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Examining the Relationship between Teachers' Artificial Intelligence Awareness and Artificial Intelligence Literacy

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Abstract

The purpose of this study is to investigate the relationship between teachers' artificial intelligence (AI) awareness and their AI literacy. Additionally, the study examines whether teachers' AI awareness and literacy vary by factors such as gender, seniority, educational level, subject area, school level, frequency of AI tool use, and daily duration of AI tool use. The study was conducted with 888 teachers from different branches working in public primary and secondary schools in a province in the Western Black Sea Region of Türkiye. As data collection instruments, the "AI Literacy Scale" and the "Teachers' AI Awareness Level Scale" were employed. In the analysis, descriptive statistics, independent-samples t-tests, One-Way Analysis of Variance, Correlation, and simple linear regression were used. The research found a significant, positive relationship between teachers' AI awareness and AI literacy. Furthermore, it was determined that AI awareness is a significant predictor of AI literacy scores and explains a high proportion of the total variance in AI literacy. Additionally, significant differences were found in all other variables, except for gender and education level in teachers' AI awareness, and gender in AI literacy. The findings further demonstrate that, although teachers' AI awareness and literacy were relatively high, they experienced significant uncertainty about the functions and pedagogical opportunities offered by AI in teaching and learning. We recommend that high-quality professional development programs be designed to support teachers in acquiring knowledge and experience related to the pedagogical use of AI.

Keywords: AI, Artificial intelligence awareness, Artificial intelligence literacy, K–12 teachers.

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Introduction

Technological advancements have influenced the field of education as they have every other domain, and the use of AI in education has been discussed since the early 21st century. Consequently, the role of AI in education has become increasingly important across the learning-teaching process, teachers' instructional practices, and student learning. Potential effects of AI in the educational process include identifying students' individual learning needs, providing learning experiences tailored to students' levels (Aleven et al., 2019), developing learning materials (Hew & Cheung, 2018), and monitoring and measuring student achievement (Cai & Shen, 2021).

In recent years, breakthroughs in fields such as deep learning and artificial neural networks have enabled AI to provide personalized instructional services. By addressing students' learning processes, abilities, and needs, these services can overcome the limitations of traditional teaching environments (Chen et al., 2020). AI applications enrich the learning process, particularly through personalized instruction tailored to students' individual learning processes, paces, and needs (Crompton & Burke, 2023), adaptive feedback mechanisms, and interactive problem-solving scenarios (Ojeda-Bazaran et al., 2021). Indeed, AI technologies have the potential to improve educational processes by over 30% (Chen et al., 2020).

When evaluating the impact of AI from the teacher's perspective, AI tools can transform education. This is because AI technologies offer significant opportunities for teachers to guide their students better and provide recommendations by analyzing student performance (Cooper, 2023; Livieris et al., 2019). For example, through AI-supported tools, teachers can monitor student progress, evaluate student performance, and provide individual support when necessary (Zhang & Lu, 2021). Furthermore, AI stands out as a critical support element in facilitating teachers' professional tasks, such as grading, measurement, and evaluation, and providing feedback during the assessment of student learning (Zawacki-Richter et al., 2019). In this respect, AI provides pedagogical and technical support to teachers during the instructional process while offering the potential to provide more meaningful learning experiences for students (How & Hung, 2019). Consequently, AI assists teachers in maximizing student potential and creating a more effective learning environment (Shastri et al., 2021). Evaluated from this perspective, the rapid development of educational technologies has further heightened the importance of teachers' digital literacy and technological competence. Therefore, this development has made it necessary for teachers to recognize AI technologies and integrate them into instructional processes to effectively use AI in education (Holmes et al., 2019; Luckin, 2017). In this context, AI can be seen as a tool that helps teachers better respond to their students' needs. Both using AI effectively and benefiting from its opportunities require AI literacy (Davenport & Ronanki, 2018; Kandlhofer et al., 2016).

