

## PEDAGOGICAL OUTCOMES OF A POLISH K-12 DIGITAL TRANSFORMATION INITIATIVE

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**Abstract:** *Technological transformation and digital mimicry characterise the present day. Trends in digitisation, computerisation and robotisation have become firmly established in societies. This article is part of this trend, emphasising the role of digital transformation in primary and secondary education. The aim of the article is to evaluate the digital transformation of the educational process (K-12) using Chromebook laptops and the Google Workspace for Education platform to develop the practical digital skills and competences of students and their teachers. Achieving this goal required research of secondary sources using monographic methods with content analysis techniques and primary sources using mixed qualitative and quantitative methods. The analyses conducted have identified the benefits of introducing Chromebooks and Google Workspace for Education cloud technology, which are changing the learning and teaching process in Polish primary and secondary schools. The results obtained indicate a significant improvement in the effectiveness of both teachers and students. Particularly noteworthy is the shift towards increasing the teacher's focus on individual students on a 1:1 basis, with the possibility of personalising learning anywhere and anytime, and strengthening student collaboration in the process of learning from each other. These results are in line with the broader implications of pedagogy supported by new technologies in the context of international initiatives in the field of digital transformation of the education process.*

**Keywords:** *digital transformation, cloud-based education, one-to-one computing, student-centred learning, K-12 pedagogy, digital competencies.*



## INTRODUCTION

We are currently living in times described as VUCA or BANI (Taskan et al., 2022), where volatility and unpredictability are becoming the norm. In this context, the digital transformation of schools has become a strategic priority, as societies recognise that future success will depend not only on subject knowledge, but also on practical skills and digital competences that enable faster and more efficient adaptation to change (Voogt & Pareja Roblin, 2012). Classrooms are increasingly seen as places where humans interact with technology, fostering new forms of learning, collaboration and creativity that are so necessary for the future. In this context, existing education systems in many countries are slowly adapting their teaching methodologies to harness the potential of new technologies (Collins & Halverson, 2009). A strategic approach leading to learner-centred transformations is essential (Ertmer & Ottenbreit-Leftwich, 2010; Selwyn, 2011). Research to date suggests that effectively integrated technology can catalyse a shift towards student-centred learning and collaboration. Individual computer initiatives in various countries have shown a positive impact on student engagement and achievement (Harper & Milman, 2016; Zheng et al., 2016). In particular, cloud-based tools offer students new ways to create, communicate, and collaborate in real time, breaking down traditional classroom boundaries (Stein et al., 2013), which is consistent with constructivist learning theory, which assumes that students learn best by actively constructing knowledge – through inquiry, problem solving and social interaction – rather than by passively receiving information (Vygotsky, 1978; Papert, 1980). In this view, digital platforms can support a learner-centred model of learning and teaching (Mishra & Koehler, 2006; Voogt & Pareja Roblin, 2012). In this process, the role of the teacher evolves from that of an information provider to that of a learning facilitator or coach, guiding students in navigating digital resources and collaborating on authentic tasks (Fullan, 2013). However, realising this potential depends on teachers' readiness and their pedagogical vision. Technology alone does not automatically improve learning outcomes (OECD, 2015). It requires enabling conditions such as teacher training, administrative capacity and a supportive organisational culture (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017).

Publications presenting the current state of research in the field of learning and teaching technology mainly refer to education systems in North America and Western Europe (Bebell & O'Dwyer, 2010; Penuel, 2006). However, there is a noticeable lack of research material covering Central and Eastern Europe. There is a visible information gap concerning changes in learning and teaching processes resulting from the implementation of digital technologies in education, especially in primary and secondary schools in non-English-speaking countries. Therefore, the authors of this article decided to fill this gap, at least in part, by presenting the results of research conducted as part of a pilot implementation of digital education in K-12 schools in Poland.

The basis for the research project was the Polish digital transformation initiative implemented as part of cooperation between the Ministry of National Education and technology partners (Google, Lenovo, Intel). In accordance with the project's assumptions, a pilot programme called "Digital Transformation of Schools with Google" was implemented in two Polish schools in 2022-2023. This initiative equipped primary and secondary schools with Chromebooks (specially designed laptops) for every student and teacher (1:1 device model) and provided access to the full suite of Google Workspace for Education applications.

The implementation project included not only the provision of technology, but also training support for teachers in the form of 64 hours of workshops culminating in Google Educator certification. The overarching goal of the project partners was to use a cloud-based ecosystem to improve teaching and learning, develop practical digital skills in students, and transform classroom pedagogy to make it more engaging and relevant to students' futures (European Commission, 2018). By placing technology as a support for human educational practices, the project reflected a human-centred approach, where technology was introduced as a means to empower teachers and students, rather than as an end in itself.

During the pilot implementation, each stage of the project was accompanied by an academic research group (Sułkowski et al., 2023) so that the project could be subject to substantive verification, including an analysis of the applicability of the solution in the educational process, together with an indication of the possibilities for replication. The results of the research group's work are presented in the following article, whose aim is to diagnose and identify the necessary and desired characteristics of communication tools (devices and digital space) that would practically support the process of developing practical digital skills and competences in learning and teaching in K-12 schools. The specific objectives were: **a theoretical objective** defined as the development of guidelines for the use of technological solutions in the process of managing the digital transformation of K-12 education, and **an empirical objective** defined as the verification of the effectiveness of the use of Chromebook laptops and the Google Workspace for Education platform in improving the digital skills and competences of students and teachers in the field of learning and teaching in K-12 schools.

The achievement of the main objective and specific objectives required the use of mixed research methods. Qualitative methods were used first, followed by quasi-quantitative methods. To diagnose the current state of scientific achievements in the field of digital transformation management in education, qualitative research methodologies were used, including searching and browsing the Scopus and Web of Science databases for the occurrence and co-occurrence of terms related to the subject matter under study, as well as a critical analysis of the content of existing literature and documents made available by the Ministry of Education in order to obtain answers to the following questions:

**RQ1** – Is the K-12 education system in Poland adapted to the real needs of a technologising socio-economic environment, and to what extent?

**RQ2** – how can technological solutions be an attractive form of education in shaping digital competence skills in formal education?

**RQ3** – what is 1:1 education and how can technology support this process, and what role do teachers play in this process?

A study of existing secondary sources has identified a research gap, which points to the inadequacy of the teaching system used in primary and secondary schools (K-12) in Poland to meet the real needs of an increasingly technological society, so that primary and secondary school graduates have the digital skills they need for the future and so that primary and secondary school graduates have the digital skills they need for the future (Spychalski, 2023). A key dimension of this challenge involves the socio-cultural formation of quality-conscious and technology-oriented attitudes among members of Generation Z and Generation Alpha — cohorts that are increasingly dominant in K-12 classrooms. This thesis was tested by examining the effectiveness of the pilot programme "Digital Transformation of Schools with Google" in real-life conditions.

