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Overcoming Digital Inequalities—Identification and Characterisation of Digitally Resilient Schools in Different Countries Using ICILS 2023 Data

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Abstract

As digitalisation transforms society, digital competences are increasingly essential. Yet students' digital competences often vary significantly, largely influenced by socio-economic background. Some schools—termed "resilient schools"—effectively counter these disadvantages and foster high digital competence. This study investigates the prevalence of such schools and examines how they differ from others. Drawing on representative ICILS 2023 data, quantitative secondary analyses—including descriptive statistics, *t*-tests, and multiple regression—were conducted. Following the identification of resilient schools, in-depth analyses focus on those countries with substantial proportions of resilient schools above 10 percent (Austria, Italy, and Portugal), as these countries seem to have effective strategies to foster school resilience. The findings highlight considerable cross-national variation, indicating that school resilience is context-dependent. Resilient schools consistently emphasise student learning-related factors—such as ICT-related attitudes and educational aspirations—while the influence of home environments is less pronounced than in other schools. Strengthening student learning-related factors appears to be crucial for building digital resilience. These insights can inform policy and practice aimed at fostering educational equity and closing the digital divide, particularly in socio-economically disadvantaged contexts.

Keywords: digital inequalities; resilient schools; digital resiliency; digital competence acquisition

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1. Background—Digital Transformation and Digital Inequalities

Amid the ongoing digital transformation of society, the acquisition of digital competences has become an increasingly critical aspect of social participation and engagement. Accordingly, schools bear a fundamental educational responsibility to systematically foster this key competence among all students (Loh et al., 2025).

Despite the existence of such an overarching responsibility, empirical research consistently indicates that students from socio-economically disadvantaged backgrounds demonstrate, on average, lower levels of digital competence across nearly all national contexts (Fraillon et al., 2020; Kennedy et al., 2025). However, the magnitude of disparities in digital competences between students of high and low socio-economic status varies both between and within countries. These disparities can be attributed to structural differences at both the national level and the level of individual schools. These structural differences are also closely linked to students' individual characteristics and the conditions of their home environment (Loh et al., 2025; Tondeur et al., 2008).

Of particular interest are those schools that, despite serving a student body with a high proportion of students with low socio-economic status (SES), nevertheless succeed in cultivating high levels of digital competences. Owing to their unexpected success in overcoming structural disadvantages, such institutions are referred to in the literature as "digitally resilient schools" (Lörz et al., 2024). In this context, they can be defined as follows:

Digitally resilient schools are institutions that, despite serving a student population with a high proportion of students with low socio-economic status (SES), succeed in fostering high levels of digital competences among their students. Their unexpected success in overcoming structural disadvantages distinguishes them as digitally resilient.

This definition is consistent with existing definitions in the literature, which similarly emphasise the ability of certain schools to achieve strong educational outcomes in the digital domain despite challenging socio-economic conditions (Drossel et al., 2020; Drossel et al., 2025; Eickelmann et al., 2019; Lörz et al., 2024).

Digitally resilient schools constitute the central focus of this paper. The identification of digitally resilient schools across different national contexts is a prerequisite for identifying and understanding the specific factors—particularly those linked to students' digital competences—that set these schools apart, given their demonstrated effectiveness in mitigating digital inequalities. These distinguishing factors may include, according to theoretical approaches, antecedent-level characteristics such as the availability and quality of ICT (information and communications technology) resources and school leadership practices, as well as process-level characteristics such as the integration of digital technologies into teaching and learning practices (Eickelmann et al., 2019). Particularly relevant are those countries with a high proportion of resilient schools (Austria, Italy, and Portugal; see Section 6), as they may demonstrate effective strategies for mitigating digital inequalities (Drossel et al., 2020).

To be more precise, this study aims to achieve three key research objectives:

1. To identify resilient schools across different countries.
2. To examine the differences in antecedent- and process-level factors between resilient and other schools in countries with substantial proportions of resilient schools.
3. To investigate the extent to which these antecedent- and process-level factors contribute to students' digital competences in resilient and other schools in countries with substantial proportions of resilient schools.

In order to achieve the aforementioned objectives, the present paper first delineates the theoretical frameworks that explain the existence of resilient schools and their characteristics that render them unique (Section 2.1). These foundations are then extended to incorporate specific factors relevant to digital competence acquisition (Section 2.2). Section 3 integrates these theoretical assumptions with empirical findings on the existence and characteristics of digitally resilient schools. Based on this synthesis, the research gap and guiding research questions are formulated in Section 4. Section 5 outlines the methodological approach, while Section 6 presents findings on the existence of resilient schools as well as the antecedent- and process-related factors of digital competence acquisition in resilient schools in comparison with other schools (all schools that do not fulfil the resilience criteria according to their definition) across different countries. Moreover, these descriptive approaches are extended by a more analytical point of view. To this end, the relationship between antecedent- and process-level factors and students' digital competences in resilient and all other schools is evaluated. Finally, Section 7 summarises the results and discusses their implications for theory, research, and educational practice.

2. Theoretical Approaches

Due to the research objectives of this article, two theoretical strands are presented below: To address the first and second research objective, approaches that explain the high average student competences in schools with a high proportion of students with low SES are considered (Section 2.1). To address the second and third research objectives, an approach is presented that highlights the interrelations and possible relevance of antecedent- and process-level factors for the acquisition of digital competences (Section 2.2).

2.1. Approaches to the Existence and Characteristics of Resilient Schools

According to Muijs et al. (2004), high average student competences in schools with high proportions of students with low socio-economic status can be elucidated by three central theoretical strands: the contingency theory, the compensatory model, and the hypothesis of additivity. These are differentiated below.

Contingency theory asserts that the effectiveness of an organisation, such as a school, is determined by situational factors (Creemers et al., 2000). These contingency factors may be internal or external, encompassing aspects such as the complexity of the environment, the age of the institution, and, crucially, the socio-economic context in which the school operates. According to this perspective, schools with a high proportion of students from low socio-economic backgrounds must identify and implement organisational structures and policies, such as an ICT curriculum, that best align with their unique contextual challenges. Consequently, effective schools within these areas are hypothesised to share common antecedent and process characteristics while also differing in certain aspects based on specific contingency factors. By focusing on contextually appropriate organisational configurations, contingency theory underscores the importance of flexible, evidence-based strategies, especially in terms of adequate ICT integration in teaching and learning, that respond to the unique demands of different educational settings (Creemers et al., 2000). With this theoretical approach in mind, resilient schools might exist and exhibit certain antecedent- and process-level factors.

The compensatory model, as proposed by Chrispeels (1992) and further developed by Teddlie et al. (2000), contends that schools serving socio-economically disadvantaged populations must actively compensate for the deficits in students' home environments. This model outlines a two-phase process for school improvement: In the initial phase, foundational conditions such as maintaining an orderly school climate and establishing high expectations for student achievement—e.g., through the school principal's priorities facilitating ICT usage—must be secured. Subsequently, the second phase entails structural reforms such as implementing an adequate ICT curriculum or sufficient ICT resources aimed at fostering systemic and sustainable improvements in educational quality. The compensatory model further posits that educators in low-SES schools must exert greater effort to achieve comparable academic outcomes given the additional barriers faced by their students. Following the theoretical assumptions of the compensatory model, this means that resilient schools exist and that they can be differentiated through certain antecedent- and process-level factors.

The hypothesis of additivity, as articulated by Reynolds and Teddlie (2000), posits that, even after controlling for student background characteristics, schools with a high proportion of low-SES students tend to underperform in comparison to those in middle- and high-SES contexts. This suggests that educational disadvantage is not solely attributable to student socio-economic status but is also compounded by the systemic challenges faced by schools operating in such environments. The hypothesis highlights the tendency for schools in more challenging settings to be less effective, thereby reinforcing patterns of social disadvantage. Potential explanations for this phenomenon include disparities in teacher recruitment—

whereby more qualified teachers may be reluctant to work in disadvantaged schools—as well as the heightened visibility of institutional deficiencies under conditions of stress and pressure (Reynolds & Teddlie, 2000). This would mean that resilient schools possibly do not exist.

These three theoretical perspectives—while distinct in their focus—are not mutually exclusive; rather, they offer complementary insights into the complex interplay between school effectiveness and socio-economic disadvantage. Collectively, they provide a nuanced framework for analysing and explaining the existence of resilient schools and possible differences between resilient and other schools.

2.2. Approaches for the Acquisition of Digital Competences

According to theoretical assumptions and framework models, certain factors are relevant for students' acquisition of digital competences in schools. Such factors can be found in school development and school effectiveness models and are often differentiated into antecedent- and process-level factors (Scheerens & Bosker, 1997), while digital competences are targeted at the output level. Due to the similarity among various theoretical models (Cabezas-González et al., 2023; Fraillon et al., 2014; Hippe & Jakubowski, 2022), only the framework model of the International Computer and Information Literacy Study 2023 (ICILS 2023) (Rožman et al., 2025) is presented below, as it incorporates empirically and theoretically substantiated central factors relevant to the acquisition of digital competences (see Figure 1). Although the presented model does not specifically refer to resilient schools, the distinction between resilient and other schools is nevertheless implicit, insofar as the socio-economic status of the students is considered through home environment-related factors at both the antecedent and process levels.

