital literacy. Teachers can support students by integrating digital literacy skills into the curriculum, providing explicit instruction on navigating digital tools and creating opportunities for practice in authentic contexts.

Teachers' professional digital competence

The realisation of the potential of integrating digital tools in education relies heavily on teachers, who are central to transforming technological possibilities into meaningful learning experiences (Hillmayr et al., 2020[10]; Olsson and Granberg, 2024[49]). Serving as facilitators, guides and mediators, teachers ensure that students not only interact with technology but also develop essential skills such as critical thinking, problem-solving and independent learning.

For instance, effective learning with XR technologies depends on teacher scaffolding and the integration of digital tools with traditional teaching methods. Studies demonstrate that without adequate guidance, students may struggle to navigate AR and VR environments, leading to diminished learning outcomes (Pellas, Kazanidis and Palaigeorgiou, 2020[12]; Yakubova et al., 2023[11]).

Furthermore, in interdisciplinary contexts like STEM (Science, Technology, Engineering and Mathematics) and programming, teacher support structures complex tasks, fosters creative reasoning, and helps manage challenges such as cognitive load and distractions (Forsström et al., 2025[1]). As mediators between policy directives and classroom practices, teachers ensure that technology integration aligns with pedagogical objectives, thereby enhancing learning outcomes.

However, many teachers lack sufficient training, highlighting the need for ongoing professional development and leadership support to address technological and pedagogical demands effectively. As facilitators of student interactions with technology, teachers play a multifaceted role in creating learning environments where digital tools enhance student outcomes across subjects and levels. This role also

requires them to develop students' digital literacy while simultaneously enhancing their own digital competence, ensuring they are better positioned to guide learning and adapt to evolving educational needs. By improving their digital literacy, teachers are better positioned to:

- **Effectively integrate technology into their teaching practices**. Proficient teachers can seamlessly incorporate technology into lessons, aligning it with curriculum goals. Pellas, Kazanidis and Palaigeorgiou (2020[12]) emphasise that the successful integration of XR technologies relies on teachers who understand how to blend these tools with traditional methods. Teachers need to be proficient in selecting the appropriate digital tools for specific pedagogical purposes, ensuring that these tools enhance rather than complicate the learning process. This requires a comprehensive understanding of both the potential and limitations of digital technologies, as seen in the accompanying working paper and its discussion on teachers' adaptation to student needs and classroom contexts (Forsström et al., 2025[1]).
- **Design learning experiences that build students' digital skills**. Competent teachers create activities that teach subject content while simultaneously developing students' digital abilities. Olsson and Granberg (2024[49]) demonstrate how, in a mathematics classroom, a teacher's guidance in using Scratch programming enabled students to engage in creative mathematical reasoning, building programming skills alongside mathematical understanding.
- **Model effective use of digital tools, setting an example for students**. Teachers who skilfully use technology serve as role models. Scherer, Siddiq and Sánchez Viveros (2020[7]) note that teachers play a crucial role in incorporating metacognitive and collaborative strategies in programming education, thereby enhancing student learning outcomes. By demonstrating effective use of programming tools, teachers encourage students to adopt best practices.
- **Address challenges and troubleshoot technical issues**. Teachers with strong digital skills are better equipped to handle technical glitches and help students overcome technological barriers, ensuring that learning is not disrupted. Meanwhile, Vinueza-Morales et al. (2021[8]) highlight that inadequate teacher training can lead to inconsistent support during transitions between programming environments.
- **Stay updated with emerging technologies and pedagogical approaches**. Teachers who continually develop their digital literacy are more aware of new tools and methods that can enhance learning. Casal-Otero et al. (2023[46]) point out that integrating AI literacy into K-12 education faces challenges due to the lack of teacher expertise in AI and programming. Ongoing professional development is essential for teachers to keep pace with technological advancements.
- **Navigate ethical considerations in digital education, fostering responsible digital citizenship**. Teachers play a critical role in guiding students to become responsible digital citizens. Forsström and Amdam (Forthcoming[53]) highlight that teachers must help students understand issues such as online privacy, data security, digital etiquette and the ethical use of information. Developing such skills requires teachers to reflect on their own digital practices and stay informed about emerging trends in digital ethics.

The complexity of teachers' roles in developing professional digital competence (PDC) is discussed in Forsström and Amdam (Forthcoming[53]), who examine the relational aspects of this process. Their review of systematic reviews highlights the interconnected ecosystems in which teachers operate. These ecosystems encompass relationships among teachers, students, colleagues, leadership and the broader educational context, including institutional policies and digital resources. The review underscores that teachers do not work in isolation but within a network of relational influences that shape their ability to integrate digital tools effectively.

Forsström and Amdam's (Forthcoming[53]) discuss that professional digital competence extends beyond technical skills to include a nuanced understanding of relational dynamics. They identify three key

ecosystems: the classroom ecosystem, the organisational ecosystem and the structural ecosystem. Each ecosystem represents distinct relational dimensions that teachers must navigate to develop their digital competence.

The classroom ecosystem in their study operates at the micro level and centres on the dynamic interplay between teachers, students, pedagogical practices and digital tools. Teachers must integrate technological knowledge with pedagogical strategies, student engagement and classroom management to create meaningful learning experiences. This ecosystem highlights how digital tools can shape classroom interactions and instructional approaches while requiring teachers to continuously adapt to students' evolving digital competencies.

Supporting teachers' digital competence through system levels

The organisational ecosystem functions at the meso level, encompassing relationships with colleagues, leadership and professional development structures. Teachers collaborate with peers and leaders to develop digital competence, engage in structured professional learning communities and participate in initiatives that support technology integration. Leadership plays a pivotal role in providing access to resources, setting strategic goals and fostering a culture of innovation. According to Forsström and Amdam (Forthcoming[53]), leaders are essential facilitators of teachers' professional digital competence by ensuring that digital policies are translated into concrete support structures within schools. Effective leadership involves not only setting clear expectations for digital integration but also creating opportunities for collaboration, professional development and shared decision-making. Leaders must act as mediators between policy directives and classroom implementation, supporting teachers in overcoming technological barriers and adapting digital tools to pedagogical needs. Additionally, leaders who actively engage in digital competence development themselves can serve as role models, fostering an environment where continuous learning and innovation are prioritised. Forsström and Amdam emphasise that teachers' digital competence flourishes in collaborative environments where peer learning, shared experiences and institutional support are actively promoted.