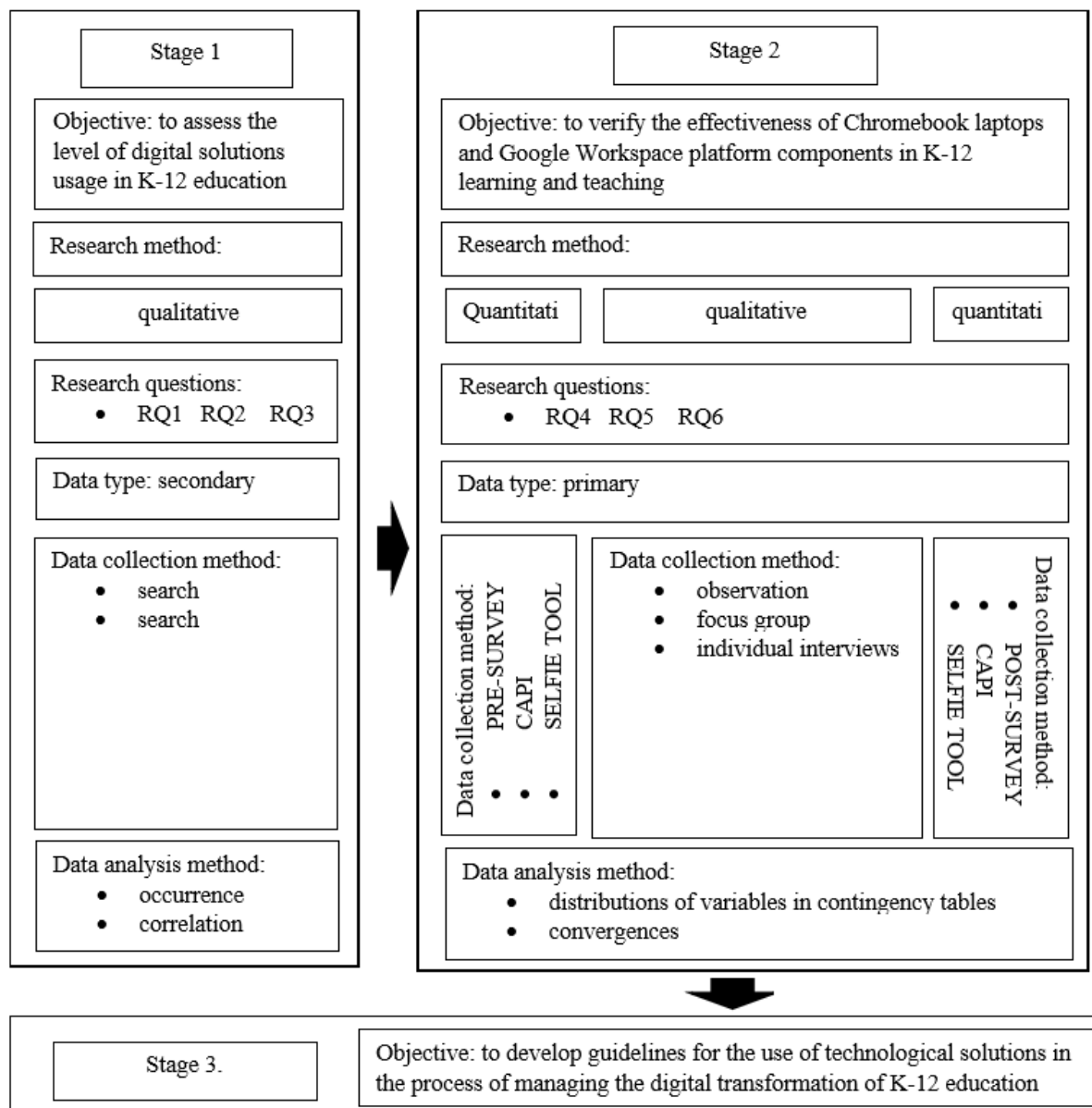


Figure 1. Research programme diagram.

The study and its results were intended to answer the following questions:

**RQ4** - How did the integration of 1:1 Chromebooks and Google Workspace affect the teaching practices of teachers and the education of students participating in the project?

**RQ5** - Are there any changes in student engagement and learning outcomes associated with the use of cloud-based tools, measured before and after the introduction of technology into the educational process, and if so, what are they?

**RQ6** - How do cloud-based technologies facilitate more personalised and active learning, and what challenges or support needs have emerged among teachers and students during this time?

To answer these questions, research hypotheses were formulated and tested:

**H1:** The introduction of Chromebooks and Google cloud-based tools leads to a significant increase in student-centred teaching practices (e.g., more project-based learning, collaboration, and facilitation by teachers, compared to teacher-led instruction prior to the intervention).

**H2:** Students using a 1:1 Chromebook environment demonstrate greater engagement and digital literacy (such as content creation and online communication skills) compared to their baseline levels prior to technology integration.

**H3:** Cloud-based educational tools enable more personalised and flexible learning experiences, which in turn lead to improved student learning outcomes (e.g., greater student engagement and better achievement of curriculum goals).

In testing these hypotheses, the researchers focused on the human elements of technological change in schools, including the changing roles, skills, and relationships of teachers and students in a digitally transformed classroom. The significance of this study was to illustrate a concrete example of how careful alignment of educational methods, technology, and teacher support can yield positive results.

The rest of the article presents the results of a review of existing scientific literature on learning and teaching methods supported by digital technologies. First, the procedure and research methodologies used in the pilot study of the "Digital Transformation of Schools with Google" programme are described. Next, both quantitative results and examples of actual opinions in the form of narrative statements by teachers and students are presented. The implications of the research results for theory and practice are then discussed, comparing them with available global data. Finally, conclusions and recommendations for decision-makers and teachers regarding the model for implementing digital transformation in the K-12 education system were presented.

## **TECHNOLOGY-ASSISTED PEDAGOGY AND DIGITAL CLASSROOMS**

Technology has long promised to revolutionise education, but research indicates that the degree of impact on education depends largely on how it is used by people (teachers and students), rather than on the mere presence of devices (Ertmer & Ottenbreit-Leftwich, 2010; Selwyn, 2011). This literature review analyses three key areas relevant to our study: (1) the shift towards student-centred learning using technology, (2) the results of implementing curricula using 1:1 devices in schools, and (3) the role of teacher training and the issue of users' digital competence in the successful integration of technology into the learning process.

The analysis of educational theory contained in the literature suggests that, over the years, education has gradually shifted from a teacher-centred approach towards student-centred paradigms, with an emphasis on active learning and collaboration. Constructivist theorists such as Vygotsky (1978) argued that knowledge is created through social interaction and that students benefit from actively engaging with content rather than passively listening. In practice, this means that classrooms should encourage discussion, group work, exploration, and problem solving. Technology can be a facilitator in this process. For example, networked devices and cloud-based applications allow students to collaborate on shared documents in real time, with immediate access to feedback. Research has shown that when teachers

integrate technology in line with constructivist principles, students tend to take a more active role in learning and develop higher-order thinking skills (Voogt & Pareja Roblin, 2012). Digital tools can then support project-based learning, inquiry-based learning, and other student-led activities, providing resources and a platform for creativity and exploration (Fullan, 2013). However, technology alone does not guarantee student-centred practice. In many classrooms where technology was used, especially in the early stages, the devices themselves were used to digitise traditional teaching (e.g. electronic textbooks or presentations) without any fundamental change in the pedagogical approach to learning processes (Law et al., 2008).

A study of the international use of information and communication technologies showed that without a clear pedagogical framework, teachers often used new technologies to do old things, such as conducting classes using PowerPoint instead of a blackboard, which had a limited impact on student engagement (Law et al., 2008). Therefore, researchers emphasise the importance of pedagogical models such as TPACK (Technological Pedagogical Content Knowledge), which emphasise that teachers need not only technical skills but also pedagogical strategies to effectively combine technology with subject content (Mishra & Koehler, 2006). When teachers develop this integrated knowledge, they are more likely to organise technology-rich activities that put students at the centre of attention – for example, collaborative concept mapping, student-led multimedia presentations, or online discussions that extend beyond class time (Harper & Milman, 2016). These strategies are consistent with the principles of deep learning and personalisation, which have been identified as goals of '21st-century education' (Voogt & Pareja Roblin, 2012).

Changes in teaching approaches can also be represented by educational initiatives involving the use of computers (laptops or tablets) in a 1:1 teaching process, which were launched on an experimental basis in several countries around the world during the first two decades of the 21st century, on the assumption that constant access to technology would modernise teaching and improve student performance. Meta-analyses and reviews of 1:1 initiatives provide optimistic evidence. For example, Zheng et al. (2016) conducted a meta-analysis of 1:1 laptop programmes and found a significantly positive, albeit modest, effect on overall student achievement. Students in these programmes often showed improvements in research skills, writing fluency and content creation skills, as well as increased motivation to learn, especially when the devices were used for interactive and creative tasks (Zheng et al., 2016; Bebell & O'Dwyer, 2010). Another argument is the results of research on the dynamics of student work. When devices are used by each student individually, teachers can carry out more projects and students can develop at their own pace, searching for information or tutorials as needed (Penuel, 2006). A literature review by Harper and Milman (2016) covering research on 1:1 laptops (2004-2014) found that individually taught classes often show an increase in student engagement and collaborative learning. In such environments, students often work in pairs or small groups, using their devices to solve problems, create digital stories, or conduct virtual experiments, which has been linked to higher engagement and attendance (Harper & Milman, 2016). Furthermore, access to online resources and productivity tools allows students to take greater responsibility for their learning process.