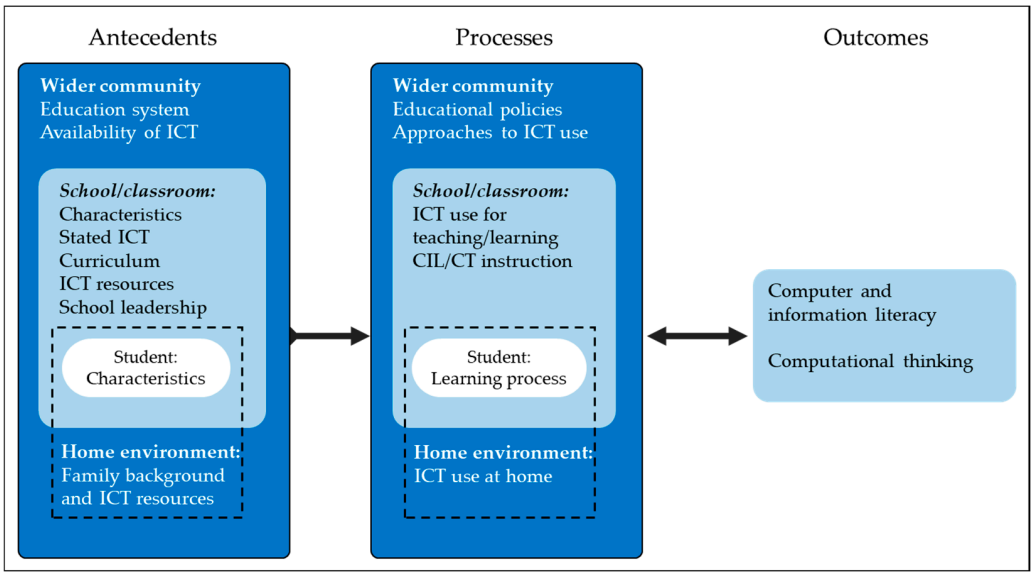

Figure 1. Framework model of ICILS 2023 (Rožman et al., 2025, p. 46).

The acquisition of digital competences, particularly computer and information literacy (CIL) and computational thinking (CT) in the model, can be examined through a structured framework comprising three interconnected components: (1) antecedents, (2) processes, and (3) outcomes (Rožman et al., 2025).

(1) Antecedents encompass the foundational conditions shaping digital competence development across the wider community, school/classroom, and home environments. The education system influences ICT availability and integration, while school-level factors—such as the existence of an ICT curriculum, the number of ICT resources, and

school leadership priorities concerning ICT integration in teaching and learning—affect implementation. At home, aspects such as socio-economic background and access to digital tools further contribute to students' digital competences (Rožman et al., 2025).

(2) Processes delineate how ICT is actively utilised in teaching and learning. In the context of the wider community, educational policies shape digital integration, while school-level characteristics—including instructional practices and ICT usage for teaching and learning—determine digital competences. The students' learning process is shaped through aspects such as ICT self-efficacy and ICT-related attitudes. Additionally, home-based digital activities, such as completing assignments and independent learning, reinforce students' digital competences (Rožman et al., 2025).

(3) Outcomes include computer and information literacy as well as competences in the field of computational thinking. These outcomes depend on process characteristics, which, in turn, are influenced by the input factors (Rožman et al., 2025).

This model provides a systematic approach to comprehending the multifaceted influences on students' digital competence development across educational and societal contexts. Consequently, it can serve as a foundation for the more in-depth analyses in the context of the second and third research objectives concerning the characteristics of resilient schools in the subsequent sections of this article.

For the sake of clarity, the main theoretical elements of the theories mentioned are summarised in a table. The table presents the theoretical assumptions about the characteristics of digitally resilient schools at the three levels of antecedents, processes, and outcomes (Table 1).

Table 1. Theoretical assumptions about characteristics of digitally resilient schools (summary).

Dimension	Theoretical Assumptions About Characteristics of Digitally Resilient Schools
Antecedents	- Context Alignment: Schools tailor digital strategies (e.g., ICT curriculum, resource allocation) to their students' socio-economic and institutional context. - Foundational Support Structures: Safe, structured environments and leadership that values digital integration are necessary preconditions. - Systemic Constraints: Consideration and minimisation of structural inequalities (e.g., resource gaps, staffing issues).
Processes	- Strategic Adaptation: Teaching practices flexibly integrate ICT in response to local demands and learning challenges. - Instructional Activation: ICT usage quality in classrooms, student motivation, and home engagement directly shape learning trajectories.
Outcomes	- High student digital competences. - Consistent achievement despite low-SES background.

3. Empirical Findings on Digitally Resilient Schools

Following the discussion of theoretical approaches explaining the existence and characteristics of resilient schools, the subsequent section presents corresponding empirical findings. Initially, these findings outline the existence of resilient schools that consistently achieve high student performance in digital competences across different countries (Section 3.1). In a second step, empirical findings on antecedent- and process-level factors (Section 3.2) in digitally resilient schools in the context of digital competence acquisition are presented.

3.1. Empirical Findings on the Identification of Digitally Resilient Schools

The extant empirical studies identifying digitally resilient schools are based on ICILS data. Consequently, they include information on ICILS-participating countries that took

part in the respective cycles of the study. Both studies presented define digital resilience based on the average scale values of schools that are located in the lower third of the HISEI (Highest International Socio-Economic Index of Occupational Status) spectrum and simultaneously in the upper third of the CIL spectrum of their respective country. These studies demonstrate the existence of digitally resilient schools across various ICILS-participating countries. However, the proportions of such schools have been found to vary significantly both between and within countries over time (Eickelmann et al., 2019; Drossel et al., 2020).

In 2013, among the countries with available data, Poland reported the highest proportion of resilient schools at 19.9%, followed by Germany with 11.8% and Australia with 10.3%. The Republic of Korea reported 7.3%, Canada 4.1%, Norway 2.2%, Denmark 1.9%, and the Czech Republic 1.2% (Eickelmann et al., 2019).

In 2018, Finland reported a proportion of 17.0% resilient schools, followed by France with 14.4%, Portugal with 10.6%, and Italy with 7.4%. Denmark, which participated in both cycles, showed an increase from 1.9% in 2013 to 7.5% in 2018. In contrast, Germany reported a decrease from 11.8% to 6.0%, and the Republic of Korea a decrease from 7.3% to 3.5%. Other 2018 findings include Uruguay having a proportion of 3.7%, the United States a proportion of 1.3%, and Chile a proportion of 0.7%, and both Kazakhstan and Luxembourg reporting no resilient schools (Drossel et al., 2020).

For several countries—namely Chile, Finland, France, Italy, Kazakhstan, Luxembourg, Portugal, Uruguay, and the United States—comparable data from 2013 are not available. Likewise, for countries including Australia, Canada, the Czech Republic, Norway, and Poland, no data are available for 2018, as these countries did not participate in that particular ICILS cycle (Eickelmann et al., 2019; Drossel et al., 2020).

The results demonstrate considerable variability in the proportion of resilient schools across countries, as well as the capacity for these proportions to change over time. The findings presented here illustrate the need for an up-to-date assessment of the proportion of digitally resilient schools across different countries, which this paper seeks to address.

3.2. Empirical Findings on Antecedent- and Process-Level Factors in Digitally Resilient Schools and Their Relevance for Students' Digital Competences

Beyond merely quantifying the prevalence of resilient schools, researchers have sought to determine the factors that facilitate or hinder school-related resilience in the domain of digital competences. Based on the aforementioned theoretical considerations, the following empirical findings are organised into (1) antecedent- and (2) process-level factors (see Section 2.2).

Lörz et al. (2024) conducted a study to investigate the characteristics distinguishing resilient from non-resilient schools in Germany. Utilising data from the ICILS 2018, the authors classified schools into four types based on their student bodies' socio-economic status and average CIL performance. It is important to acknowledge the limitations of comparability, as Lörz et al. (2024) employed a distinct approach to identifying resilient schools. Specifically, the study defined a school as resilient if the average student HISEI value was within the lower half of the national distribution and the average CIL score was within the upper half. Employing a series of regression analyses, the study examined the extent to which disparities in CIL proficiency could be attributed to factors at the student, parental, and school levels. Multivariate regression models revealed that differences in students' digital competences (measured via CIL) across school types were partly attributable to antecedent-level factors such as student characteristics (e.g., gender, immigrant background, educational aspirations) and home environments (e.g., access to digital devices, cultural resources). School-level antecedents such as digital infrastructure

and teacher attitudes toward ICT exhibited only limited explanatory power regarding school-specific CIL disparities (Lörz et al., 2024).

Moreover, findings from the ICILS 2013 indicate that school leadership—particularly principals' emphasis on cultivating a shared vision for ICT integration in teaching and learning—constitutes a fundamental antecedent-level characteristic for resilience in this domain (Eickelmann et al., 2019). However, this result was not confirmed by Lörz et al. (2024).