The structural ecosystem operates at the macro level, shaping teachers' digital practices through policies, infrastructure and curriculum frameworks. Institutional and governmental policies dictate how digital tools are implemented in education, influencing resource allocation and strategic priorities. Teachers must navigate these policies to align their classroom practices with broader educational objectives. For instance, digital infrastructure and access to technology significantly impact the feasibility of integrating digital tools, necessitating policy directives that support sustainable implementation. Forsström and Amdam (under review) highlight that well-aligned policies, institutional investments and technological support structures are crucial for ensuring the effective digitalisation of education.

In conclusion, while teachers play a central role in the successful integration of digital tools in education, this responsibility does not rest solely on their shoulders. Forsström and Amdam (Forthcoming[53]) emphasise that teachers cannot and should not navigate these complexities in isolation. Their effectiveness depends on the broader ecosystems they are part of, including classroom dynamics, professional collaboration, leadership support and policy frameworks. Successful digital integration requires interconnected structures that provide teachers with resources, guidance and professional development opportunities at all levels.

The success of digital integration in education hinges on the collective strength of these ecosystems, ensuring that teachers, leaders and institutions work in harmony. Only by supporting each of these interrelated levels can we fully realise the potential of digital tools in education, fostering an environment where both teachers and students can thrive in a digitally enhanced learning environment.

Cognitive processes

Digital tools offer opportunities to enhance personalised learning and encourage students to take greater responsibility through goal-setting, self-monitoring and reflection. However, these technologies also present challenges that need to be carefully managed. This section examines themes such as promoting student well-being, fostering self-regulated and personalised learning through digital tools and managing cognitive load.

Fostering self-regulated and personalised learning through digital tools: Student support and balance between individual and collaborative approaches

Integrating digital tools holds significant potential for enhancing students' self-regulation by providing opportunities for personalised learning. Self-regulation involves the ability to monitor and control one's learning processes, including goal-setting, self-monitoring and reflection. While digital tools can empower students to engage in self-regulated learning, challenges remain, particularly regarding students' varying levels of competence in using these tools effectively.

One-to-one solutions, where each student is equipped with a personal digital device, further enhance personalised learning by allowing students to work at their own pace and on tailored learning pathways. Providing students the opportunity to work at their own pace has the potential to improve learning outcomes by fostering deeper engagement and better comprehension (Lopez et al., 2023[31]; Rigney, Hixson and Drevon, 2020[15]). These solutions enable greater flexibility, giving students the autonomy to revisit concepts as needed, track their progress and receive individualised feedback. However, the success of one-to-one solutions relies not just on providing students with devices but on how these devices are used and connected with thoughtful pedagogical practices and effective integration into the curriculum. For example, serious games in mathematics have shown how adaptive learning environments can enhance personalised learning. These games adjust to students' progress, providing real-time problem-solving tasks and feedback, allowing them to experiment with variables and refine their strategies while engaging deeply with mathematical concepts (Lopez et al., 2023[31]). Similarly, Headsprout, a computer-assisted instructional programme, exemplifies how one-to-one digital solutions can foster personalised learning. By enabling students to work at their own pace, this programme builds foundational reading skills through interactive, game-like episodes that provide immediate feedback, gradually helping students master skills such as phonics and fluency (Rigney, Hixson and Drevon, 2020[15]).

Furthermore, learning analytics in virtual laboratories can enhance self-regulation by providing real-time feedback, allowing students to reflect on their progress and adjust their learning strategies as needed. According to Elmoazen et al. (2023[36]), AI-based learning analytics (LA) tools integrated into virtual labs can track student behaviour, offer immediate feedback and promote self-regulated learning by helping students reflect on their performance and adapt their strategies accordingly. This data-driven approach encourages students to take initiative and fosters a sense of ownership over their learning.

However, it is important to recognise that some students may struggle to interpret and use this feedback without sufficient guidance. Elmoazen et al. (2023[36]) note that the complexity of interpreting feedback generated by LA tools can lead to confusion, limiting the effectiveness of the feedback. Additionally, the fragmentation of virtual lab platforms can make it challenging to standardise feedback and learning interventions, which can impact students' development of self-regulatory skills.

The role of teachers is particularly significant in this context. Teachers serve not only as facilitators of learning but also as essential support in helping students develop self-regulation skills. They assist students in navigating the complexities of personalised learning environments by guiding them in interpreting feedback and scaffolding learning activities. For example, Ouyang and Zhang (2024[54]) emphasise that teacher intervention is crucial when using AI tools in collaborative learning settings, as teachers can interpret AI-generated feedback and ensure that students engage effectively.

Moreover, the balance between collaborative and individual learning is central in supporting students' learning. Digital tools can foster collaborative learning experiences while supporting individual learning pathways requiring self-direction. Teachers play a crucial role in balancing these approaches, promoting group work and collaboration while remaining responsive to individual learning needs. In programming education, Scherer, Siddiq and Sánchez Viveros (2020[7]) found that collaborative learning environments, such as pair programming, enhance student engagement and learning outcomes. Teachers facilitate these collaborative processes, ensuring that students benefit from both collective and individual learning opportunities.

Nevertheless, challenges persist. Not all students possess the same level of digital literacy, which can lead to disparities in access to personalised learning opportunities. Xu (2024[38]) notes that students with lower digital literacy may struggle to fully engage with AI tools, resulting in reduced motivation and learning outcomes. It is, therefore, important for teachers to recognise these differences and provide targeted support to help all students thrive. Teachers can play a pivotal role in developing students' digital literacy skills, enabling them to use digital tools effectively for self-regulated learning.

Additionally, reliance on digital tools can sometimes lead to disengagement for certain learners. For example, Pengelley, Whipp and Rovis-Hermann (2023[55]) found that the format of assessments (digital vs. paper-based) can impact student performance due to differences in cognitive load. Teachers need to consider individual student needs and preferences when integrating digital tools to ensure that learning remains accessible and effective.