International case studies illustrate these benefits. In the United States, Mooresville Digital Conversion implemented a 1:1 programme that resulted in significant increases in student test scores and graduation rates, attributing the success to strong leadership and a

focus on using laptops for collaboration and critical thinking rather than drills (Friday Institute, cited in Zheng et al., 2016). Similarly, initiatives to use tablets in 1:1 teaching in European schools have been linked to improved digital skills and slightly better results in science and reading, although results vary significantly depending on how the devices were used (OECD, 2015). It is worth noting that the addition of technology may initially result in a decline or no change in outcomes if it is not accompanied by changes in teaching practice (OECD, 2015; Selwyn, 2011). For example, early evaluations of large-scale laptop deployments in education (examples of initiatives in the US in 2000) found that some teachers simply replaced textbooks with PDF files and saw no benefits (Penuel, 2006). Hence, it can be concluded that computers in 1:1 education yield positive results mainly in cases where the introduction of technology is part of a broader instructional innovation towards active, personalised learning (Zheng et al., 2016; Stein et al., 2013). Cloud-based systems such as Google Workspace enhance this potential by enabling continuous connectivity and collaboration. Students can collaborate on documents from home or school, and teachers can provide real-time feedback, extending learning beyond the classroom (Stein et al., 2013). Such capabilities support the idea of the "flipped classroom" and blended learning, where instructional content can be accessed online at home, while class time is devoted to interactive, human-centred activities (Johnson & Johnson, 2014).

The key human factor in successful technology integration is the teacher's competence and confidence in using the tools effectively. Research consistently points to teachers' attitudes and skills as the main determinants of whether technology will be used in a transformative way or at all (Ertmer & Ottenbreit-Leftwich, 2010; Potjanajaruwit, 2023; Tondeur et al., 2017). Many teachers initially feel anxious or reluctant to relinquish control or try new approaches to teaching with technology, especially if they fear technical glitches or lack ICT proficiency. Therefore, professional development and ongoing support for teachers by both hardware and software providers and digital teaching methodology trainers is crucial. Effective training programmes in the use of digital technologies not only teach technical skills, but also model pedagogical approaches to technology-enhanced learning and allow teachers to practise their teaching skills in a new environment (Darling-Hammond et al., 2014). For example, training may involve teachers playing the role of students in a collaborative online project, allowing them to experience first-hand the type of learning they will later implement. Research conducted by Tondeur et al. (2017) showed that professional development that is practical, sustained over time and tailored to teachers' curricular needs leads to more frequent use of ICT in the classroom in a more student-centred way. In contrast, one-off workshops on technical features often do not translate into changes in classroom practice.

In Europe, the European Commission promotes a tool known as SELFIE (Self-reflection on Effective Learning by Fostering Innovation through Educational technology) to help schools assess their digital capabilities (European Commission, 2018). The self-assessment solution encourages the whole school to reflect on areas such as infrastructure, teachers' digital skills, pupils' digital competences and leadership support. By identifying gaps (for example, a school may find that although equipment is available, teachers feel they need more training in digital content creation), schools can target their efforts for improvement. The emphasis on self-assessment is consistent with the concept of building a digital culture in schools, where continuous learning and improvement in the use of technology is part of

organisational practice (European Commission, 2020). The study accompanying the implementation project "Digital transformation of schools with Google" presented in this article used the SELFIE tool to assess the initial and post-implementation conditions for measuring and recommending the development of digital competences at multiple levels (teacher, student, institution).

It is also important to take a holistic view of the digital transformation of education. Technology should be seen as enhancing human potential and meeting human needs in education (Fullan, 2013) as it has an essential impact on employability and career path (Jurgelevičius & Raišienė, 2025; Mishchuk et al., 2025; Vovk & Vovk, 2024). For example, one of the arguments for introducing Chromebooks was to prevent future digital exclusion of students (Sułkowski et al., 2023) – ensuring that all children, regardless of their background, have access to modern educational tools and develop the digital skills needed in Society 5.0 (Sulkowski et al., 2021). The COVID-19 pandemic has clearly revealed gaps in access and skills (Kołodziej & Kołodziej-Durnaś, 2024; Mishchuk et al., 2023). During remote learning, students and teachers who were already comfortable with digital tools fared better, while those without access or skills fell behind (United Nations, 2020; Davidavičiene et al., 2023). Therefore, digital transformation initiatives often carry the promise of reducing the digital divide, but only if they are accompanied by measures to ensure equal access, robust infrastructure and integration strategies (OECD, 2020; Staniec et al., 2023).

A human-centred design for the integration of educational technologies also meant increasing the involvement of teachers and students in planning and providing feedback, addressing their concerns (e.g. privacy, workload) and focusing on how technology can strengthen human connections in the learning process (e.g. more communication between teachers and students and greater parental involvement through online portals), rather than replace them.

The literature review suggests that the successful implementation of 1:1 technology in schools can transform the learning and teaching process. Students in classrooms can collaborate with each other while adapting to the individual needs of each student. However, this outcome depends on important human factors – the approach of teachers, the readiness of students and supportive school leadership (Law et al., 2008; Tondeur et al., 2017). Implementation and research projects such as the Polish Chromebook pilot programme provide an opportunity to explore this interaction between technology and pedagogy in practice.

## METHODS

The conclusions from the analysis of secondary source research results presented above formed the basis for formulating research questions and implementing the second stage of the research programme, which included primary sources: teachers and students. The defined research issue was the diagnosis and analysis of the possibilities for the effective use of Chromebook laptops and the Google Workspace for Education platform in developing the practical skills and digital competences of teachers and pupils in primary and secondary schools, as well as an assessment of the degree of acceptance of the innovations introduced. The subject of the measurement was the experiences of participants in the educational

process in the area of the usefulness of Chromebook laptops and the Google Workspace for Education platform in developing practical digital skills and competences. The researchers wanted to find out how the respondents used Chromebooks and the Google Workspace for Education platform in communication and educational processes, how they assessed the functionality of the system, and what results were achieved in terms of developing digital skills and competences.

The research is descriptive, explanatory and prognostic in nature. The descriptive aspect boils down to compiling the characteristics of Chromebook laptops and the Google Workspace for Education platform that are conducive to the development of digital competences among young people, teachers and administrators. The explanatory nature, on the other hand, stems from the need to verify hypotheses concerning the legitimacy of using Chromebook laptops and the Google Workspace for Education platform in developing the ability to build practical digital skills and competences. This translates into identifying, defining and evaluating the cause-and-effect relationships between the use of Chromebook laptops and the Google Workspace for Education platform by young people and teachers in the educational process. The prognostic nature refers to identifying the prerogatives of using Chromebook laptops and the Google Workspace for Education platform in the future in the educational process, as a derivative of recommendations resulting from the assessments of direct users of the Workspace for Education ecosystem, i.e. students and teachers.

After formulating research questions RQ4, RQ5 and RQ6 and defining the empirical objective in the form of verifying the effectiveness of using Chromebook laptops and the Google Workspace for Education platform in improving the digital skills and competences of students and teachers in the field of learning and teaching in schools K-12, it was pointed out that it was necessary to use mixed research methods combining qualitative, quantitative and qualitative approaches in order to achieve the adopted assumptions. This compilation of methods was used in order to identify both the measurable results of the use of digital technology solutions and the qualitative results indicating the context of changes in the classroom environment. In practice, the research required the use of a parallel mixed-methods approach, which means that quantitative and qualitative data were collected simultaneously using quantitative and qualitative methods, respectively, and the results were then triangulated to ensure a comprehensive understanding (Creswell & Plano Clark, 2011).

The research was field-based. Pupils and teachers from two schools participated in the pilot implementation project: a public primary school in Warsaw and a public secondary school (high school) in Katowice. These schools were deliberately selected based on criteria that ensured they represented different educational stages and geographical regions (one in the capital and one in a provincial capital), as well as differing in size and socio-economic context. All pupils from one class/cohort from each school (25 pupils in the 6th grade of primary school and 31 pupils in the 2nd grade of secondary school) took part in the study, as well as all their core subject teachers (14 teachers in primary school; 16 teachers in secondary school), therefore the sample selection can be described as non-random quota sampling. A total of 56 pupils (aged ~12 in primary school and ~15-16 in secondary school) and 30 teachers participated in the study. In addition, school administrators (headteachers and IT coordinators) were involved in the process.