According to Lörz et al. (2024), most process-level factors, such as the use of ICT in instruction, do not significantly differ between resilient and non-resilient schools. However, digital self-efficacy at the student level—a process-related factor—does significantly differ between school types and appears to be an important contributor to resilience. Drossel et al. (2025) examined the role of teaching quality as a process-level characteristic in fostering digital competences at resilient schools, emphasising that effective teaching and learning processes are central to their success. Based on qualitative data from guided interviews with teachers and students in Germany, the study identified four key dimensions of teaching quality that contribute to digital competence acquisition.

Resilient schools optimise classroom management through digital tools and reciprocal technical support, ensuring seamless integration of digital learning. Cognitive activation is enhanced by linking digital content to students' prior knowledge, while constructive support fosters self-directed learning and peer collaboration through cooperative learning structures. Furthermore, content selection and focused instruction highlight the intentional prioritisation of digital competences in curricula, emphasising structured instructional strategies such as project-based learning (Drossel et al., 2025). The authors of this qualitative study emphasise the relevance of specific facets at the instructional level as a defining characteristic of digitally resilient schools.

Despite these findings, a considerable portion of the variation in CIL achievement between resilient and non-resilient schools remains unexplained. This suggests that additional, yet unidentified, factors contribute to organisational resilience in the digital domain. Accordingly, further research is needed to identify the factors that enable resilient schools to foster high digital competence despite socio-economic adversity (Lörz et al., 2024).

In a similar manner to the procedure for the theoretical assumptions, the central empirical findings on the characteristics of digitally resilient schools mentioned above are presented in tabular form below for greater clarity (Table 2).

Table 2. Empirical findings on characteristics of digitally resilient schools (summary).

Dimension	Empirical Findings on Characteristics of Digitally Resilient Schools
Antecedents	- Supportive school leadership with ICT vision - Supportive student digital home environments
Processes	- High digital self-efficacy among students - High ICT-related teaching quality (e.g., classroom management, cognitive activation, collaborative learning, focused instruction)
Outcomes	- High student digital competences - Consistent achievement despite low-SES background

4. Research Desideratum and Derived Research Questions

The current state of research highlights a gap regarding the existence of digitally resilient schools today, as well as structural differences between resilient and other schools. The limited findings available (e.g., Eickelmann et al., 2019; Drossel et al., 2025; Lörz et al., 2024) underscore the need for further investigation—both into whether resilient schools still exist, given that the most recent data date from 2018, and into how antecedent- and

process-level factors differ between resilient and other schools, as well as into how these factors relate to students' digital competences at resilient schools across countries with substantial proportions of resilient schools.

Based on these considerations, the present article addresses the following research questions:

1. What is the current state of digitally resilient schools in different countries?
2. To what extent do antecedent- and process-level factors for acquiring digital competences differ between resilient and other schools across countries with substantial proportions of resilient schools?
3. Which antecedent- and process-level factors predict students' digital competences at resilient schools compared to other schools across countries with substantial proportions of resilient schools?

5. Methodological Approach

The following section outlines the methodological approach employed to address the research questions. First, the sample, study implementation, and country selection are described in detail (Section 5.1), followed by a presentation of the instruments and data analysis methods (Section 5.2).

5.1. Sample, Study Implementation, and Country Selection

To answer the research questions, data are required that make it possible to identify resilient schools based on students' average digital competences and socio-economic backgrounds, as well as to map antecedent- and process-level factors. Based on these prerequisites, the representative data from the International Computer and Information Literacy Study (ICILS 2023) appear to be particularly suitable. The ICILS 2023 provides results for 34 countries and 1 benchmarking participant worldwide and is based on computer-based competence tests of students (N = 132,889) (Fraillon, 2025a), as well as surveys of students, school principals, teachers, and IT coordinators.

The ICILS 2023 followed a rigorous methodological approach to assess students' digital competences, with a specific focus on CIL, which is central to this paper. The study employed a stratified two-stage sampling design to ensure representativeness across participating education systems. The target population consisted of eighth-grade students with a minimum average age of 13.5 years, representing a stage at which foundational digital competences are expected to be developed (Fraillon, 2025a).

To ensure international comparability, strict sampling guidelines were applied, including specifications regarding minimum participation rates, school and student selection criteria, and permissible exclusion thresholds. Each participating country was required to adhere to these guidelines, ensuring that the data remained representative and comparable across different educational contexts (Fraillon, 2025a). Given the high quality of the data and their suitability for addressing the research questions, ICILS 2023 data were selected for the secondary analyses conducted in this article.

5.2. Instruments and Data Analysis Methods

In order to answer the formulated research questions, resilient schools first had to be identified. The classification of a school as resilient is determined by the criteria established by Drossel et al. (2020) if the mean HISEI—used to operationalise the socio-economic background aggregated at the school level—was in the lower third of the country HISEI spectrum and the mean digital competences operationalised through the CIL of the students aggregated at the school level were in the upper third of the country-sample spectrum. For

reasons of comparison, these resilient schools are contrasted with the results of all other schools that do not fulfil the above-mentioned criteria (non-resilient schools).

The population estimates of digital competences are determined by the plausible values approach, ensuring the most accurate conclusions about the characteristics of the entire population from the students' individual test results (Mislevy, 1991). In addition, the Jackknife replication method was used to estimate sampling and measurement errors (Johnson & Rust, 1992; Rust, 2013), and the data were weighted to compensate for sample bias (Meyer et al., 2025). In the analysis conducted for this paper, all data were weighted on the student population using student weights.

Relevant scales validated internationally in the context of the ICILSs (Meyer et al., 2025), as well as single items, were used to operationalise the different antecedent- and process-level factors in order to answer the second and third research questions.

Table 3 presents an overview of the key variables utilised in this study, categorised into two main levels (Rožman et al., 2025): (1) antecedent- and (2) process-level factors. The wider community level, referring to both antecedents and processes, is addressed through country-specific analyses, which allow for the consideration of national contexts and their influence on school resilience. The selection of the subsequent factors is based on the aforementioned theoretical and empirical considerations (see Sections 2 and 3).

The antecedent level (1) encompasses factors that may influence the integration of information and communication technology (ICT) in schools, including school characteristics, the stated ICT curriculum, ICT resources, and school leadership, as well as student characteristics and home environment factors (Rožman et al., 2025). Specifically, school characteristics are measured through the existence of digital learning materials (II3G16). The presence of a formal plan for ICT integration in teaching (IP3G13) is assessed as an indicator of a structured ICT curriculum. Furthermore, ICT resource availability including availability of software such as adaptive learning systems or digital learning games, as reported by ICT coordinators (C_RESTOOL), and the priority given to ICT facilitation by school principals (P_PRIORS) are included as key antecedent variables. Student characteristics at the antecedent-level include gender (S_SEX), aspired for educational qualification (S_ISCED), and immigration background (S_IMMBGR). These variables capture essential socio-demographic dimensions. The home environment at that level is represented through two indicators: the number of books available at home (S_HOMLIT), which serves as a proxy for cultural capital, and access to digital devices for schoolwork (IS3G16BA), reflecting technological resources that support learning.

The school-level processes (2) comprise variables related to the utilisation of ICT in paedagogical practices as well as aspects related to the learning process and the home environment. The use of ICT for teaching is operationalised as the general application of classroom ICT resources (S_GENCLASS). The presence of CIL instruction in the current school year is evaluated as a binary variable (S_ICTSTUD), indicating whether ICT studies are part of the teaching. ICT use for learning is examined through students' self-reported learning of internet-related tasks (S_LRNINITS). Moreover, the learning process is operationalised through the ICT self-efficacy regarding the use of general applications (S_GENEFF). Attitudes, which are also relevant for the learning process, are examined through agreement or disagreement with the statement "it is important for students to learn ICT at school" (IS3G25BG). With regard to the home environment at the process level, the learning about internet-related tasks outside of school (S_LRNINTO) is examined. These variables reflect distinct yet interconnected components of the theoretical model (Rožman et al., 2025) and align with empirical findings on digitally resilient schools (e.g., Eickelmann et al., 2019; Drossel et al., 2025; Lörz et al., 2024) (see Sections 2 and 3).

Table 3. Operationalisation of the characteristics at antecedent and process levels.