In conclusion, while digital tools offer promising avenues for enhancing self-regulation and personalised learning, their effectiveness is closely tied to students' digital literacy and the support provided by teachers, as concluded also in the previous chapter.

Managing cognitive load in digital learning environments

Cognitive load is a central factor in shaping the effectiveness of digital learning environments, particularly in complex settings such as VR, programming, gaming and digital media literacy education.

Managing cognitive load is essential for optimising learning outcomes across different grade levels and subjects. In VR environments, intrinsic cognitive load can be mitigated by breaking complex tasks into manageable segments. Albus, Vogt and Seufert (2021[42]) illustrate this in their study, where secondary school students learned about the process of seawater desalination in a virtual environment. By breaking the desalination process into smaller, manageable tasks and using attentional aids, students could focus on individual components without becoming overwhelmed. This scaffolding approach aligned with the students' prior knowledge and allowed them to build understanding gradually.

However, determining the optimal segmentation of tasks can be a complex challenge. Teachers may find that too much segmentation leads to fragmented understanding, while too little can overwhelm students. Striking a balance requires a nuanced understanding of students' prior knowledge and the specific context of the learning material.

Extraneous cognitive load can be significantly reduced by designing user-friendly digital interfaces. Pellas, Kazanidis and Palaigeorgiou (2020[12]) note that younger learners, particularly in primary education, are especially vulnerable to distractions caused by complex interfaces. Simplifying VR environments by removing unnecessary elements helps minimise cognitive strain and reduces the likelihood of distractions. However, teachers face the challenge of ensuring these simplified designs do not strip away essential functionalities supporting exploration and engagement.

In addition, the use of attentional cues – such as visual signals and annotations – can enhance germane load by directing students' focus toward key elements of the material. Alpizar, Adesope and Wong (2020[52]) found that incorporating signalling in multimedia learning environments assists students in focusing on

essential content, thereby reducing cognitive load and enhancing retention. While such strategies are beneficial, they require careful integration to avoid adding to the cognitive burden. If students encounter too many cues or unclear signals, they may experience increased cognitive load, countering the intended benefits. Therefore, ongoing assessment of the effectiveness of these cues is important for teachers as they adapt their teaching strategies.

- In programming and robotics education, the transition from block-based to text-based programming presents a significant cognitive challenge. Block-based environments like Scratch reduce cognitive load for younger students by simplifying syntax and making tasks more accessible (Hu, Chen and Su, 2021[6]; Scherer, Siddiq and Sánchez Viveros, 2020[7]). However, the shift to text-based programming increases complexity due to the need to understand syntax and abstract logic. Vinueza-Morales et al. (2021[8]) suggest that to facilitate this transition, teachers can employ scaffolding techniques, gradual transitions and collaborative strategies such as pair programming. These methods help distribute the cognitive load, making tasks more manageable while promoting collaborative problem-solving.
- In game-based learning, well-designed tasks can effectively manage cognitive load by fostering decision-making and problem-solving. However, younger students often experience cognitive overload when faced with complex choices, which can lead to disengagement. Hainey et al. (2016[20]) suggest that teachers provide guidance to ensure tasks remain age-appropriate and accessible. This approach involves careful task design and ongoing formative assessments to monitor students' understanding and adjust challenges as needed.
- In media literacy and digital storytelling, the design of multimedia tools can significantly influence cognitive load. Thoughtfully designed interactive features that engage multiple senses can enhance learning outcomes. Takacs, Swart and Bus (2015[14]) found that multimedia elements aligned with the story improved comprehension and vocabulary acquisition. Conversely, integrating too many complex or irrelevant features can increase cognitive load, particularly for students with learning difficulties. Teachers are encouraged to be selective in their choice of digital tools, ensuring these tools align with pedagogical goals and enhance, rather than hinder, the learning process.

Students' individual needs and the balance between collaborative and individual approaches are also critical when considering cognitive load, as individual needs vary widely. While some students thrive in collaborative settings, others may find social dynamics overwhelming, increasing their cognitive strain. Sun and Zhou (2023[40]) highlight the need for teachers to adapt strategies flexibly, fostering supportive and inclusive learning environments. However, rapid technological advancements often challenge teachers' ability to keep pace with effective methods. As discussed, continuous professional development and reflective practice are essential, enabling teachers to assess their strategies, refine their methods and tailor interventions to meet students' diverse needs effectively (Vinueza-Morales et al., 2021[8]; Sun and Zhou, 2023[40]).

In conclusion, effectively managing cognitive load in digital learning environments requires a multifaceted approach. By balancing task complexity, simplifying interfaces and employing scaffolding and collaborative strategies, teachers can create engaging learning experiences that promote deeper understanding and knowledge retention. Ongoing assessment and adaptation of these strategies are essential to address the unique challenges posed by cognitive load, ultimately fostering an environment conducive to meaningful learning across diverse educational contexts.

Classroom management and handling disruptions in digital learning environments

The accompanying working paper identified several disruptions linked to digital technologies in education (Forsström et al., 2025[1]). These include distractions, cognitive overload, technical issues, health concerns, cyberbullying, digital inequities and balancing digital with analogue methods. Immersive tools

like AR/VR and social media can divert attention, while complex interfaces may overwhelm learners, especially younger ones. Technical glitches interrupt lessons and social challenges such as cyberbullying affect students' well-being and academic focus.

The accompanying working paper highlights strategies to address digital disruptions, stressing thoughtful task design, tool choice and blending digital with traditional methods (Forsström et al., 2025[1]). Teacher professional development, student digital literacy and cognitive load management are key, with Box 3.2 offering insights from highly digitised Norwegian schools.

Box 3.2. Insights from a study on highly digitised schools in Norway

Amdam et al. (2024[51]) conducted a study on classroom management practices in highly digitalised Norwegian schools. The data from Amdam et al. (2024[51]) originates from the GrunnDig project, which, in addition to a systematic review, examined digitalisation in Norwegian education through survey responses from 1 505 teachers working in 1:1 computing classrooms where each student has their own personal device. The study explored what teachers consider essential for good teaching practices in these contexts, focusing on the role of classroom management and digital teaching competence.