Therefore, due to its subject matter, the study can be described as explanatory, monothematic, focusing on the achievement of a single research objective related to a single

determinant source – the applicability of Chromebook laptops and the Google Workspace for Education platform in the process of developing practical digital skills and competences. Due to the scope of the measurement, the study is also fragmentary (using sampling, only selected schools were surveyed, which deterministically represent the studied population of primary and secondary school pupils, their parents and teachers). Due to the nature of the reported demand, the studies are one-off, with a two-stage implementation, before and after the implementation and temporary use of Chromebook laptops and the Google Workspace for Education platform by members of the Workspace for Education ecosystem.

The technical implementation of the study consisted of collecting research material using various methodologies so that the identification and analysis of factors would allow for the creation of an orbital compass of possibilities for using Chromebook laptops and Google Workspace for Education platform as a representation of the possibilities for developing practical digital skills and competences. To make this possible, Lenovo provided each teacher and student participating in the project with a personal Chromebook device for use at school and at home, and Google enabled the creation of digital accounts in the Workspace for Education system (including tools such as Google Classroom, Docs, Sheets, Slides, Google Drive, etc.). In addition, schools were provided with high-speed internet and Wi-Fi infrastructure. The programme lasted for one full semester (from September 2022 to February 2023), with preparation and training taking place in the summer of 2022. Teachers underwent approximately 64 hours of training workshops before and during the early implementation phase, focusing on both technical skills (e.g., Google Classroom management, use of educational applications) and pedagogical strategies (e.g., collaborative learning methods, technology-facilitated project-based learning). The training was delivered by certified trainers and emphasised hands-on practice. Teachers were encouraged to redesign some of their upcoming lessons to incorporate Chromebooks and Google tools in meaningful ways, as well as to share their experiences. In addition to providing hardware, software, and training throughout the semester, programme partners provided technical support for troubleshooting device issues, and mentors and educators in the use of digital technologies in education were available as pedagogical support for teachers.

As part of the study, data was collected before the devices were introduced in June 2022 and in January/February 2023 after approximately five months of regular use of Chromebooks. Data collection included quantitative data collection in the form of a survey (SELFIE Tool), computer-assisted personal interviews (CAPI), and qualitative data collection, including observation methods, focus group interviews, and individual interviews.

The first research method was the SELFIE survey method using a questionnaire developed by the European Commission (European Commission, 2018), which allows data to be collected on various dimensions of digital teaching and learning practices in schools. Teachers and students participating in the implementation and research project were asked to complete the tool twice, before the programme was launched and after its implementation. When completing the digital questionnaire, teachers answered questions on areas such as leadership and vision, infrastructure, continuous professional development, pedagogical practices using technology, digital skills level, collaboration and assessment practices. Students, in turn, answered questions about their use of technology in learning, collaboration, digital skills and attitudes towards digital learning. The response options for questions in each area were scaled according to Rensis Likert's recommendations. The SELFIE Tool was used

to obtain data on the overall level of digital maturity of each school and to measure changes – for example, whether teachers rated their ability to use digital tools for teaching higher after the programme than before it.

The second method used was a personalised computer-assisted interview with a tool in the form of a proprietary questionnaire in two variants, which was used to conduct the CAPI survey. The questions in the questionnaire allowed data to be collected on the use and impact of Chromebooks and Google applications in the teaching process. The questionnaire for teachers contained elements concerning the frequency of use of technology in various teaching tasks (lesson planning, instructions, communication with students/parents, assessment), confidence in using specific Google tools, perceived benefits for student learning, and perceived challenges. The student questionnaire, on the other hand, included items on the frequency of technology use for various educational activities (in class and at home), self-assessment of digital skills, engagement and interest in classes with Chromebooks compared to those without, and any difficulties encountered. Many questions were multiple choice based on a rating scale, and some allowed for multiple answers (e.g., selecting all classes in which Chromebooks were used). The data obtained using the questionnaires and CAPI technique provided quantitative indicators of changes resulting from the implementation of the project and the use of Chromebooks and the Google Workspace for Education platform.

The third research method used in the research project was non-participatory observation, during which observation sessions were conducted in schools to directly observe teaching practices in classrooms. Observations took place both before and after the introduction of digital methods in learning and teaching processes. In the pre-implementation phase of Chromebooks and the Platform, typical lessons were observed to establish a baseline for teaching methods. In the final phase, lessons in various subjects using Chromebooks (1:1) were observed. During the study, an observation protocol was used to record aspects such as: classroom layout and use of technology (e.g. whether students were clustered around screens or still in rows), the nature of educational activities (lecture, discussion, group work, individual exercises, project work), the role of the teacher (lecturing vs. facilitating), the level of student engagement (behaviour during the task, participation in discussions, etc.) and interactions using technology (e.g. students searching for information online, collaborating on a Google document, etc.). The observers also noted any problems (technical problems, use of devices outside the task) and how teachers dealt with them. Ultimately, research material was obtained from 15 lessons (covering different teachers and subjects in each school).

The fourth research method used in the research programme was a focus group interview. In each class, after a semester of working with Chromebooks and the Platform, meetings were organised with students divided into groups of 6-8 (of different genders and different levels of academic performance) with whom moderators conducted a structured discussion about their experiences using Chromebooks and Google tools in the classroom. The students talked about their experiences, pointing out the advantages of the technology, and also mentioned the challenges. Their honest opinions were invaluable for interpreting the impact on engagement and learning habits.

The fifth research method used in the project was individual in-depth interviews with ten selected teachers chosen to represent each of the schools, teach different subjects, and have both enthusiastic and sceptical attitudes towards technology. The interviews, lasting

approximately 45-60 minutes each, were conducted according to a semi-structured questionnaire covering specific topics. The key topics of the interview were: changes in the teacher's own teaching strategies after obtaining Chromebooks, perceived changes in student behaviour and performance, support and challenges encountered, and attitudes towards the continued use of these tools. All interviews were recorded and transcribed for analysis.

An additional important aspect of the project was the collection of anonymised administrative data on student grades and ICT skills test results. Although not the main focus of this article, students' ICT proficiency test results (conducted as part of the IT curriculum) were compared to see if there had been an objective improvement in digital skills. Similarly, student attendance and homework completion rates were monitored as indirect indicators of engagement.

The collected research material was coded, verified and analysed. Survey data from SELFIE and the customised questionnaire were analysed using IBM SPSS Statistics. For items on the Likert scale, descriptive statistics (means, standard deviations) were calculated for pre- and post-survey responses. The analyses of the results for the student and teacher groups were used to assess significant differences in key indicators before and after the intervention (e.g., average frequency of technology use in lessons per week or average self-assessment of digital skills by students). For categorical or multiple-choice items, the percentage of respondents selecting each option before and after the intervention was compared to check for changes in usage patterns. An additional analytical effect obtained from the study was the creation of indices, including, among others, for "students' digital content creation skills" based on a combination of responses to questionnaire items concerning the creation of documents, presentations and other media, and an index of "students' communication skills" which combines data on the use of email, chat or forums for learning.

On the other hand, data obtained from qualitative research (observation notes, focus group transcripts, interview transcripts) were analysed thematically in accordance with an inductive coding process, which was influenced by the principles of grounded theory as well as some a priori codes contained in the research questions (e.g. codes for "student engagement", "teaching strategies", "cooperation", "technical challenges", "pedagogical challenges", "change in the role of the teacher", etc.) In the analysis of the material, the transcripts and notes were first read to obtain an overall picture, and then two researchers independently coded segments of the text. After coding, the team compared and discussed emerging themes such as: increased student agency (students taking more initiative and responsibility for educational tasks), collaborative learning (peers teaching each other, group work facilitated by shared online documents), the teacher as a facilitator (teachers providing guidance and support rather than one-way lectures), and trust in technology (both students and teachers becoming more creative thanks to digital tools). Analysis of the research material also identified challenges, including the "initial learning curve," "distraction from devices," and "the need for ongoing professional support." The reliability of the qualitative analysis was strengthened by triangulating these findings with quantitative results, including results from the CAPI survey.

The mixed approach allowed for triangulation, increasing reliability. If a pattern was observed (e.g. greater student engagement), it was possible to check whether the data obtained from the surveys confirmed the assumption (e.g. students themselves reported

greater engagement) and whether teachers also mentioned this. The use of recognised instruments such as SELFIE increased the reliability of the study, as this tool has been used in many schools across Europe and is based on the European Commission's framework for digitally competent schools (European Commission, 2018). The original survey questionnaire, created exclusively for the purposes of the study, underwent internal pilot testing to ensure transparency. In terms of reliability, the survey instruments showed acceptable internal consistency (for example, the set of items comprising the 'pupils' digital competence' scale yielded a Cronbach's alpha of around 0.82 after the intervention, indicating good reliability). Qualitative data collection and analysis were conducted in accordance with best practices to ensure reliability, with two observers and four interviewers comparing notes to minimise individual bias and errors.