Characteristic	Operationalisation	(Recoded) Values	Variable Name
Antecedent level—school/classroom			
Characteristics of the school	School provides teachers with digital learning materials	0: No 1: Yes	II3G16
Stated ICT curriculum	Existence of a curriculum for ICT use in teaching	0: No 1: Yes	IP3G13
ICT resources	ICT coordinators' reports on availability of ICT resources at school—tools	Scale (α = 0.860)	C_RESTOOL
School leadership	Principals' reports on priorities for facilitating use of ICT	Scale (α = 0.926)	P_PRIORS
Antecedent level—student characteristics			
Student characteristics	Gender	0: Male 1: Female	S_SEX
Student characteristics	Aspired for educational qualification	0: ISCED level 2 or below 1: ISCED level 3 or higher	S_ISCED
Student characteristics	Immigration background	0: No immigration background 1: Immigration background	S_IMMBGR
Antecedent level—home environment			
Home environment	Number of books at home	0: Up to 25 books 1: More than 25 books	S_HOMLIT
Home environment	Access to desktop or laptop computers at home for schoolwork	0: Sometimes or less often 1: Most times or always	IS3G16BA
Process level—school/classroom			
ICT use for teaching/learning	General classroom applications usage	Scale (α = 0.803)	S_GENCLASS
CIL instruction	ICT studies in current school year	0: No 1: Yes	S_ICTSTUD
Process level—student learning process			
Learning process	Learning about internet-related tasks at school	Scale (α = 0.844)	S_LRNINITS
Learning process	ICT self-efficacy regarding the use of general applications	Scale (α = 0.910)	S_GENEFF
Learning process	Attitudes towards statement "It is important for students to learn ICT at school"	0: Disagree 1: Agree	IS3G25BG
Process level—home environment			
Home environment	Learning about internet-related tasks outside of school	Scale (α = 0.809)	S_LRNINTO

All scale-based variables are measured using Likert-type scales, allowing for a nuanced analysis of different school-level characteristics across various educational contexts. As shown in Table 3, the scales utilised in this study demonstrate adequate reliability, as evidenced by their Cronbach's alpha coefficients. Furthermore, all scale scores have been internationally standardised to a mean of m = 50 scale points with a standard deviation of $\pm$10 points (Meyer et al., 2025).

To answer the second research question, descriptive analyses and *t*-tests (Lehmann & Romano, 2022) are employed. Percentages or scale mean values are reported separately for resilient and other schools, differentiated by country, and tested for significant differences.

The third research question is addressed using hierarchical linear regression analysis, as the dependent variable—digital competences operationalised through CIL—is continuous and linearity can be assumed (Olive, 2017). Two models are presented: the first includes only antecedent-level factors, and the second additionally incorporates process-level factors, as described above (Rožman et al., 2025).

Both *t*-tests and multiple linear regression analyses require certain assumptions to be met for valid results. These prerequisites were checked and fulfilled. The analyses are conducted on countries exhibiting a substantial proportion—exceeding 10 percent—of digitally resilient schools.

6. Results on Digitally Resilient Schools in Different Countries

This section presents an analysis of the existence of digitally resilient schools (Section 6.1), differences in antecedent- and process-level characteristics between resilient and other schools across different countries (Section 6.2), and the predictive value of these characteristics for students' digital competences at both resilient and other schools (Section 6.3). Through this analysis, the research questions guiding the study are addressed, providing empirical insights into the phenomenon of resilient schools and their structures.

6.1. Current State of Digitally Resilient Schools in Different Countries

To answer the first research question, this section presents both the proportions of students from different countries in the lower third of the HISEI spectrum and the proportions of students attending a resilient school, along with the absolute sample sizes of students attending resilient schools (see Figure 2).

The data reveal notable disparities in school resilience, with some countries exhibiting a relatively high percentage of resilient schools despite also having a substantial proportion of schools in the lower socio-economic segment.

Italy (29.4% of students attending a resilient school) stands out with the highest percentage of students attending resilient schools, yet it also has the largest proportion of schools in the bottom third of the HISEI spectrum, suggesting significant socio-economic disparities within its education system. Similarly, Portugal (13.7% of students attending a resilient school) and Austria (10.2% of students attending a resilient school) demonstrate relatively high percentages—above 10%—of students attending resilient schools but also face considerable challenges, as evidenced by their large shares of students in the lower third of the HISEI spectrum. In contrast, countries such as the Czech Republic (5.6% of students in the lower third of the HISEI spectrum) and Cyprus (12.0% of students in the lower third of the HISEI spectrum) exhibit no school resilience.

These findings underscore the varying degrees of resilience among schools across different countries, highlighting the complex relationship between socio-economic background and educational success. Countries with high proportions of students in the lower third of the HISEI spectrum may require targeted interventions to support student achievement and mitigate the impact of socio-economic barriers. The results further suggest that, while some education systems foster resilience despite adversity, others may struggle to provide adequate support for students from disadvantaged backgrounds.

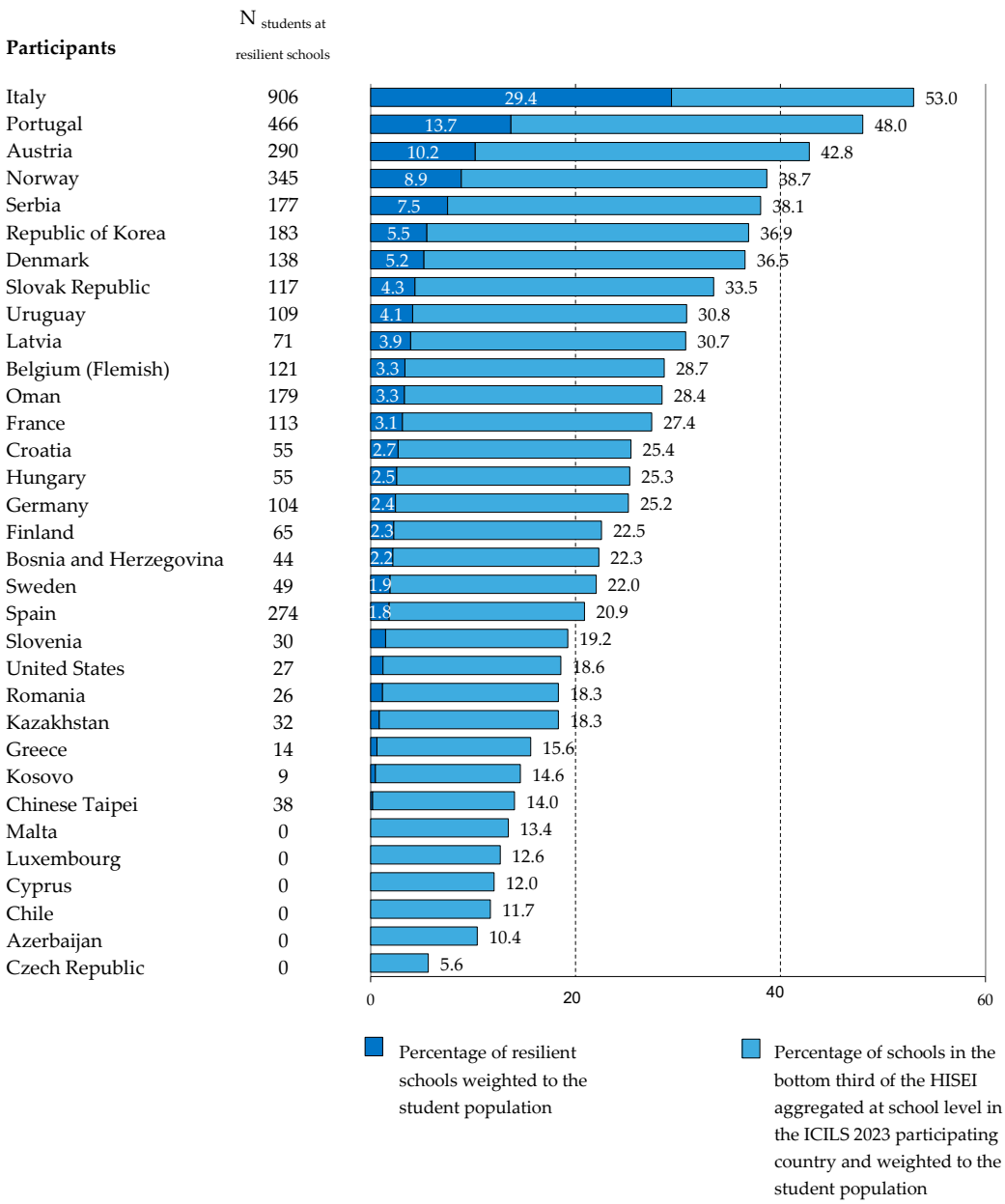

Figure 2. Percentage of students attending resilient schools across ICILS 2023-participating countries.

6.2. Differences Between Antecedent- and Process-Level Characteristics in Resilient and Other Schools in Countries with Substantial Proportions of Resilient Schools

In the following section, antecedent- and process-level factors that may contribute to the acquisition of digital competences in resilient and other schools across Austria, Italy, and Portugal are compared (see Table 4), as these countries exhibit a relatively high proportion of resilient schools—above 10%—and may therefore be employing particularly effective strategies for fostering school resilience.

Table 4. Differences in antecedent- and process-level factors for acquiring digital competences between resilient and other schools in Austria, Italy, and Portugal.