Amdam et al. (2024[51]) emphasise classroom management as a central element in addressing disruptions in digital learning environments. Their findings highlight the importance of establishing clear routines, rules and teacher-led control measures to maintain order and focus in 1:1 computing classrooms. For instance, strategies like using software to monitor student activity and implementing strict rules on device usage were commonly cited as ways to minimise distractions and prevent misuse of digital tools.

While these measures address immediate disruptions, the study reveals a reliance on external regulation rather than fostering students' self-regulation skills. Teachers often employ reactive approaches, such as disciplinary actions and restrictions, which can mitigate short-term issues but may fail to develop students' autonomy and digital responsibility. Amdam et al. (2024[51]) note that many teachers focus predominantly on maintaining order rather than fostering relational dynamics or developing students' socio-emotional skills in digital contexts. However, Amdam et al. (2024[51]) suggest that as teachers gain experience in 1:1 classrooms, their focus shifts from technical challenges to classroom management. Nevertheless, the tendency to prioritise control over collaboration or autonomy highlights an area for improvement.

Amdam et al. (2024[51]) highlight the need to integrate proactive and relational strategies into classroom management. While reactive measures like monitoring and rule enforcement address immediate disruptions, they do not fully support the development of students' digital literacy and self-regulation skills. Managing disruptions effectively requires teachers to adopt a more holistic approach that combines preventive measures, such as clear task design and balanced use of digital and traditional resources, with relational strategies that build trust and mutual respect.

Moreover, fostering digital literacy among students is critical. By teaching students how to navigate digital tools responsibly, manage distractions and critically engage with content, teachers can reduce the need for constant oversight and create more autonomous learners. Professional development programmes should prioritise these aspects, providing teachers with the knowledge and tools to address both technical and pedagogical challenges in digital learning environments.

In conclusion, managing disruptions in digital learning requires a multifaceted approach that incorporates structured routines, task design and teacher-student relationships. Professional development programmes should aim to broaden teachers' understanding of classroom management, incorporating strategies that balance structure with flexibility and empower students to regulate their digital behaviours effectively.

4 Cyberbullying

As highlighted in the accompanying working paper, "The impact of digital technologies on students' learning: Results from a literature review" (Forsström et al., 2025[1]), digital tools have the potential to bring several benefits for students learning and motivation, but access to digital devices and the internet has also led to one of the most pressing challenges linked to digitalisation: the rise of cyberbullying. This issue, encompassing both perpetration and victimisation, has become a significant concern in school systems worldwide.

There are several terms that are used to describe the behaviour (e.g. cyberbullying, internet bullying and internet harassment) and overlaps between the terms cyberbullying and cyberhate have also been found (Fulantelli et al., 2022[56]). Although there is overlap, cyberbullying is used to describe the harmful use of technology among students, whereas criminal harassment is harmful actions (digital or not) among adults. In this chapter, we examine key issues related to cyberbullying and present potential solutions to address this demanding challenge. Our discussion is based on several systematic reviews in this field.

Dan Olweus's (1993[57]) definition of face-to-face bullying includes three key criteria: intent to harm, imbalance of power and repetition. These criteria are often applied to cyberbullying definitions as well. However, studies on cyberbullying do not always include all three of Olweus's criteria; some may focus on one or use different criteria altogether. The time frame used when asking students about their bullying experiences, such as 'during this past semester' versus 'during this past year', can significantly affect reported prevalence and make comparisons difficult. Additionally, prevalence rates vary depending on whether measurements use single or multiple items to assess cyberbullying.

In cyberbullying, the concept of 'repetition' differs from traditional bullying. The act (e.g. creating a negative post about someone) might be carried out once, but the post can be re-posted by others or forwarded to many, and the original sender can lose control of the post, too. Cyberbullying can also occur at any time, and the perpetrator may be known or anonymous (Zych, Farrington and Ttofi, 2019[58]). This brief introduction to the topic shows how important it is to always carefully consider how cyberbullying has been conceptualised in research studies before comparisons or generalisations are made.

Table 4.1. Key terms in cyberbullying

Term	Definition
Cyberbullying	Using digital devices or online platforms (such as social media, messaging apps, or gaming forums) to repeatedly harass, intimidate, or harm someone.
Cyberbystanding	The role of individuals who witness cyberbullying incidents but are not themselves direct perpetrators or victim.
Cyberpenetration	The extent to which digital technology and internet access have become widespread and deeply embedded in everyday life – especially among young people.
Cybervictimisation	The experience of being the target of harmful actions or harassment carried out through digital means (e.g. social media, texting, gaming platforms).
Affective empathy	The ability to feel and respond to the emotions of others on an emotional level.
Cognitive empathy	The ability to intellectually comprehend and take the perspective of another person's emotional state, without necessarily sharing or experiencing those emotions oneself.
Pro-sociality	Behaviours, attitudes and actions that are intended to benefit other people or society as a whole.

Prevalence of cyberbullying

Cyberbullying is linked to the onset of the use of mobile phones and social media (Evangelio et al., 2022[59]). The minimum age to open social media accounts, set by providers, is 13 years. However, insights into actual use show that it is quite common for children much younger than 13 to have their own social media profiles. For instance, Ofcom (2022[60]) reported that in Britain:

- **Children under 13 with profiles.** A majority of children under 13 had their own profile on at least one social media app or site.
- **Multiple profiles.** More than six in ten children aged 8-17 reported having multiple profiles on some online apps and sites. The most common reason was to maintain one profile for their parents, family or general visibility while keeping another profile more private for their friends.
- **Parental awareness**. Only 42% of parents of children aged 3-17 knew the minimum age requirement is 13; 38% of parents of 8-11-year-olds allowed their child to use social media.