Ethical considerations were also important in the implementation of the study, including obtaining informed consent from all adult participants and consent from students (with parental consent). Given the involvement of minors, ethical approval was obtained through the researchers' university IRB and the Ministry of Education's research approval process. Confidentiality was assured to participants, meaning that responses obtained during the study were anonymised and interview quotes were recorded without identifying information. The dual role of some researchers as facilitators in the training created potential bias, but steps were taken to separate roles (for example, those who facilitated the training did not interview those teachers). Throughout, the researchers sought to maintain an objective stance, emphasising that the purpose of the study was to learn and improve, not to evaluate the teachers' work.

In summary, the research methodology used allowed for a combination of quantitative rigour and qualitative depth, which made it possible to capture the multifaceted impact of the use of Chromebooks and cloud tools in the learning process of students and teachers in the schools selected for the implementation project. By comparing the conditions before and after and collecting multiple forms of evidence, an attempt was made to paint a reliable picture of the educational transformation, taking into account the applicability of digital technologies in the teaching and learning process and the possibility of replication.

## FINDINGS

The research conducted allowed us to obtain data for analysis in the area of changes in teaching practices (results at the teacher level), changes in student engagement and learning competencies (results at the student level), and the role of technology and the cloud in facilitating personalised and collaborative learning. Below is an integrated description of the results obtained from quantitative research with the results from qualitative research to obtain a complete picture of the effects of the implementation project.

### Transformation in teaching practices

First, it is worth looking at **the adoption of digital technologies in classrooms**. Before implementation, the use of technology by teachers in the schools selected for the project was sporadic. The results obtained from the CAPI baseline survey indicated that less than 40% of

teachers used digital tools in the classroom on a daily basis, and most of them used them only a few times a month (mainly for presentations or occasional sessions in the computer lab). After the introduction of Chromebooks and training, this number changed dramatically. Nearly 90% of teachers reported that they used technology in some form in their lessons every day. This confirms expectations for widespread use of technology. Teachers not only used technology frequently, but also in more diverse ways. The results of the CAPI survey indicate a significant increase in the number of teachers using specific practices, such as: online quizzes for assessment (an increase from 20% at baseline to 70% after), documents for collaboration in student groups (from 15% to 80%), and educational videos or simulations in the classroom (from 25% to 75%). These changes suggest a shift from incidental or one-off use of technology to more embedded use in various teaching activities.

Classroom observations confirmed these self-reported changes. In observations after the introduction of digital technology solutions, every class observed used Chromebooks in some pedagogical way in their lessons. For example, in a secondary school history lesson, instead of a teacher lecturing for the entire hour, students were divided into teams and each team was given a set of guiding questions about a historical event. They used their Chromebooks to search for information (accessing online archives and encyclopaedias), collaboratively compiled their findings in a Google Slides presentation, and then each group presented their findings to the class. The teacher's role was largely one of facilitation – circulating among the groups, encouraging deeper inquiry ("Have you considered checking the primary source for this information?") and managing time. This was a clear departure from the traditional teacher-centred approach observed in a similar history lesson prior to the intervention, where the teacher discussed a slide show and the students quietly took notes. As one teacher put it, "I feel liberated from having to be the sage on the stage all the time. With Chromebooks, I can design an activity and then step back and watch the students take more control—I'm there to guide, but not dominate the lesson."

Another point worth noting is **the shift towards student-centred teaching** as a result of the use of digital technologies. Namely, in interviews, many teachers reported that they deliberately reduced lectures and increased interactive work. For example, a science teacher described how she moved away from simply explaining concepts on the board in favour of having students virtually simulate experiments: "When we were learning about the solar system, I simply showed a film and talked about the topic. This time, I let the students explore a simulation of the Solar System on their Chromebooks in pairs and come up with their own explanations for the movement of the planets, and then we discussed them in class. The level of curiosity and the questions they asked were on a completely different level than before." This statement highlights the increased activity and inquisitiveness of the students. Another teacher who teaches literature mentioned using Google Docs for a collective analysis of a poem. In this task, each student could highlight verses and insert comments with their interpretations, which were visible to everyone. This transformed the traditional teacher-led discussion into a collaborative annotation exercise. According to her, "quieter students found their voice by typing in their comments; some who never spoke up in class wrote insightful observations in the document. It changed the dynamic — it wasn't just me asking a question and one student answering. It was the whole room of students building on each other's thoughts." This is not only an example of collaboration, but also a demonstration of how technology can increase student participation, particularly benefiting those who speak less

often (in line with a human-centred approach that gives every student the opportunity to contribute). The results of the CAPI questionnaire survey also indicate **changes in the pedagogical approach to teaching**. Namely, teachers rated different teaching methods on a scale of frequency of use. Following the introduction of Chromebooks and the platform, there was a statistically significant increase in the use of project-based learning and group work. On a 5-point frequency scale (1 = never, 5 = very often), the average for "I organise project-based tasks in which students use digital tools to create something (e.g. a presentation, video or report)" increased from 2.8 (rarely) before to 4.1 (often) after ( $p < .01$ ). Similarly, for the statement "I facilitate students working in groups during class," the average increased from 3.0 to 4.2. In contrast, "I mainly conduct classes or give direct instructions while students listen" decreased from 4.0 to 3.2. These changes are consistent with a shift towards student-centred pedagogy.

The next area of research was to define **the role of the teacher and verify the effectiveness of their teaching activities**. Here, the results of the CAPI questionnaire survey indicate that teachers asked to self-assess by responding to statements such as "I am able to tailor my teaching to the needs of different students" and "I feel confident managing a class where students use devices" after the introduction of digital technologies, most agreed or strongly agreed (85% of respondents) that they could better personalise learning through the use of Chromebooks (compared to 50% agreement previously), citing the ability to assign different resources to different students (e.g., advanced exercises for fast learners, remedial tutorials for those struggling). Furthermore, teachers' confidence in managing a technology-rich classroom has increased. Initially, many teachers expressed concerns about distraction or loss of control, but by the end, 90% of respondents said they felt comfortable or very comfortable with students using devices in the classroom. This confidence likely grew through practical experience and the realisation that problems could be solved (e.g., they established routines such as "lowering lids" when they needed students' full attention or used monitoring software to see what students were doing). One teacher noted in an interview with that discipline problems did not escalate as feared: "I was worried that students would get distracted from their tasks – yes, from time to time someone would stray into gaming or chatting – but I found techniques to deal with that. At the beginning, we agreed on clear rules together. In fact, some students' behaviour improved because they found the lessons more interesting." This refers to a frequently mentioned benefit of engaging teaching: when students are actively involved, there is less room for disruptive behaviour (Johnson & Johnson, 1999).

In addition, a secondary effect was noted **in the form of improved digital competence and efficiency in teachers' work**. Almost all teachers (95%) said that thanks to the project, they had learned new skills in the field of information and communication technologies. Many emphasised the time savings achieved thanks to the Google ecosystem: for example, using Google Forms to create quizzes that grade themselves, or Google Drive to organise and share materials, which reduced the administrative burden. One teacher said, "I used to spend hours photocopying lesson plans and marking tests by hand. Now I publish materials in Classroom and we use quizzes for self-assessment. This has saved me time that I can invest in planning better lessons." Thus, the transformation in teaching practices also included behind-the-scenes changes in planning, assessment, and resource management. Teachers who

use technology to streamline tasks correlate with a greater ability to innovate pedagogically, a positive cycle noted in earlier research (Darling-Hammond et al., 2014).