	Austria					Italy					Portugal				
	Resilient Schools			Other Schools		Resilient Schools			Other Schools		Resilient Schools			Other Schools	
	Sig.	% or Points	SE	% or Points	SE	Sig.	% or Points	SE	% or Points	SE	Sig.	% or Points	SE	% or Points	SE
Antecedent level—school/classroom															
School provides teachers with digital learning materials (yes)	■	77.2	12.6	64.0	4.3	■	50.1	7.1	49.3	4.8	■	58.8	12.0	42.1	4.5
Existence of a curriculum for ICT use in teaching (yes)	■	72.6	13.2	78.2	3.7	■	87.4	5.2	79.4	4.3	■	83.4	7.7	81.9	2.8
ICT coordinators' reports on availability of utility software at school (scale)	▲	57.3	1.9	53.0	0.5	▼	44.6	1.5	48.8	0.6	■	49.6	2.5	49.6	0.9
Principals' reports on priorities for facilitating use of ICT (scale)	■	47.3	1.6	46.8	0.7	▲	52.3	1.4	48.9	0.9	■	53.1	2.4	51.7	0.8
Antecedent level—student characteristics															
Gender (female)	▲	58.0	3.1	49.9	1.5	■	46.4	1.4	49.5	1.0	■	49.7	2.5	50.3	1.3
Aspired for educational qualification (ISCED level 3 or higher)	■	95.0	1.1	95.1	0.5	■	96.7	0.6	96.2	0.4	■	88.9	2.2	90.9	0.6
Immigration background (immigration background)	■	20.0	4.4	28.1	1.3	▲	20.3	2.2	11.3	1.2	■	9.2	2.8	14.6	1.0
Antecedent level—home environment															
Number of books at home (more than 25 books)	■	69.1	3.1	71.3	1.5	■	62.8	1.8	66.7	1.8	▼	47.0	2.6	57.2	1.6
Access to computers at home for schoolwork (most times or always)	■	91.3	1.9	89.1	0.7	■	72.2	1.9	67.3	1.6	■	89.8	1.5	87.9	0.7
Process level—school/classroom															
General classroom applications usage (scale)	▲	48.7	0.6	47.2	0.3	▲	48.3	0.5	46.8	0.4	■	52.4	0.5	52.4	0.2
ICT studies in current school year (yes)	■	69.2	6.7	56.7	3.0	■	57.8	3.6	55.7	2.3	■	84.8	2.8	82.0	1.6
Process level—student learning process															
Learning about internet-related tasks at school (scale)	■	48.5	0.6	47.4	0.2	■	48.5	0.5	47.6	0.4	■	55.2	0.8	55.3	0.3
ICT self-efficacy regarding the use of general applications (scale)	■	49.1	0.4	49.6	0.2	■	51.0	0.3	51.1	0.2	■	50.3	0.5	50.5	0.2
Attitudes towards statement "It is important for students to learn ICT at school" (agree)	■	87.4	1.8	88.1	0.8	▲	94.3	0.8	92.0	0.6	■	94.1	1.1	94.3	0.5
Process level—home environment															
Learning about internet-related tasks outside of school (scale)	■	46.3	0.7	47.3	0.2	■	51.7	0.3	51.9	0.2	■	53.7	0.6	52.6	0.2

▲ Percentage/point value is significantly higher than the corresponding value for other schools ($p < 0.05$). ■ No significant difference in percentage/point value compared to the corresponding value for other schools. ▼ Percentage is significantly lower than the corresponding value for other schools ($p < 0.05$).

6.2.1. Antecedent Level

At the school and classroom levels, differences in ICT infrastructure and leadership priorities emerged as significant in several countries. In Austria, resilient schools reported a significantly higher availability of utility software, with ICT coordinators rating availability at 57.3 scale points compared to the 53.0 in other schools. Conversely, in Italy, the availability of such software was significantly lower in resilient schools, scoring 44.6 compared to the 48.8 in other schools. Leadership priority for facilitating ICT use also distinguished resilient schools. In Italy, principals of resilient schools rated this priority at 52.3, significantly higher than the 48.9 reported by principals in other schools. These differences suggest that school leadership's emphasis on digital integration plays a role in supporting resilience, particularly in Italy. However, there were no statistically significant differences across countries regarding whether schools provided digital learning materials to teachers or had a curriculum for ICT use in teaching.

In terms of student characteristics, resilient schools in Austria had a significantly higher proportion of female students, with 58.0% of the student body being female compared to 49.9% in other schools. Gender was not a distinguishing factor in Italy or Portugal. Immigration background also showed significant contrasts. In Italy, 20.3% of students in resilient schools had an immigration background, significantly higher than the 11.3% observed in other schools. There were no significant differences in the proportion of students aspiring to complete ISCED level 3 or higher in any of the countries.

At the home environment level, a significant difference was found only in Portugal, where students in resilient schools were less likely to report having more than 25 books at home. Specifically, 47.0% of students in resilient schools reported this level of book ownership compared to 57.2% in other schools, suggesting that resilient schools in Portugal often serve students from less text-rich environments. Access to computers at home for schoolwork did not differ significantly between resilient and other schools in any country.

6.2.2. Process Level

In the school/classroom process dimension, the use of general ICT applications in the classroom was significantly higher in resilient schools in both Austria and Italy. In Austria, the scale score was 48.7 in resilient schools compared to 47.2 in other schools. In Italy, resilient schools scored 48.3 versus the 46.8 in other schools. In Portugal, both resilient and other schools reported the same score of 52.4, with no statistically significant difference despite the relatively high value. The percentage of students taking ICT studies during the current school year did not differ significantly across countries.

Student learning processes showed fewer significant differences. ICT self-efficacy and reported learning of internet-related tasks at school were comparable between resilient and other schools in all countries. For example, in Italy, ICT self-efficacy scores were nearly identical: 51.0 in resilient schools and 51.1 in other schools. However, Italian students in resilient schools were significantly more likely to believe it is important to learn ICT at school, with 94.3% agreeing compared to 92.0% in other schools. This may indicate a stronger motivational emphasis on digital learning among students in resilient schools in Italy.

Regarding learning internet-related tasks outside of school, no significant differences were observed. For instance, in Portugal, 53.7% of students in resilient schools reported such learning compared to 52.6% in other schools.

Overall, statistically significant differences between resilient and other schools were relatively limited but concentrated in meaningful areas. No uniform patterns emerged across countries concerning specific characteristics of resilient schools. Rather, country-specific factors appear to be relevant for the resilience status of schools within each analysed country.

6.3. Antecedent- and Process-Level School Characteristics as Predictors of Digital Competences in Resilient and Other Schools in Countries with Substantial Proportions of Resilient Schools

Building on the descriptive comparisons in the previous sections (Sections 6.1 and 6.2), this section adopts a more analytical approach by examining the relationships between antecedent- and process-level school characteristics and students' digital competences. Through linear hierarchical regression analysis, we aim to provide a deeper understanding of how these factors contribute to students' computer and information literacy (CIL) in both resilient and other schools across Austria, Italy, and Portugal. Given the multifactorial nature of digital competence acquisition, it is crucial to not only assess the individual influence of school characteristics but also account for their potential interaction effects. This analysis offers insights into the predictive value of contextual school features and educational processes, highlighting how these differ across national contexts and between school types.

Tables 5–7 present the results of the hierarchical linear regression models for Austria, Italy, and Portugal, respectively. Model 1 includes only antecedent-level factors, while Model 2 extends the analysis by incorporating process-level variables. The dependent variable in all models is student digital competence, operationalised via the CIL scale. Separate regressions were conducted for resilient and other schools to identify specific patterns and variations in predictors.

Table 5. Linear regression analysis results on antecedent- and process-level factors predicting CIL in resilient schools and other schools in Austria.

	Austria							
	Resilient Schools				**Other Schools**			
	Model 1		**Model 2**		**Model 1**		**Model 2**	
	b	**b.se**	**b**	**b.se**	**b**	**b.se**	**b**	**b.se**
Antecedent level—school/classroom								
School provides teachers with digital learning materials [1]	−6.2	24.7	−3.6	12.2	1.2	6.6	0.5	6.4
Existence of a curriculum for ICT use in teaching [1]	−1.0	11.9	−6.1	23.1	9.8	6.4	9.8	6.3
ICT coordinators' reports on availability of ICT resources at school [2]	−0.8	1.1	−1.0	1.1	1.1	0.7	0.7	0.6
Principals' reports on priorities for facilitating use of ICT [2]	1.8	1.9	1.7	2.0	−0.5	0.5	−0.3	0.4
Antecedent level—student characteristics								
Gender [3]	6.6	6.8	4.8	6.7	**10.0**	3.6	**9.6**	3.9
Aspired for educational qualification [4]	**46.6**	13.6	30.2	17.2	**38.5**	8.6	**29.5**	8.3
Immigration background [5]	−0.8	13.5	0.8	13.2	−9.0	5.2	−8.3	4.8
Antecedent level—home environment								
Number of books at home [6]	**37.0**	10.8	**31.6**	10.3	**44.8**	5.5	**35.4**	4.9
Access to desktop or laptop computers at home for schoolwork [7]	−8.3	27.3	−17.4	27.3	**49.4**	7.1	**39.4**	6.4
Process level—school/classroom								
General classroom applications usage [2]			0.7	0.6			**−0.6**	0.2
ICT studies in current school year [1]			8.0	10.1			−5.8	4.7
Process level—student learning process								
Learning about internet-related tasks at school [2]			−0.5	0.7			−0.2	0.3
ICT self-efficacy regarding the use of general applications [2]			0.2	0.6			**1.0**	0.3
Attitudes towards statement "It is important for students to learn ICT at school" [8]			**47.6**	17.6			**33.0**	5.7