A review of prevalence among Australian children and adolescents found that cyberbullying was less prevalent than face-to-face or 'traditional' bullying (Jadambaa et al., 2019[61]). However, their results also show that many children who were victims of traditional bullying were also victims of cyberbullying. Zych et al. (2019[62]) found that among Canadian youths, cyber-perpetration rates were 6.2%–10.4% when measured with one to two items but increased to 24.8%–26.4% with multiple items. Cybervictimisation rates rose from 10.4%–18.6% to 38.4%–48.5% under the same conditions. Similarly, Zych, Ortega-Ruiz and Del Rey (2015[63]) found that prevalence rates were about twice as high for cyberbullying among Spanish children and adolescents if multiple items were used to measure victimisation or perpetration compared to one to two items.

Foody, Samara and O'Higgins Norman (2017[64]) found similar results for the Irish population of children and adolescents: traditional victimisation was twice as high as cybervictimisation in primary schools (statistically significant differences), and the rates of cybervictimisation were also less at the post-primary level, but the differences were not statistically significant. The authors point out that prevalence rates varied greatly and significantly when separated for the type of assessment used. It is worth noting that this review included studies published up to April 2016 and the authors acknowledged the aging nature of the data at the time of their publication.

A review covering 25 European Union countries found wide variations in cyberbullying prevalence: cybervictimisation ranged from 2.8% to 31.5%, cyber-perpetration from 3.0% to 30.6%, and cyber-bystanding from 13.0% to 53.1% (Henares-Montiel et al., 2022[65]).

Cyberbullying also takes various forms. Yemima (2023[66]) identified five different forms:

- **Flaming**: sending text messages with harsh words, a dispute or argument using vulgar, demeaning language
- **Harassment**: insults regarding a person's persona or personal life (e.g. how they look, dress, behave)
- **Impersonation**: pretending to be someone else on social media with the aim of damaging someone's reputation
- **Denigration**: the posting of rumours and cruel lies also to damage someone's reputation
- **Outing and trickery**: spreading other people's secrets publicly or tricking someone to gain access to personal pictures and videos belonging to the victim

Cyberbullying takes place on various platforms, including emails, mobile phones and chat applications (Balakrisnan and Kaity, 2023[67]). Social media platforms like Instagram, Facebook and Snapchat are reported to be the most common platforms for cyberbullying perpetration (Djuraskovic, 2020[61] in

Balakrisnan and Kaity, 2023[65]). In a review of 68 cyberbullying detection studies, Balakrisnan and Kaity (2023[67]) reported that Twitter was the most widely investigated platform followed by Instagram and Formspring.me.

Topics related to cyberbullying

Mental health, well-being and self-harm

Kwan et al. (2020[68]) searched for all systematic reviews about cyberbullying that focused on the effects cyberbullying had on children and young people's mental health and well-being. They found a strong negative correlation between cyberbullying and mental health issues and negative experiences of well-being as well as low self-esteem (Kwan et al., 2020[68]). Notably, none of the studies included in the different samples were longitudinal studies, and it is therefore not possible to conclude whether problems were there in the first place or whether they are primarily results (based on the research). They write that it could be a negative spiral where problems only get worse through cyberbullying.

Kwan et al. (2020[68]) refer to qualitative studies in their sample that indicate that cyberbullying is being used as a strategy to harm girls who may already be experiencing low self-esteem and depressive emotions. Pupils experience cyberbullying as being worse than face-to-face bullying because they do not know the identity of the bullies, and the information online can be spread without those exposed to it being in control. Removing harmful information reduces the stress experience. The researchers emphasise that fellow pupils play an important role. Experiencing that other people disapprove of what is happening and that they show support for victims of bullying can be an effective way to prevent the worst outcomes.

Relationships between cyberbullying and self-harm, and suicidal behaviours, have also been identified. John et al. (2018[69]), Dorol–Beauroy-Eustache and Mishara (2021[70]) and Predescu, Calugar and Sipos (2024[71]) find that adolescents who have been victims of cyberbullying are more likely to self-harm, to exhibit suicidal behaviours and to attempt suicide than non-victims of bullying. Factors such as stress and negative emotions played a significant role in the relationship between cyberbullying and self-injury, whereas factors such as strong peer connections and school engagement provided protection (Predescu, Calugar and Sipos, 2024[71]). Cyberbullying perpetrators were also more likely to exhibit suicidal behaviours and to experience suicidal ideation than non-perpetrators.

Cyberbullying, empathy, moral disengagement and forgiveness

Zych, Farrington and Ttofi (2019[58]) write that there is ground to hypothesise that a low level of empathy would be associated with cyberbullying, whereas a high level of empathy would be associated with cybervictimisation. They refer to previous studies who found that cyberbullies scored significantly lower than uninvolved children on affective empathy, but the relationship between cyberbullying and cognitive empathy was not significant.

Also, it is important to note that Zych, Farrington and Ttofi (2019[58]) differentiate between roles such as cybervictims, cyberbullies, cyber bully/victims and defenders. Based on their meta-analysis, they found that cyberbullies had significantly higher odds of scoring low in empathy (both affective and cognitive empathy). The relation between empathy and cybervictimisation was not statistically significant. However, they did find significant relations between cybervictimisation and affective empathy. Only four of the included studies contained data which allowed the researchers to calculate effect sizes for the association between being cyberbully/victim and empathy (Zych, Farrington and Ttofi, 2019, p. 92[58]). The results were not significant. Based on three studies, they did find significant results for the relationship between empathy and defending the cybervictim.

Lo Cricchio et al. (2021[72]) define moral disengagement as "a family of cognitive processes by which individuals disengage from their own moral responsibilities in order to damage others without experiencing guilt or self-condemnation feelings" (pp. 271-272). They state that the specific role that moral disengagement plays in cyberbullying might be less evident than the role it plays in traditional bullying for two reasons: aggression in an online context might be considered less serious and dangerous than in real life, and because the perpetrator cannot see the immediate response of the victim, this can allow the aggressor to minimise the impact of their harmful behaviours (pp. 274-275).