### **Student engagement and learning outcomes**

One of the most noticeable effects achieved after the project was **an increase in student engagement**. Engagement was assessed based on factors such as: self-reported independence from questionnaires completed by students, observations of teachers' work in class, and attendance/participation records. In a survey conducted among students, when asked to compare "How interested and engaged do you feel in lessons with Chromebooks compared to when you did not have a personal device?", 78% of students responded that they felt more engaged than before (with 15% "significantly more engaged" and 63% "somewhat more engaged"), 20% felt about the same, and only 2% felt less engaged. Several factors contributed to this increased engagement. These included the fact that students appreciated the interactive nature of the classes ("Lessons are more fun when we can do things online ourselves"), immediate access to information ("If I'm curious about something, I can look it up right away, which keeps me interested"), and the element of novelty and variety ("We don't just sit and listen. One day we can do a slideshow, another day we can do a quiz or work on a group document – there's always something new"), as confirmed by statements obtained from the focus group study. This state of affairs is confirmed by the majority of teachers (88% of respondents) who agreed with the statement that "students participate more actively in discussions or classes after the introduction of Chromebooks" (compared to about 40% who expected this beforehand). These results are also confirmed by notes from classroom observations. In observations of classes before the introduction of digital technologies, it was often the case that in a class of 25 students, perhaps 5-6 students actively answered questions or contributed ideas, whereas in observations of student-centred classes after the introduction of Chromebooks and the platform, almost every student was engaged through speaking, writing on a shared platform, or manipulating educational materials. In one observation at a primary school, for example, during a maths lesson using a quiz application on Chromebooks, all students were clearly excited - they stared at their screens, some leaning forward in excitement, occasionally cheering or groaning as they got answers right or wrong, and having a sense of healthy competition that the teacher later used to discuss problem-solving strategies. This contrasted with the basic observation of a maths lesson, where a handful of students responded to the teacher's questions while many remained passive or unengaged.

Another indicator of engagement is **attendance and homework completion**. Although the short study period and small sample size do not allow for definitive conclusions, school data showed a slight improvement in attendance in the classes participating in the study compared to the previous semester (the number of unexcused absences fell by about 10%). Teachers also reported an improvement in homework completion rates. One possible interpretation is that homework assignments, assigned and sent via Google Classroom, became more transparent and accessible to students, reducing the likelihood that a student would "forget" or lose a worksheet. In addition, some homework assignments included interactive tools that students found more engaging (e.g., digital simulation instead of writing answers on paper).

Another indicator is **the development of digital competence skills**, as indicated by both student self-assessment and practical assessment. The SELFIE survey for students included elements related to the areas of digital skills defined by the EU (such as information search, content creation, communication, safety and problem solving). Students' self-assessment improved significantly in key areas. For example, on a scale of 1 (no confidence) to 5 (very confident), the average student rating in the category "I can create digital content (text, presentations, images or videos) to express my ideas" increased from 3.1 before the programme (moderate confidence) to 3.8 after the programme ( $p < .001$ ). For "I can communicate and collaborate with others using digital tools (e.g., email, chat, shared documents)", the average increased from 3.5 to 4.4 ( $p < .001$ ). These are consistent with the previously cited improvements (~15% and ~25% relative increase in these domains, respectively). "I know how to use the internet to learn new things or solve problems" showed an increase in confidence, suggesting that they are better prepared for independent learning. This was also confirmed by a basic ICT skills test (covering tasks such as creating a document, using spreadsheet formulas, Internet search strategies, and understanding online safety) at the beginning and end of the programme. While students at both schools improved on average, older students in secondary school showed the greatest increase (their test scores improved by about 15 percentage points, from an average of ~60% correct to ~75% correct). Primary school pupils also achieved an improvement (an increase of about 10 percentage points). This objective measure confirms the self-assessment of skill growth. Teachers also noticed significant development in digital competence among pupils, which they confirmed in interviews, emphasising that pupils produced more polished work at the end. For example, one teacher was impressed that her sixth-grade pupils had learned how to correctly insert images and hyperlinks into their written assignments, something she had not explicitly taught them, but which they had picked up, probably through exploration and learning from their peers. She said, "Even beyond specific classroom assignments, they are gaining digital literacy. These are skills that will be valuable outside of school."

The impact of technology use on **students' grades in the traditional sense** is also worth noting. Given the short duration of the programme, we did not expect drastic changes in standard test results, nor were any conducted during this period. However, teachers reported that students' formative assessment results (e.g., quizzes, class tests) in some subjects improved in areas taught using new methods. For example, a biology teacher shared that in a unit on human anatomy, students scored higher on average on the unit test than the previous group. Such anecdotal evidence suggests that when engagement and skills improved, content learning was also positively affected. Students in interviews often mentioned that it was easier for them to remember material when they "learned it by doing" — one student gave the example: "I will remember better how to calculate area because we actually used an interactive tool to design a floor plan – it stuck in my mind more than when we just practised the formulas." This is consistent with research on learning that active learning can increase retention (Johnson & Johnson, 1999). It should be noted, however, that not all subject areas benefited equally. Several teachers noted that for highly theoretical parts of the curriculum (such as certain advanced mathematical procedures), the Chromebook was less directly useful and they still resorted to traditional teaching, although they could use it for practical exercises. Thus, the improvement in results was more evident in areas where technology supported visualisation, practice and creative expression.

**It is** worth noting **the increased level of collaboration and communication** among students as a result of using Chromebooks and the Platform. According to statements from students in the focus group study, collaborative work became easier and more frequent. Students enthusiastically talked about their experiences of writing stories together in Google Docs, reviewing each other's essays by leaving comments, or creating slides for a group presentation together, with each member responsible for several slides. They appreciated features such as the ability to view their work in real time and even continue collaborating after school from home. Collaboration anywhere, anytime is a new behaviour that was not previously possible in the same way. Teachers noticed that shy students who rarely spoke up were presenting ideas in shared documents or chat channels, effectively providing alternative ways to participate. One English teacher said, "I posted a discussion question on Google Classroom as homework — something like, 'Which character do you sympathise with and why?' — and to my surprise, almost every student wrote a response, even those who almost never raise their hands in class. They also started responding to each other's posts. By the next lesson, we had a lively online debate that I was able to continue in class." This example illustrates how digital tools can extend classroom discussion and engage a wider range of voices (Harper & Milman, 2016). This is confirmed by the results of the SELFIE Tool survey, where there was a noticeable increase in the 'collaboration and networking' section. Teachers rated the statement "students at this school often collaborate with each other using digital technologies (for example, through joint projects or online discussions)" significantly higher in their self-reflection after than before (the average teacher rating increased from 2.5 to 4.0 on a 5-point agreement scale). Students similarly reported greater collaboration with their peers. Some also mentioned collaborating with peers from another pilot school through joint online sessions facilitated by the research team – indicating the potential for wider networks (although a limited experiment, it excited pupils to interact beyond their own class).

In addition to the benefits gained from using digital technology solutions, there were also **challenges**. Both students and teachers noted the issue of distraction – the temptation for students to navigate to unrelated websites or games. According to the results of the author's questionnaire, about 30% of teachers noted that managing student distractions was initially at least "somewhat of a problem," although most said it became less of an issue once clear rules and classroom management strategies were established. On the student side, 25% admitted that they were sometimes distracted by non-educational content. This is a known challenge in 1:1 classrooms (Selwyn, 2011). Mitigation, as described in interviews with teachers, included lessons on responsible use of computers and the internet, use of monitoring software, or setting tasks in such a way that students had less time for idleness, and sometimes simply wearing off the novelty – as one student said: "At first, a few of us played with the webcam filters or sneaked onto YouTube, but after a while we realised we could do that at home, and it's more interesting to do a project with everyone in class." Essentially, many students self-corrected when the tasks were engaging enough. Nevertheless, a few students felt that some of their classmates still strayed from the tasks and that this could be distracting to others. The solution adopted by the teacher was to freeze all students' screens while giving instructions and to enforce the rules more actively. Another challenge that arose concerned the use of technology. For example, a small number of devices had connectivity or battery issues on a given day. Teachers in focus groups mentioned that contact with technical support was

crucial for both informational and technical assistance. Without this support, these glitches could have disrupted lessons.

Personalised teaching and student autonomy are among the benefits achieved through teaching and learning with Chromebooks and the Platform. Evidence of this has emerged in many ways. Teachers used tools such as Google Classroom to assign differentiated work—for example, advanced reading for stronger students and simplified text or additional exercises for students who needed it, without singling anyone out in front of their peers. 70% of teachers said that Chromebooks made it easier to adapt to different learning rhythms and paces (only 30% said so before the intervention). Students, in turn, gained autonomy. In focus groups, several students mentioned that they enjoyed the independent exercises available online. One student said, "If I finish my work early, I can do extra exercises posted by the teacher or explore something on my own. I feel like I can always be learning, rather than just waiting for others to catch up." Conversely, those who needed more time or help could quietly access tutorials or ask questions via a private comment in Google Classroom to the teacher, which is less intimidating than asking questions in front of everyone. This practice was noticed by the teacher: "One student who rarely asks for help in person started sending me questions via comments in Google Classroom. I was able to respond during class without embarrassing him. It's a new channel of communication that has helped him stay on track." This highlights how technology can open up new opportunities for personalised support for teachers.