Table 5. *Cont.*

	Austria							
	Resilient Schools				Other Schools			
	Model 1		Model 2		Model 1		Model 2	
	b	b.se	b	b.se	b	b.se	b	b.se
Process level—home environment								
Learning about internet-related tasks outside of school [2]			0.2	0.8			0.3	0.2
Constant	421.5	69.7	394.3	74.9	342.0	39.9	333.5	40.6
Adj. R^2	0.15		0.20		0.19		0.21	

Notes: b—regression weights (unstandardised); dependent variable: CIL; significant coefficients are bolded ($p < 0.05$). [1] 0—no, 1—yes; [2] scale; [3] 0—male, 1—female; [4] 0—ISCED level 2 or below, 1—ISCED level 3 or higher; [5] 0—no immigration background, 1—immigration background; [6] 0—up to 25 books, 1—more than 25 books; [7] 0—sometimes or less often, 1—most times or always; [8] 0—disagree, 1—agree.

Table 6. Linear regression analysis results on antecedent- and process-level factors predicting CIL in resilient schools and other schools in Italy.

	Italy							
	Resilient Schools				Other Schools			
	Model 1		Model 2		Model 1		Model 2	
	b	b.se	b	b.se	b	b.se	b	b.se
Antecedent level—school/classroom								
School provides teachers with digital learning materials [1]	0.2	6.7	−1.0	7.6	−5.3	7.0	−8.6	6.3
Existence of a curriculum for ICT use in teaching [1]	−3.4	6.9	−4.3	7.4	−5.2	8.0	−2.9	7.8
ICT coordinators' reports on availability of ICT resources at school [2]	0.1	0.3	0.1	0.3	0.3	0.5	0.2	0.4
Principals' reports on priorities for facilitating use of ICT [2]	−0.3	0.6	−0.3	0.7	−0.3	0.5	0.0	0.4
Antecedent level—student characteristics								
Gender [3]	**11.2**	5.3	10.2	5.3	**15.1**	3.9	**14.1**	3.3
Aspired for educational qualification [4]	**71.7**	14.1	**66.8**	14.1	**20.3**	9.0	**18.2**	9.3
Immigration background [5]	−11.8	6.8	−8.2	6.7	−1.3	6.5	1.0	6.0
Antecedent level—home environment								
Number of books at home [6]	**17.6**	5.0	**16.5**	5.1	**36.2**	5.5	**33.9**	4.9
Access to desktop or laptop computers at home for schoolwork [7]	**29.5**	5.4	**25.1**	5.3	**41.2**	4.3	**32.5**	4.2
Process level—school/classroom								
General classroom applications usage [2]			−0.1	0.4			0.0	0.2
ICT studies in current school year [1]			−1.4	6.3			−5.5	4.7
Process level—student learning process								
Learning about internet-related tasks at school [2]			0.0	0.3			0.1	0.2
ICT self-efficacy regarding the use of general applications [2]			**0.7**	0.3			**1.4**	0.2
Attitudes towards statement "It is important for students to learn ICT at school" [8]			**38.4**	16.1			**24.8**	7.4
Process level—home environment								
Learning about internet-related tasks outside of school [2]			**0.8**	0.3			0.0	0.2
Constant	417.9	30.9	328.8	51.4	413.5	34.7	324.5	37.1
Adj. R^2	0.16		0.21		0.17		0.22	

Notes: b—regression weights (unstandardised); dependent variable: CIL; significant coefficients are bolded ($p < 0.05$). [1] 0—no, 1—yes; [2] scale; [3] 0—male, 1—female; [4] 0—ISCED level 2 or below, 1—ISCED level 3 or higher; [5] 0—no immigration background, 1—immigration background; [6] 0—up to 25 books, 1—more than 25 books; [7] 0—sometimes or less often, 1—most times or always; [8] 0—disagree, 1—agree.

Table 7. Linear regression analysis results on antecedent- and process-level factors predicting CIL in resilient schools and other schools in Portugal.

	Portugal							
	Resilient Schools				Other Schools			
	Model 1		Model 2		Model 1		Model 2	
	b	b.se	b	b.se	b	b.se	b	b.se
Antecedent level—school/classroom								
School provides teachers with digital learning materials [1]	−5.4	8.0	−10.1	7.8	1.8	5.7	0.4	5.2
Existence of a curriculum for ICT use in teaching [1]	−8.0	7.4	−2.4	8.3	9.9	8.9	4.5	7.4
ICT coordinators' reports on availability of ICT resources at school [2]	0.5	0.3	0.3	0.3	0.5	0.3	0.3	0.2
Principals' reports on priorities for facilitating use of ICT [2]	0.4	0.3	0.5	0.3	**−0.7**	0.3	−0.5	0.3
Antecedent level—student characteristics								
Gender [3]	10.4	6.0	**12.0**	6.0	2.5	3.5	4.8	3.4
Aspired for educational qualification [4]	17.0	13.2	10.1	13.9	**39.8**	6.9	**37.6**	6.7
Immigration background [5]	−12.8	9.0	−12.3	10.3	−8.5	5.6	−9.1	5.4
Antecedent level—home environment								
Number of books at home [6]	**33.5**	7.5	**32.7**	7.6	**43.7**	4.2	**36.7**	3.7
Access to desktop or laptop computers at home for schoolwork [7]	**63.9**	13.3	**59.9**	12.9	**43.1**	5.8	**33.3**	5.6
Process level—school/classroom								
General classroom applications usage [2]			0.0	0.5			−0.1	0.2
ICT studies in current school year [1]			9.7	9.7			**11.3**	4.6
Process level—student learning process								
Learning about internet-related tasks at school [2]			−0.2	0.4			**−1.0**	0.2
ICT self-efficacy regarding the use of general applications [2]			**1.1**	0.5			**1.8**	0.2
Attitudes towards statement "It is important for students to learn ICT at school" [8]			−15.2	13.1			**30.7**	7.2
Process level—home environment								
Learning about internet-related tasks outside of school [2]			0.0	0.4			−0.2	0.2
Constant	401.6	31.8	367.6	37.3	413.5	23.3	377.0	26.9
Adj. R^2	0.20		0.24		0.19		0.24	

Notes: b—regression weights (unstandardised); dependent variable: CIL; significant coefficients are bolded ($p < 0.05$). [1] 0—no, 1—yes; [2] scale; [3] 0—male, 1—female; [4] 0—ISCED level 2 or below, 1—ISCED level 3 or higher; [5] 0—no immigration background, 1—immigration background; [6] 0—up to 25 books, 1—more than 25 books; [7] 0—sometimes or less often, 1—most times or always; [8] 0—disagree, 1—agree.

Results are presented with a focus on statistically significant coefficients ($p < 0.05$), which are marked in bold in the tables. The unstandardised regression coefficients (b) are reported, allowing for direct interpretation in terms of CIL scale points. This facilitates an understanding of how much a unit change in a given predictor is associated with a change in students' digital competence scores.

The country-specific presentation of findings acknowledges the national variations in school system contexts, as already revealed in the descriptive findings relating to research question 2. This approach allows for a more nuanced interpretation of the mechanisms that underpin digital resilience in each educational system.

6.3.1. Austria

For resilient schools in Austria (Table 5), Model 1 showed significant associations for aspirations regarding educational qualifications (b = 46.6, SE = 13.6) and books at home as an indicator of cultural capital (b = 37.0, SE = 10.8). In Model 2, books at home (b = 33.6, SE = 10.3) and ICT attitudes (b = 47.6, SE = 17.6) remained significant, indicating that attitudinal factors gain predictive power once process-level variables are included. Students' aspired for educational qualifications lost their significance in Model 2.

In other schools, results were slightly different. Model 1 identified gender (b = 10.0, SE = 3.6), aspirations (b = 38.5, SE = 8.6), books (b = 44.8, SE = 5.5), and computer access (b = 49.4, SE = 7.1) as significant. Model 2 confirmed these and also highlighted a negative relationship with general classroom application usage frequency (b = −0.6, SE = 0.2), as well as positive associations with ICT self-efficacy (b = 1.0, SE = 0.3) and ICT attitudes (b = 33.0, SE = 5.7) as meaningful contributors.

To sum up, the main difference between resilient and other schools in Austria appears to be the magnitude of the ICT attitude coefficient, which is stronger in resilient schools, suggesting enhanced receptivity to digital learning environments. In addition, certain student home environment factors, such as access to computer resources, seem to be less important for the acquisition of competences among students at resilient schools.