In the work of Lo Cricchio et al. (2021[72]), 41 studies were used for data extraction, with sample sizes ranging from 52 to 3 339 participants in grades 3 to 12. The authors report statistically significant relations between moral disengagement and cyberbullying in 91% of the articles (30), and non-significant association in 9% (3 articles). It was impossible to conclude whether age or gender was a moderating factor. Moral reasoning and moral identity decreased the link between moral disengagement and cyberbullying in two studies, and impulsivity and self-efficacy beliefs might also be other variables worth pursuing.

Finally, Quintana-Orts, Rey and Worthington (2021[73]) also find that adolescents who report higher forgiveness levels bully less and are less victims of cyberbullying. Unforgiveness is positively related to cyberbullying. The authors describe forgiveness as an intrapersonal decision about one's behaviour toward a bully, and as an emotional change from negative emotions and motivations to an emotionally neutral or even positive emotion regarding the perpetrator. Forgiveness is internal, they explain, "it does not interfere with a victim's pursuit of justice, which is social and societal" (p. 589[73]).

Physical activity and cyberbullying

Rusillo-Magdaleno et al. (2024[74]) investigated the influence of Physical Activity (PA) before, during and after school hours on bullying and cyberbullying in children and adolescents. The authors claim that PA during the school day is related to significant improvements in bullying behaviours, reduction in depressive symptoms, and strengthening of social relationships, responsibility and self-esteem in girls and boys. PA after school hours is also beneficial, but there is more variation in different studies related, for instance, to the quality of the after-school activities. The authors address the need for future studies to include co-variates and moderators to understand more about these relations.

Different groups of students

Laffan et al. (2024[75]) conducted a survey among 195 gifted adolescents between the ages of 14 and 18 years in Ireland. The survey was designed to assess the bullying and cyberbullying prevalence, well-being, indicative mental health and friendship quality outcomes. The Cyberbullying and Online Aggression Survey Instrument (COAS) was used, and results showed considerably higher prevalence rates of bullying and cyberbullying victimisation among gifted adolescents compared to an all-Ireland national prevalence rate. Bullying and cyberbullying victimisation were associated with higher levels of negative outcomes. Furthermore, the authors found that females, LGBTI+ and twice exceptional participants scored significantly lower on satisfaction with life and significantly higher on negative outcomes compared to other gifted participants.

Martínez-Monteagudo, Martínez-Monteagudo and Delgado (2023[76]) found that studies that compared gifted students with students not identified as gifted could be grouped into different categories based on the risk of being a victim or a bully. They argue that the number of studies is far too limited to be conclusive but argue that there is reason to be concerned about academically gifted students being more vulnerable. They also point to methodological challenges in how actual victimisation or bullying is assessed.

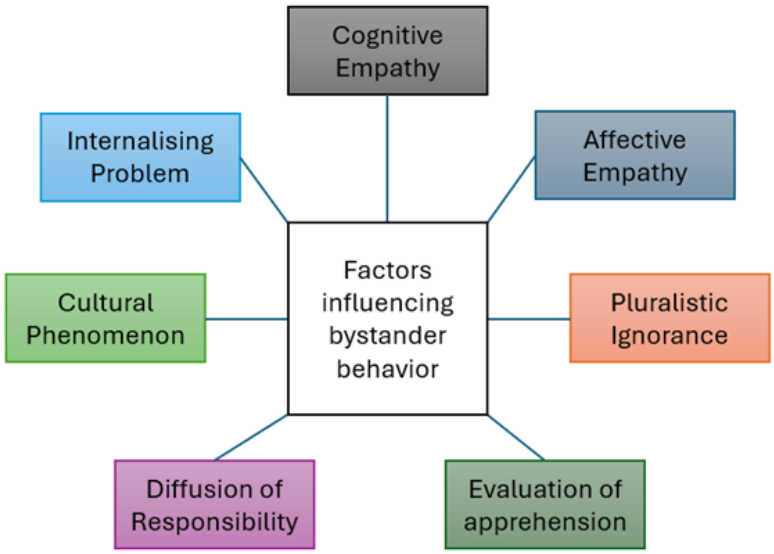
Estévez et al. (2020[77]) conclude from their review that it is necessary to continue investigating the coexistence of bullying and cyberbullying and the exchange that occurs in certain contexts and for certain people. They report that the 19 studies included in their review that investigated roles in bullying and cyberbullying mainly find that there is a component of continuity or superposition in the roles in both forms. For instance, a person who is the victim of traditional bullying may turn to cyberbullying to get back at their aggressor. This review also has limitations not least due to the variability in measurements used.

The role of bystanders

Lo Cricchio et al. (2021[72]) highlights the important role of bystanders, finding their actions in cyberbullying incidents are significantly associated with moral disengagement. The association between 'passive bystander' and moral disengagement was positive, whereas active bystander roles (constructive defending) is negatively associated with moral disengagement and cyberbullying. Bystanders are other students or people who get involved in cyberbullying without necessarily having initiated it. However, through their behaviours, they can influence cyberbullying and either strengthen or prolong it – or help stop it. In cyberbullying, the 'bystander' is standing by metaphorically, but studies show similar consequences and drivers as in traditional bullying contexts.

Alfurayj et al. (2024[78]) have illustrated some of the important findings about what can influence bystanders' behaviours (see Figure 4.1). We have already mentioned affective and cognitive empathy (above), and in addition, they point to factors such as diffusion of responsibility. This is well-known from research on traditional bullying, but in cyberbullying there might be many more bystanders while taking action to stop the negative behaviour might also be more daunting because it is not possible to know who they all are.

Figure 4.1. Influences on bystanders' behaviours



Source: Adapted from Alfurayj et al. (2024[78]) *Exploring bystander contagion in cyberbully detection: a systematic review*, Journal of Ambient Intelligence and Humanized Computing, https://link.springer.com/10.1007/s12652-024-04831-w

Figure 4.1 is also in line with an earlier review by Domínguez-Hernández, Bonell and Martínez-González (2018[79]). They identified contextual factors that can moderate bystanders' actions (e.g. friendship, social environment, bystander effect, incident severity, action of other bystanders, knowledge of effective strategies) and personal factors (e.g. empathy, moral engagement/engagement, self-efficacy, previous experience). They conclude that what appears to be the strongest moderators are friendship and social context, empathy, moral disengagement and self-efficacy.