Although we did not conduct a formal experiment on learning outcomes, the combination of high engagement, improved digital skills, and anecdotal evidence of content mastery suggests that the overall educational experience of students was enriched. In terms of the scope of this pilot, we can say that students finished the semester better prepared in both subject matter and cross-cutting skills (digital skills, collaboration, self-directed learning) than they were at the beginning, meeting a key goal of the initiative to develop "future skills" (Darling-Hammond et al., 2014).

## DISCUSSION

The results obtained from the research programme provide evidence that, when implemented thoughtfully, a technology initiative based on a system prepared for this process in the form of devices, software and cloud technology can lead to significant pedagogical changes and improvements in student engagement and skills. This is also confirmed by other studies (Asad et al., 2021; Akhmedov, 2023). One of the main changes observed was the shift in the role of the teacher from a knowledge transmitter to a learning facilitator. This is closely aligned with constructivist and socio-cultural theories of learning (Vygotsky, 1978; Papert, 1980), which emphasise that students actively and socially construct knowledge. Chromebooks and Google tools provided teachers with a practical way to apply theory in everyday practice. Teachers were able to delegate some instructional functions using technology - for example, using online tutorials or adaptive quizzes to deliver basic content or practice - which freed up class time for interactive, higher-order tasks, also considered more creative and needed in schools (Bilyk et al., 2023). The results obtained from the research indicate that teachers engaged in more project-based and collaborative activities,

which is consistent with Fullan's (2013) that technology can be a catalyst for implementing so-called "deep learning" methodologies that develop creativity, critical thinking and problem solving (Dainys, Jašinauskas, 2023; Franceschelli, Musolesi, 2022). Interviews with teachers revealed that many of them had a hidden desire to teach in a more innovative way, but previously lacked resources or confidence. The introduction of a technological ecosystem, combined with training, allowed them to conduct the teaching process in a more student-centred manner. This confirms the view of Ertmer and Ottenbreit-Leftwich (2010) that access and training can help overcome first- and second-order barriers to technology integration (beliefs and confidence).

The results obtained from the research also reflect the findings of Law et al. (2008) from the IEA SITES study, indicating that educational technology brings the greatest benefits when combined with constructivist teaching practices (Riznyk, Kulko, Lebedyk et al., 2024; Alam & Mohanty, 2023). In the case of Poland, prior to the launch of this project, digital tools were not fully utilised in K-12 classrooms, representing significant untapped potential (Szyszka et al., 2022; Kruszewska et al., 2020). By combining technology and training, the project effectively accelerated a transformation that would otherwise have taken many years of gradual change. The conclusion is that technology initiatives should be designed with pedagogical transformation as a clear goal, rather than simply providing ICT (Kokaj et al., 2023; Singh et al., 2025). The results obtained during the implementation confirm this. The value of technology in education is ultimately measured by human factors, including student engagement, teacher innovation and the development of the skills of both, rather than by the technology itself.

Another positive effect was the observed significant increase in student engagement, which is consistent with previous research on 1:1 programmes, which often show increased student motivation and interest (Harper and Milman, 2016; Zheng et al., 2016). The novelty of the devices may explain some short-term engagement, but the sustained engagement observed (once the routine stabilised and the novelty wore off) suggests more intrinsic factors. Students became more active in their own learning, taking the initiative to search for information, express ideas creatively, and collaborate. This is similar to the shift from passive recipients to active learners, which is a key goal of the 21st-century education framework (Voogt & Pareja Roblin, 2012; ISTE, 2016). Feedback from Polish students that they enjoyed learning more when they could "do different things" is consistent with the theory of experiential learning (Colombelli et al., 2022; Skulmowski, 2024) and the concept that active engagement leads to deeper engagement (Johnson & Johnson, 1999).

The effects achieved in the work of teachers and students in the Google ecosystem are consistent with the psychological theory of self-determination, which indicates that students have basic needs for autonomy, competence, and relatedness in order to be intrinsically motivated. The introduction of Chromebooks seems to support all three:

- autonomy by giving students more control over their work,
- competence, thanks to immediate feedback, students can see how their skills and competences are improving
- and connectedness, thanks to greater interaction with peers, strengthening their sense of belonging to a community.

It can be concluded that the improvement in digital competence among students highlights the dual outcome of the programme. Not only has the way of learning and teaching

changed in schools, but students have also become better prepared for the digital world through the use of the Google ecosystem. The educational discourse often refers to "21st century skills" (Efremova, Huseynova, 2022) – our results specifically show an increase in such skills (digital skills, collaboration, independent learning). This fulfils part of Poland's strategic objectives under the "Integrated Strategy for Skills 2030", which emphasises the development of key skills for the future (as mentioned in the introduction to the Polish report; Ministry of National Education, 2019). This is also linked to global goals – for example, the UNESCO framework (2018) recommends that every student should leave school with basic ICT skills and the ability to continue learning using technology. The results of the study indicate that relatively short and intensive use of digital technologies can increase students' digital competences and skills. Therefore, integrating technology into everyday learning, rather than teaching ICT as a separate subject, can be an effective way to build digital competence in context (OECD, 2015).

There is no outright contradiction between the empirical findings and the existing literature, but interpretive tensions are clearly evident. The existing body of literature points to studies that have emphasized the conditional nature of the effectiveness of educational technologies. It is important to note that the devices themselves do not yet improve learning, and positive results depend on teachers' competencies, pedagogical frameworks, the school's organizational culture, and how the tools are used. The results of the pilot study are consistent with the current line of thinking, indicating an increase in student activity, more frequent use of project-based work, collaboration, and more student-centered practices. This consistency pertains to the mechanism of change implementation. However, due to the time constraints of the project and the incidental nature of its implementation, it is difficult to justify the universal effectiveness of the studied learning model.

## CONCLUSIONS

A unique aspect of the implemented Google cloud ecosystem is its comprehensiveness. By combining Chromebooks and the Google Workspace platform, a complementary effect was achieved, which is consistent with the results of research on other solutions (Stein et al., 2013). The positive results of the digital technology application programme were possible thanks to:

- providing access to infrastructure in the form of Chromebooks and the Internet (Wi-Fi) to cloud resources, which enabled the project to be implemented. The smooth operation of the technology built trust. As one teacher said, initially sceptical teachers "believed" when they saw that the system worked day after day without chaos.
- Comprehensive participation by schools, which helped to create a supportive community. Teachers were able to share their experiences in the staff room, and pupils in the classrooms, which fostered a culture of innovation. The involvement of the school management meant that school rules and timetables were adapted to facilitate the implementation of the project. This comprehensive approach is similar to what the European Commission (2020) calls a "holistic digital education strategy" - encompassing technology, content, pedagogy and organisation.

- support for teachers by project partners, which was made possible by methodological and technical training for teachers (64 hours) and support for their activities, which improved student learning outcomes, in line with global practices (Darling-Hammond et al., 2014). In addition, teachers were able to obtain confirmation of their digital skills through Google Educator certification.
- relevance to real needs in terms of improving communication and collaboration. During the training, the moderators clearly indicated how the use of Google Workspace could solve the problems reported by the teachers themselves (e.g. difficulties in engaging students, heavy workload, students' lack of ICT skills). This participatory and needs-based approach ( ) increased teacher engagement, as suggested by theories of adoption in education (Rogers 2003).
- It also increased student enthusiasm and peer support, with students helping each other in difficult situations, reducing the burden on teachers. This approach increased the class's ability to cope with technology, making them "technology leaders" (Bebell & O'Dwyer, 2010).