6.3.2. Italy

In resilient schools in Italy (Table 6), Model 1 indicated that being female (b = 11.2, SE = 5.3), aspiring to higher education (b = 71.7, SE = 14.1), having more than 25 books at home (b = 17.6, SE = 5.0), and regular access to a computer for schoolwork (b = 29.5, SE = 5.4) were significantly associated with higher CIL scores. These relationships persisted—except for in the case of gender—in Model 2, where educational aspirations (b = 66.8, SE = 14.1), books at home (b = 16.5, SE = 5.1), and computer access for learning (b = 25.1, SE = 5.3) remained significant. Additionally, ICT self-efficacy (b = 0.7, SE = 0.3), positive attitudes toward ICT education (b = 38.4, SE = 16.1), and learning about internet-related tasks outside school (b = 0.8, SE = 0.3) emerged as significant predictors once process-level variables were included.

In other schools, the same pattern largely held. In Model 1, gender (b = 15.1, SE = 3.8), aspirations (b = 20.6, SE = 9.1), books at home (b = 36.2, SE = 5.5), and computer access (b = 41.5, SE = 4.3) were significant. These factors remained significant in Model 2, with ICT self-efficacy (b = 1.4, SE = 0.2) and ICT attitudes (b = 24.8, SE = 7.4) also reaching significance.

All in all, the main differences when comparing resilient schools to other schools in Italy appear to be the stronger relevance of the ICT attitude coefficient in resilient schools, as well as the heightened impact of aspired for educational qualifications on CIL outcomes.

6.3.3. Portugal

Among resilient schools in Portugal (Table 7), Model 1 showed that only home environment-related factors such as books (b = 33.5, SE = 7.5) and computer access (b = 63.9, SE = 13.3) were significant predictors. In Model 2, the effects of books at home (b = 32.7, SE = 7.6) and computer access (b = 59.9, SE = 12.9) remained significant, with female gender (b = 12.0, SE = 6.0) and ICT self-efficacy (b = 1.1, SE = 0.5) also becoming significant. Interestingly, the coefficient for ICT attitudes was not significant in resilient schools and even trended negatively, suggesting possible contextual factors limiting its impact.

In other schools, Model 1 yielded significant results for educational aspirations (b = 39.8, SE = 6.9), books at home (b = 43.7, SE = 4.2), and computer access (b = 43.1, SE = 5.8), as well as a negative relationship with principals' priorities for facilitating the use of ICT (b = −0.7, SE = 0.3). Model 2 confirmed these findings—except for the significant negative relation to the principals' priorities—and additionally identified ICT studies during the current school year (b = 11.3, SE = 4.6), ICT self-efficacy (b = 1.8, SE = 0.2), and attitudes toward ICT (b = 30.7, SE = 7.2) as significant predictors. Moreover, there was a weak but significant negative relationship between learning about internet-related tasks at school (b = −1.0, SE = 0.2) and students' digital competences. This relationship did not apply to resilient schools, suggesting differences at the level of the learning process. The

stronger relationship of ICT attitudes to CIL in other schools compared to resilient ones may point to a differentiated emphasis on motivational engagement strategies in Portugal.

Overall, the aforementioned results reveal certain patterns in relation to relevant factors for digital competence acquisition in resilient schools, which will be specified and theoretically grounded in the Discussion part. However, the impression of country-specific differences between resilient and other schools remains, following on from the answer to the second research question.

7. Cross-National and Country-Specific Summary and Discussion

The findings of this study provide important insights into the multifaceted nature of resilient schools in the context of digital competence acquisition. In the following, these findings are discussed against the theoretical and empirical background (Section 7.1), and theoretical (Section 7.2), research-related (Section 7.3), and practical implications for schools (Section 7.4) are derived.

7.1. Discussion of the Results of This Paper in Light of the Theoretical and Empirical Background

To answer the first research question, the existence of resilient schools across the world was analysed. In line with previous research findings (Eickelmann et al., 2019; Drossel et al., 2020), it was shown that resilient schools exist in different forms in many, but not all, of the countries analysed. This could indicate that the contingency theory (Creemers et al., 2000), the compensatory model (Teddlie et al., 2000), and the hypothesis of additivity (Reynolds & Teddlie, 2000) are all applicable, depending on the country. While the contingency theory and the compensatory model could explain the existence of resilient schools in certain countries, the hypothesis of additivity appears to apply to countries without resilient schools, although other reasons for the non-existence of resilient schools, such as a very small proportion of students in the lower third of the HISEI, could also play a role. A comparison with the current state of research indicating the proportions of resilient schools in different countries in 2013 and 2018 also shows the variability of the proportion of resilient schools over time. The proportion of resilient schools has tended to decrease in some countries such as Germany, whereas, in other countries, there seems to have been an increase, such as in Italy, which may also go along with the general digital competence increase in Italy between 2018 and 2023 (Fraillon et al., 2025).

The application of the theoretical framework of the ICILS 2023 (Rožman et al., 2025) to address the second research question reveals that only a limited number of antecedent- and process-level factors differ between resilient and other schools. However, the varying significance of these factors across different national contexts emphasises the complexity of resilience as a context-dependent phenomenon. This finding lends support to the contingency theory, which posits that resilient schools must adapt to their unique environment (Creemers et al., 2000). This may account for the observed country-specific variations in the findings. It is imperative to emphasise that the absence of variation between resilient and other schools for specific factors does not imply the negligible nature of these factors. It is conceivable that these measures could be of importance for both resilient and other schools. In fact, the ICILS model (Rožman et al., 2025) suggests that some baseline antecedents, such as a supportive ICT infrastructure and access to digital learning opportunities, may be necessary conditions across all school types. Therefore, the observed similarity might indicate a shared foundation for fostering digital competences, rather than a lack of relevance. In conclusion, it is possible to interpret these results as indications of differences. However, it should be noted that they do not allow any direct conclusions to be drawn about the actual promotion of digital competences. Instead, they point to the need for more nuanced

analyses that incorporate both antecedents and processes, as outlined in the ICILS 2023 framework and addressed by the third research question.

The third research question focused on the relationship between antecedent- and process-level factors and students' digital competences in resilient schools and in other schools in different countries. At a cross-national level, the presence of a discernible distinction between resilient schools and all other schools as their counterparts becomes evident. This distinction is characterised not solely by variances in student performance outcomes, but also by the manner in which these schools leverage and respond to the unique characteristics of their students and the contextual resources available to them.

A hallmark of resilient schools could be their augmented capacity to modify the characteristics of certain students, including their educational aspirations and their positive attitudes towards ICT, and to correlate these with digital competences. In Austria and Italy in particular, aspirations and attitudes related to learning with ICT have been shown to be strong predictors of competence in resilient schools. This finding indicates that these environments might be more successful at cultivating and leveraging students' engagement. This would constitute a substantiation of the compensatory model, which emphasises the significance of elevated expectations with regard to students' achievements. As ISCED level 3 is used in this study as a cut-off point for dichotomisation of the variable—a relatively low educational aspiration threshold—supporting expectations related to student achievement might also be relevant in this regard. Portugal seems different in this context, as aspirations and attitudes are not significant predictors in resilient schools for digital competences. Nevertheless, the differences also seem to lie in connection to student learning, as learning about internet-related tasks at school is negatively related to digital competences at other schools, whereas, at resilient schools, there is at least no significant relation. This implies that there might be differences related to the quality of teaching and learning with and about ICT in resilient schools, and aligns with the qualitative empirical results of Drossel et al. (2025). Another notable difference lies in the degree to which resilient schools depend on students' home environments. While cultural and material resources—such as the number of books at home or access to a computer for learning—are strong predictors of digital competence in general, resilient schools appear to be less reliant on these external advantages. This might suggest that resilient schools are better equipped to compensate for potential deficits in students' home environments and provide compensatory support that promotes equity in digital competence development. These results might be country-specific, as they are not in line with the findings of Lörz et al. (2024), who reported the relevance of such home environment factors for digital competences, especially at resilient schools in Germany.

In addition to the cross-national perspective outlined above, the results clearly indicate the need for a country-specific approach. In accordance with this approach, the results obtained specifically for Austria, Italy, and Portugal are discussed below. These country-specific results need to be interpreted in light of the respective national educational and digital policy contexts, which shape how resilience is enacted in schools and how digital competence is supported.

In Austria, for example, the long-standing efforts of the Federal Ministry of Education, Science, and Research to digitise education—starting with strategic frameworks in 2000 and culminating in the "8-point plan" launched in 2020 (Fraillon, 2025b)—appear to have laid strong foundational conditions for the development of resilient schools. The nationwide rollout of personal digital devices and the compulsory subject "Digital Literacy" for lower secondary students (Fraillon, 2025b) could explain why students' attitudes and aspirations in Austria are particularly influential in resilient schools. These developments might also

contribute to a culture where resilient schools can activate student engagement with ICT more effectively, aligning with the compensatory model.