Interventions to stop or prevent cyberbullying

Using technology to detect, stop or prevent cyberbullying

Automatic cyberbullying detection is a growing field of innovation and research. Rosa et al. (2019[80]) examine what kinds of behaviours were assessed in the automatic detection programmes developed. They found shared aspects of cyberbullying across 22 studies, but they also found that key aspects of cyberbullying were not fully represented. This, they propose, may lead to a mischaracterisation of the phenomenon. In fact, they conclude that the most representative studies on automatic cyberbullying detection have conducted isolated online aggression classification, as opposed to cyberbullying.

Balakrisnan and Kaity (2023[67]) may also have identified characteristics of online aggression rather than the features of cyberbullying that are in definitions based on Olweus's understanding of bullying (see above). Their review shows five overarching features that are detected in what is understood as cyberbullying: textual features (e.g. text length, use of hashtags, pronouns); social network features (e.g. number of friends/followers); affective features (e.g. sentiment, emotion); user-profile features (e.g. age, gender); and image/video features (e.g. number of faces, presence of drugs).

The majority of the existing studies focused on supervised learning algorithms to enable a classification of bully vs non-bully. More recent studies have begun to explore deep learning algorithms (Hasan et al., 2023[81]). Keeping up with language development is an issue, however. New slang, abbreviations, etc, complicate the recognition of textual features. Also, it is common to communicate in native languages – not just English. Furthermore, most of the studies have only looked at text, not images.

Artificial Intelligence (AI) is central to detecting cyberbullying and blocking users. As Milosevic, Van Royen and Davis (2022[82]) and Milosevic et al. (2023[83]) point out, previous research found that content removal could be a helpful first step when someone is targeted by cyberbullying but not a sufficient one. Therefore, Milosevic et al. (2023[83]) designed interventions that incorporate AI to detect cyberbullying, remove content and block users, and they included social support for those who are targeted. What they were interested in learning more about was how students aged 12-17 (N = 59, based in Ireland) perceived the effectiveness and impact of such interventions on children's rights. Milosevic et al. (2023, p. 8[83]) conclude that:

> *while children would largely welcome the option of having such interventions, as long as they can opt-in and out of them, they raised concerns about their effectiveness and willingness to use them. Most importantly, children revealed the ways in which peer norms interfered with the need to ask for help in cyberbullying situations.*

Some of the students interviewed were concerned about what they were signalling if they requested social support due to cyberbullying. Asking for help is not straightforward.

Another area of growth is serious games to prevent and detect cyberbullying. Calvo-Morata et al. (2020[84]) classified the games they identified (many of which are no longer available) in five broad categories: (1) videogames that were all directed at prevention (20 games); (2) simulations showing situations and outcomes depending on choices made (seven); (3) prevention programmes which are comprehensive and include video games as part of the programme (three); (4) virtual environments where different players can interact with each other or non-playable characters via chat (two); and (5) apps which are neither comprehensive programmes nor just video games, but include several tools where at least one is a game (one). The most commonly used mechanic is to show a situation and provide the players with options to choose among. Games that do not use this mechanic, tend to pose simple questions with correct answers.

The main goals of the games can be many (the authors identified 12 main goals), including teaching strategies to stop, prevent or overcome the problem, raising awareness so players understand the consequences and effects of actions, or helping teachers deal with bullying/cyberbullying in class. All of

the resources have at least one scientific publication, but not all of them describe how they were validated or how their effectiveness was tested (Calvo-Morata et al., 2020, p. 9[84]).

Notably, the Anti-Bullying Centre (ABC) at Dublin City University, Ireland, is a world-renowned research centre on bullying and cyberbullying. They are currently involved in the development of software to detect online bullying or harassment both for those receiving and sending. One of the innovations is an app called 'Chirp' that parents can elect to have installed on their child's devices.

School-based intervention programmes

School-based education programmes to prevent or stop cyberbullying often include the following content (Chicote-Beato et al., 2024[85]): online safety, empathy, school climate and inclusion, critical thinking skills, self-regulation and the role of the bystander. In particular, Polanin et al. (2022[86]) defined seven programming categories: skill-building, curricula and prepared materials, psychoeducation, multimedia materials, training, school climate or school policy and group or individual targeted responses.

Lan, Law and Pan (2022[87]) classified 19 selected programmes according to whether they were focused on intrapersonal processes, interpersonal processes or community-oriented events. Intrapersonal processes (which all 19 included) intended to help learners' knowledge, skills and confidence in handling cyberbullying, and to change their attitude towards it. Interpersonal approaches focused on interactions between students, teachers, peers, family and others. Peer interactions could be supported and influenced. The social conditions reflect the wider community's attitudes and culture for pro-social behaviours rather than aggressive behaviours.

Effectiveness of programmes

Henares-Montiel et al. (2023[88])included 36 different interventions in their review and find mixed results. One of the studies aimed to reduce global cyberbullying, and this intervention was multifaceted and effective. There were 33 studies that targeted cyber-perpetration, and of these, 10 were effective. Of the 32 interventions to reduce cybervictimisation, eighteen were effective and five were partially effective. None of the three that targeted cyber-bystanding were effective. The authors conclude that multi-component interventions are more effective than single-component interventions, echoing Lan, Law and Pan (2022[87]).

Doty et al. (2022[89]) also find that interventions delivered through schools are effective (a moderate, significant effect), but they suggest that future research should have longer follow up times, ideally exceeding three months post-intervention. They also find that interventions solely relying on digital interventions and lasting under eight hours may not be the best to pursue further.

However, another review concludes that results are not so positive for interventions to reduce cyberbullying. Ng et al. (2022[90]) included 17 studies with 35 694 adolescents from 11 different locations in their meta-analysis of traditional and cyberbullying interventions. They find small or very small effect sizes and also interesting differences. Cyberbullying interventions showed a significant but negligible effect for long-term reduction in cyberbullying victimisation, but not cyberbullying perpetration. This brings up questions of sustainability and continuity of intervention programmes. They also found that more 'technology-savvy' experts were more effective at implementing a programme than teachers. This could be related to teachers' own digital knowledge and skills.