Despite the positive results, several challenges must be addressed to ensure the long-term success of the implementation in selected schools, including:

- the continuous professional development of teachers as technology and pedagogy evolve. Fullan (2013) notes that knowledge about how to sustain and develop innovation is critical to sustainable development. Schools should institutionalise a formula for continuous professional development related to digital teaching by building a network of practices where teachers can share resources and success stories, which would help in the development of a digital school.
- scaling and equity in access to resources (equipment, training, support staff). Scaling up the digital school project to the national level will require significant investment. Decision-makers must consider how to prioritise schools or regions. One approach is to scale up gradually, starting with motivated schools (as Poland did in its pilot programme) and gradually expanding the digitisation of schools so that all interested parties have equal access.
- Adapting the curriculum and assessment to the possibilities offered by digital solutions. Innovative teaching can be constrained by traditional examination requirements (Voogt & Pareja Roblin, 2012). To ensure a lasting pedagogical transformation, education managers should consider updating curricula to give teachers more flexibility in terms of project orientation and updating assessment methods to measure skills such as collaboration, creativity and digital skills. Some countries have begun to introduce digital components into examinations or alternative assessments (OECD, 2020). Poland may consider doing the same to verify and encourage the results of such initiatives. The results of the study can be used as evidence to support such policy adjustments.
- Maintain a human-centred focus and do not become overly enamoured with technology, remembering that it should serve education (Selwyn, 2011). In the long term, schools should continually reflect (using tools such as SELFIE or other evaluations) on whether the use of technology actually improves teaching and learning. A human-centred approach means prioritising teacher-student interaction over technology (UN, 2020). Therefore, school managers should strive for thoughtful

integration, where technology enhances rather than replaces the human elements of teaching (Johnson & Johnson, 2014).

The most challenging aspect of the solution under review is the ability to scale it up without compromising the quality of the results demonstrated in the pilot. The project's success depended on the strong involvement of technology partners, training support, and careful planning of the implementation and usage process. This means that success does not stem solely from the use of Chromebooks and the cloud environment, but from the entire implementation infrastructure, which is costly and organizationally demanding. On a large scale, there is a risk of a disparity in the quality of implementation due to variations in teachers' willingness to participate in the digital transformation. Added to this is the risk of overburdening teachers with additional responsibilities, schools becoming dependent on a single platform ecosystem, infrastructure disparities between institutions, and underestimated costs of long-term equipment maintenance, technical support, and data security. It is important to recognize that replicating a tested solution may result in partial failure if there are no sustainable mechanisms for support, evaluation, and adaptation to diverse school conditions.

Comparing the results obtained in studies on the Google implementation project with international cases of modern 1:1 pedagogical practices, a certain consistency can be identified, which increases their generality. For example, in the United States, the Maine Learning Technology Initiative (the first nationwide laptop programme) ultimately reported improvements in student writing and engagement, but only after significant professional development and curriculum integration – in the early years, more mixed results were reported (Bebell & O'Dwyer, 2010). The Polish case, carefully prepared through training, seems to be more direct in achieving positive results, illustrating the importance of learning from previous experiences. In the European context, similar projects (such as those under the European Schoolnet Future Classroom Lab initiatives) have highlighted the role of school culture and teacher collaboration in sustaining innovation (European Commission, 2020). The school-based approach used in our study ensured a supportive culture in each pilot school, reflecting international best practice.

A long-standing discourse in the world of science (Ihde, 2008) concerns how people and technology shape each other. In the case in question, it is clear that teachers and students not only used technology and adapted to it, but that technology adapted to them in practice (along with the evolution of new norms, behaviours and routines). This co-evolution was evident when students taught themselves or each other new digital skills that even teachers had not anticipated. This demonstrates the resilience and creativity of users in adapting technology to their needs (Selwyn, 2011). Recognising this state of affairs, education managers and digital educators should involve students and teachers in the ongoing design of such programmes, treating them as co-creators of a new, digitally enhanced education, rather than just end users. The success of this pilot programme is largely due to the enthusiastic participation of its participants, and not just the technology itself.

It can therefore be concluded that the findings obtained during the research project do not refute current theoretical models of teaching using digital solutions, but rather clearly clarify and refine them. First, the data indicate that models such as TPACK, constructivism, and student-centered approaches require supplementation at the organizational and implementation level: the effective use of technology depends not only on the relationship

between content, pedagogy, and the tool, but also on school leadership, systemic support, teacher training, and the coherence of the entire work environment. Second, the collected data expands our understanding of student autonomy, indicating that it does not arise automatically from access to a device, but from the combination of greater independence with well-designed instructional scaffolding. Third, the results suggest a model that is more socio-technical than purely didactic, in which educational outcomes are generated by the configuration of technology, teaching practices, student collaboration, and institutional conditions, allowing us to reframe the question from “does technology work?” to “under what conditions, for whom, and through what organizational mechanisms can technology support learning?” Such a correction is of great value because it guards against simplistic technological optimism and better describes the real conditions for lasting educational change.

## SUMMARY

In summary, the study documented a clear and positive transformation in teaching practices and student engagement resulting from the integration of Chromebooks and cloud-based tools in two Polish primary and secondary schools. Over the course of the semester, classrooms evolved from teacher-centred environments to more dynamic, student-centred spaces characterised by collaboration, creativity and active learning. Teachers began to take on the role of facilitators, using technology to enable more personalised and project-oriented teaching. Students responded with increased motivation and developed important digital competences that are essential in today's knowledge-based society.

Most importantly, the changes achieved highlight the importance of the human-technology relationship in education. Technology was not a magic solution in itself, but rather a combination of human factors – teacher training and engagement, student curiosity and peer support, visionary leadership – that allowed the tools to truly enhance learning and teaching processes. Essentially, the initiative was successful because it respected a human-centred approach, empowering teachers with new skills and providing students with the opportunity to take responsibility for their own learning. Thus, it can be argued that when technology is introduced to enhance human potential, it can act as a catalyst for improving education, rather than being merely an add-on.

The implications of this study are significant for both managers and other stakeholders in the education sector. Firstly, they show that investing in comprehensive digital transformation – devices, professional development and support – can bring measurable benefits, which is a strong argument for extending such programmes to more schools, both in Poland and in other countries. However, it is crucial that implementation is well thought out, with appropriate preparation, support and adaptation to the objectives set. Secondly, modern educational priorities require an approach that combines technology with student-centred education by ensuring that all students have access to digital tools and support in order to bridge the digital divide and prepare students for the demands of the future workforce and society (European Commission, 2020). Thirdly, the continuous improvement of teachers' qualifications should be a policy priority, as teachers are the foundation of all innovation in the classroom. Permanent communities of practice, mentoring programmes and perhaps

formal recognition (such as digital teaching certificates) can maintain the momentum observed in the pilot phases.

The study also opens up opportunities for further research. One limitation is that the pilot was studied over a relatively short period. A natural next step would be to conduct longitudinal studies to see whether these pedagogical changes persist over multiple semesters or years. Do students who learn in a one-to-one environment continue to perform better or remain more engaged in the long term compared to their peers who do not? How do their academic trajectories differ? Another area to explore would be the impact on different subgroups of students - for example, did students struggling academically benefit the most (through greater engagement), or did students who were already high achievers more often take advantage of the new opportunities? Preliminary observations suggest that many benefits would be universal, but subtle differences may inform differentiated support (Darling-Hammond et al., 2014). Furthermore, qualitative research that focuses on students' in-depth experiences - perhaps through student journals or digital ethnography - could provide richer insights into exactly how technology is changing their approach to learning, their identity as students, and their styles of collaboration.

Finally, as schools around the world consider post-pandemic transformations, this study confirms that simply returning to the old normal would be a missed opportunity. The rapid shift to online learning during COVID-19 forced many teachers and students to leap forward in their digital competencies (UN, 2020). The Polish initiative can be seen as part of a continuum of leveraging these benefits to create a new, better norm in education – one that is more resilient, flexible and student-centred. The human touch of learning, where teachers inspire students and students collaborate with their peers, remains at the heart of education. Only when technology is wisely integrated can it enhance this "human touch". The term "school in the cloud" (used in programme descriptions) should therefore not mean a virtual, impersonal experience, but rather a school that uses cloud tools to strengthen human connections and personalise learning.

In summary, the pilot project "Digital Transformation of Schools with Google" in Poland serves as a valuable case study demonstrating how thoughtful integration of technology can rejuvenate teaching practices and enrich students' educational experiences. It proves that with the right support, teachers will embrace innovation and students will thrive in a more interactive and empowering learning environment. As education systems around the world undergo an ongoing digital revolution, the findings of this study help to fill the information gap by confirming that the greatest value of technology in education is realised only when it is implemented in harmony with human-centred pedagogy. The classrooms of the future do not have to sacrifice humanity for efficiency. Instead, as this article has shown, they can combine the best of technology with the irreplaceable qualities of good teaching and engaged learning by both teachers and students.

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