In Italy, similar national efforts under the "Piano Nazionale Scuola Digitale" provide a framework for systemic ICT integration (Fraillon, 2025b). The strong performance of resilient schools in Italy regarding student aspirations and attitudes might be linked to these efforts, as well as the flexibility granted to schools in implementing digital assessment and certification. The observed increase in the number of resilient schools in Italy between 2018 and 2023 could reflect both policy momentum and improving digital competencies, indicating a potentially successful application of both compensatory and contingency models.

In contrast, Portugal's approach emphasises transversal digital literacy and a recent digital transition action plan (PADDE) including infrastructure, teacher training, and resource development (Fraillon, 2025b). However, the lack of significant predictive power of student aspirations and attitudes for digital competence in resilient schools may suggest a stronger reliance on systemic support rather than leveraging student-driven motivation. This would support a slightly different interpretation of the compensatory model in Portugal, where school-level adaptation to systemic frameworks might be more critical than fostering individual student characteristics.

These observations underscore the relevance of contingency theory in understanding school resilience, as national frameworks and institutional autonomy intersect differently in shaping digital learning environments across countries.

7.2. Theoretical Implications

As outlined in the preceding section, the present study provides substantiation for all four theoretical approaches—namely, contingency theory, the compensatory model, the hypothesis of additivity, and the ICILS 2023 framework model—that have been previously mentioned and described. Therefore, an overarching approach that integrates these four theoretical perspectives into a theory of digital school resilience would be appropriate. The ICILS 2023 framework (Rožman et al., 2025) provides a valuable foundation for this integration by offering a structured model that distinguishes between antecedents (e.g., school ICT infrastructure, home digital environment), processes (e.g., paedagogical ICT use, student self-efficacy), and outcomes (e.g., computer and information literacy). This framework not only captures the multifaceted nature of digital competence acquisition but also aligns with the theoretical emphasis on differentiated inputs, responsive strategies, and outcome disparities in disadvantaged school contexts. A school resiliency theory of this nature would encompass components such as environment-specific school responses to address students' pertinent issues, with a focus on enhancing learning quality and associated factors to develop students' digital competences and bridge the digital divide (Van Dijk, 2020). Specifically, the ICILS framework highlights how resilient schools might leverage antecedent conditions—such as leadership priorities and equitable ICT access—to establish robust digital learning processes that actively compensate for socio-economic disadvantages. This aligns with the compensatory model on context-awareness. It is also conceivable that this is related to the autonomy and resources of individual schools, as well as their country-specific context, in implementing such strategies. The integration of the ICILS also supports the contingency theory's claim that digital school resilience is not uniform but varies based on systemic and institutional conditions, including policy frameworks, funding models, and digital infrastructure. Such an overarching theoretical approach should be further developed and empirically examined in future work in order to enhance school resiliency and thereby improve the digital competences of all students. By combining the layered insights of the ICILS with the explanatory power of

resilience-oriented educational theories, future research can more precisely identify which configurations of conditions and strategies foster equitable and effective digital learning environments, particularly in socio-economically challenged contexts.

7.3. Further Research Implications

Building on the multifaceted findings of this study, several important implications—both conceptual and methodological—for future research emerge. First and foremost, the context-dependent nature of resilient schools highlights the need for mixed-methods approaches to fully capture the dynamics at play. While this study offers valuable quantitative insights across countries, the observed high heterogeneity in the characteristics and mechanisms of resilience—reflected in large standard errors and varying predictors—strongly suggests that qualitative studies are essential for a deeper understanding.

To this end, in-depth case studies of resilient schools could uncover the specific strategies, cultural conditions, and leadership practices that enable resilience in different settings. Such studies should focus not only on institutional structures but also on student-level processes, including engagement, self-efficacy, and learning experiences with digital tools. Ethnographic or longitudinal designs may be particularly valuable in tracing how resilient practices develop and are sustained over time.

In particular, it is important to acknowledge the methodological limitations of using standardised instruments such as Likert scales to assess complex learning processes. While such scales are useful for capturing general attitudes or self-reported frequencies of behaviours, they may fall short in accurately depicting crucial elements of learning—such as time on task, interaction patterns between students and teachers, or the depth and quality of engagement with digital tools. These nuanced aspects of learning, which are highly relevant for identifying truly resilient practices, are often better observed through non-participant classroom observation, video analysis, or process-tracing methods (Reinhold et al., 2020). Therefore, future research should reconsider the overreliance on self-reported survey data and incorporate naturalistic or behaviour-based data sources to improve the validity of findings related to digital school resilience.

Alongside qualitative exploration, further quantitative research is needed to validate and expand upon the results of this study. Future studies should aim to include a broader range of countries, especially those with limited representation in current datasets, in order to better understand global patterns of digital school resilience. Larger and more representative samples would enhance the statistical reliability of country-level comparisons and facilitate robust multilevel modelling that captures both system-level and school-level effects.

A crucial area for further investigation concerns the normative frameworks used to define school resilience. As this study applied strict operationalisation—based on students in the lower third of the HISEI spectrum performing in the upper third of the digital competence distribution—the question arises as to how different thresholds might influence both empirical results and policy relevance. Other approaches, such as that of Lörz et al. (2024), apply broader criteria, leading to alternative interpretations. Comparative studies that explicitly test the effects of different operational definitions could offer much-needed clarity and support the development of standardised yet context-sensitive classification systems.

Future research should also examine causal mechanisms more explicitly. While this study has revealed associations between antecedent-/process-level factors and digital competence, further studies employing quasi-experimental designs or structural equation modelling may better isolate the causal pathways through which school practices mediate disadvantage. In particular, the role of student aspirations and attitudes deserves further scrutiny, as these factors were consistently relevant in resilient schools in Austria and Italy,

although not in Portugal. Here, too, qualitative and mixed-methods approaches may be key in explaining such cross-national differences.

7.4. School Practical Implications

In order to address the digital divide (Van Dijk, 2020) and enhance school resilience—thereby cultivating students' digital competences—it is imperative to translate the findings of this study into tangible school practices.

The findings are of particular pertinence to schools with high proportions of students with low socio-economic status, as they assist in the development of digital resilience. However, the results are also relevant to all schools, as they address and compensate for socio-economic disparities.

Consequently, the professional development of teachers should encompass methodologies for addressing students' needs, enhancing learning, and influencing learning-related domains, including attitudes and educational aspirations. School leadership should support collaboration (Schmitz et al., 2025) among staff and use student data to guide evidence-based strategies.

Beyond school-level changes, support is also needed at the system level. Educational policies should provide schools with the flexibility, resources, and professional support necessary to address their students' challenges effectively (OECD, 2024). Partnerships with local communities and digital education networks can further reinforce this process (Hands, 2023).

While these general recommendations apply across school systems, the findings of this study also underscore the importance of tailoring interventions to national contexts. The mechanisms through which resilient schools foster digital competences vary across countries, reflecting different educational cultures, structural conditions, and socio-economic realities. The following country-specific insights illustrate how resilience manifests uniquely in Austria, Italy, and Portugal—and suggest differentiated focal points for policy and practice in each setting.

The findings from Austria highlight the particularly strong predictive power of positive ICT attitudes in resilient schools. Professional development initiatives in Austria should therefore focus on promoting positive dispositions toward ICT, both among students and teachers. Furthermore, the reduced importance of home digital access in resilient schools suggests that internal school structures may be compensating for external disadvantages. Schools in Austria may benefit from ensuring consistent access to ICT and fostering motivation for digital engagement, rather than relying solely on students' home environments.

In Italian resilient schools, educational aspirations and ICT attitudes emerged as particularly strong predictors of digital competence. This implies that fostering future-oriented mindsets and intrinsic motivation is key. Italian school leaders and policymakers should prioritise mentorship programs, goal-setting workshops, and culturally relevant digital curricula that inspire higher educational trajectories. Additionally, process-level factors such as ICT self-efficacy and informal digital learning opportunities outside of school were important, suggesting that Italian schools should leverage extracurricular digital activities and peer learning communities.

The Portuguese case indicates that resilient schools rely more on basic enabling conditions, such as access to books and digital devices, while ICT attitudes played a less significant role than in other countries. This may reflect a structural or motivational bottleneck. Therefore, in Portugal, ensuring widespread access to digital infrastructure remains critical, but must be coupled with efforts to build ICT confidence and meaningful usage, especially among students in non-resilient schools. Moreover, the negative association with school-based internet-related learning in non-resilient schools suggests a need to re-

think digital paedagogy, perhaps moving toward more integrated and application-oriented ICT instruction.

These country-specific findings affirm that resilient school practices are deeply context-dependent, in line with contingency theory. They also highlight that different countries may require differentiated policy approaches and tailored support mechanisms to enhance digital resilience. While overarching strategies such as improving teacher training and providing digital resources are universally important, the emphasis on student attitudes, aspirations, and contextual learning opportunities must be adapted to national educational cultures and school system structures.

In sum, resilient schools are characterised by their ability to enhance learning-related factors, buffer against socio-economic and cultural disadvantages, and structure digital learning in a way that maximises student engagement and inclusivity. These findings underscore the paedagogical and institutional distinctiveness of resilient schools and suggest that their practices can offer valuable insights for promoting digital competence and educational equity on a broader scale.

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