Lim, Lau and Islam (2023[91]) also find that cyberbullying programmes were more successful when administered by technology-savvy content experts compared to educators, regardless of the intervention type, programme duration, or presence of parental engagement. In addition, they found evidence of some components being more effective: awareness training, coping skills and interactive serious games.

The research cited above suggests that school-based programmes should be multifaceted, involving cognition, skills and emotions. This is in line with reviews that point to the multifaceted protective factors for both cyber-perpetration and victimisation. Self-oriented personal competencies are strong protectors against victimisation (pro-sociality, efficacy, social competence, etc.) as well as school climate, positive communities and school safety (Zych, Farrington and Ttofi, 2019[58]). Protective factors against cyberbullying perpetration (and bullying) are community factors, a positive school climate, a positive home environment with good parental interaction and peer status. Not surprisingly, the low frequency of technology use was also related to low levels of cyber-perpetration.

Policy implications to prevent and stop cyberbullying

The Irish Minister for Education, Norma Foley, introduced an Action Plan on Bullying (Cinéaltas) (Irish Department of Education and Youth, 2022[92]) building on many years of national work to minimise bullying in schools. Ministers of Education in many other countries have done the same, consistently using research to develop new ways that can help children and adolescents avoid both perpetration and victimisation.

Main components of these plans are often targeted at age-specific ways to: create safe and inclusive school environments as a foundation to prevent bullying; create awareness among children and adolescents about what bullying is and how harmful it is; create awareness of cyberbullying, risks and critical digital literacy; create awareness of the bystander role and what bystanders can do in both face-to-face and cyberbullying. Additionally, plans often target helping teachers, school leaders and families identify bullying; helping teachers, school leaders and families follow up on bullying to stop the negative behaviours; and emphasising school as a community and the need for all to work together to prevent bullying (parents, teachers, other staff, school leaders, after-school activities and more).

Programmes emphasise how to start building relations in new groups of children and adolescents, how to repair relations and specifically target transitions (change school, change class, etc). Some also help schools identify ‘hot areas’ where face-to-face bullying occurs more frequently (for a review on how school (built) environments impact face-to-face bullying see Francis et al., 2022[93]).

The main results of a meta-analysis by Gaffney et al. (2019[93]) suggest that cyberbullying intervention programmes are effective in reducing both cyberbullying perpetration and victimisation. They report that cyberbullying perpetration can be reduced by about 10% - 15%, and cyberbullying victimisation by about 14%. However, the researchers were not able to investigate the relative effects of the various components in the programmes. Ng, Chua and Shorey (2022[90]) also conducted a meta-analysis and concluded that the educational interventions had very small to small effect sizes on traditional bullying and cyberbullying. Both Ng, Chua and Shorey (2022[90]) and Lim, Lau and Islam (2023[91]) found that intervention design factors (whole-school, classroom-based, parental involvement, duration) did not moderate programme effectiveness, but cyberbullying programmes were more effective if someone knowledgeable about technology (experts) delivered the lessons compared to teachers.

Reviews highlight the need for programmes to not just provide information as this may not reduce the problem of cyberbullying. It is crucial to promote peer interaction and adult involvement and supervision, they state, to reduce aggressive online behaviours. Students need opportunities to practise new behaviours and skills. At the same time, the teacher’s role is central to work on cyberbullying, and requires deep knowledge about bullying, cyberbullying and strategies to promote positive relations and learning in schools and prevent cyberbullying. But addressing cyberbullying also places demands on teachers’ digital knowledge, knowledge about social media, what is currently trending among children and how to teach critical digital literacy for different age groups. Overall, these reviews highlight that it is possible to stop and prevent cyberbullying – in some cases or for some students, but there is still more work to be done. Researchers point out that we still know too little about whether certain components are more effective than others, whom the components are most effective for and what kinds of differentiation are needed, and whether several combined components are needed to have any effect.

5 Conclusion

Digital tools have the potential to transform education by enhancing learning and motivation across subjects, supporting diverse skill development and fostering self-regulated and personalised learning experiences. Technologies such as programming environments, digital games, media production tools, simulations, artificial intelligence and digital assessment platforms can enable collaborative learning, powerful visualisations and educational activities that would otherwise be difficult or impossible to achieve. When thoughtfully integrated, these tools support deeper understanding and interdisciplinary connections through interactive and engaging experiences.

However, these benefits are not guaranteed. The impact of digital technologies depends on making deliberate choices about which tools to use, when to introduce them and how to align them with specific educational aims. Challenges such as increased cognitive load, digital distractions, gaps in digital literacy among both students and teachers and ethical issues like cyberbullying can hinder effective integration. Addressing these challenges requires selecting tools appropriate to students' developmental levels, clearly aligning technology with learning objectives and purposefully combining digital and analogue approaches to maintain balanced learning environments.

Effective digital integration hinges on digital literacy. Both teachers and students must be able to navigate, evaluate and use digital resources critically and efficiently. Teachers play a central role by guiding students in the use of digital tools suited to their individual needs and supporting the development of self-regulation and autonomy. Continuous professional development is essential to ensure teachers remain up-to-date with digital competence and effective pedagogical strategies. Collaboration among colleagues and strong institutional support are key enablers of this process.

School leaders also play a crucial part in successful digital integration. Leadership should provide clear strategic direction, secure access to adequate resources and cultivate a culture of sharing and professional learning within the school community. Ensuring that digital initiatives are aligned with broader educational goals and that teachers receive the necessary support is essential for sustaining effective digital learning environments.

Reliable infrastructure is a prerequisite for meaningful digital learning. One-to-one device availability and robust access to digital platforms and resources are necessary foundations for supporting self-regulated and personalised learning.

Finally, ethical considerations must be integrated into all aspects of digital strategy. This includes protecting online privacy and data security and promoting responsible digital citizenship. Risks such as cyberbullying require comprehensive approaches that combine empathy-building, teacher involvement and active engagement from families and the wider community to support victims, address perpetrator behaviour and foster a safe and inclusive environment for all learners.

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