Internationally, countries such as China, Korea, India, and various European nations have recognized the transformative potential of AI in education and have begun integrating this technology into their curricula (Karan & Angadi, 2023; Park & Lim, 2023). Similarly, AI literacy has increasingly been included in the national curricula of many countries in recent years (Ayanwale et al., 2022; Han et al., 2018). However, research on the systematic, comprehensive, and holistic integration of this concept into teacher education programs is quite limited (Vazhayil et al., 2019). The growing impact of AI applications in education necessitates equipping teachers with the knowledge, skills, and attitudes to interact with them in a critical, ethical, and reflective manner during their professional development (pre-service and in-service) (Sperling et al., 2024). This global trend clearly underscores the importance of supporting teachers with the professional knowledge, technical skills, and pedagogical resources needed to integrate AI-based tools into instructional processes effectively. Thus, there is a significant need for research that reveals teachers' levels of AI-based competency.
An examination of the literature reveals that studies on AI literacy (Eguchi, 2021; Ng et al., 2021) have primarily been conducted in various fields such as K–12 (from preschool to secondary education), higher education (Bond et al., 2024; Laupichler, 2022), and professional life (Cetindamar et al., 2022), generally within the context of general AI literacy; teacher-oriented research appears to be quite limited. Therefore, to utilize AI technologies accurately, reliably, and effectively in

educational processes, it is considered crucial to determine the AI awareness and literacy levels of teachers responsible for planning these processes. Indeed, it is emphasized that determining teachers' competencies is vital not only for their ability to use technology but also for their capacity to guide students in critical thinking and to navigate AI-supported content (Ng et al., 2023).

Artificial intelligence awareness

Various studies in the literature have examined teachers' AI awareness. Analyzing these studies is essential for accurately assessing teachers' AI awareness and for identifying effective strategies to develop it. In some of these studies, AI awareness has been addressed through different dimensions. For instance, Li et al. (2025) define AI awareness through four fundamental components: "metacognition," "self-awareness," "social awareness," and "situational awareness." Metacognition is defined as the ability to represent and reason about one's own cognitive state; self-awareness as the capacity to recognize one's identity, knowledge level, and limitations; social awareness as the skill to understand the mental states, emotions, and intentions of others and to model social norms; and situational awareness as the competence to evaluate the environmental context and provide appropriate responses. At the national level, Ferikoğlu and Akgün (2022) address AI awareness in four dimensions: "Association," "Belief and attitude," "Theoretical knowledge," and "Practical knowledge." The association dimension measures the extent to which individuals relate AI to daily life, education, and professional practices; the belief and attitude dimension examines general acceptance and attitudes toward AI; the theoretical knowledge dimension assesses cognitive awareness regarding the fundamental concepts and mechanisms of AI; and the practical knowledge dimension measures individuals' skills in recognizing, using, and implementing AI tools in instructional environments. Furthermore, Ünal (2025) classifies AI awareness into two dimensions: cognitive and pedagogical. Cognitive awareness refers to teachers' level of understanding of the basic concepts, operating principles, potential, and limitations of AI, encompassing the skills to accurately define, exemplify, and relate to AI in interdisciplinary contexts. Pedagogical awareness, on the other hand, refers to the level of consciousness regarding how teachers can integrate AI technologies into instructional processes, use them to enrich teaching strategies, and manage the effects of AI on students' learning experiences. These studies demonstrate that AI awareness is a multifaceted construct that encompasses not only possessing knowledge but also how teachers internalize this knowledge and reflect it in educational processes.

In addition to studies aimed at identifying the dimensions of AI awareness, research is conducted at international and national levels to develop teachers' AI awareness. One such initiative is the "Education and Awareness for Intelligent Systems (ENARIS)" project, carried out by educators in Austria and Hungary. The project aimed to strengthen the AI awareness and conceptual understanding of K–12 teachers. Within this framework, workshops were conducted over two years under the titles of "AI basics," "Ethics," "Supervised learning," "Reinforcement learning," "Natural language processing," "Neural networks," "Art and artificial intelligence," and "AI and manipulation in social media." Although the results of this long-term research showed a significant increase in teachers' awareness and general knowledge of AI, they also highlighted that a large group of teachers still had low awareness. Another study conducted by Chiu (2023) found that the majority of teachers believed generative AI technologies, such as ChatGPT, made instruction more enjoyable and engaging, and that teachers were eager to learn more about the pedagogical applications of these technologies. Additionally, this research reported that some teachers expressed concerns regarding the potential impact of AI on the role of the teacher and the quality of education. At the national level, research on teachers' AI awareness remains quite limited. In a study examining teachers' AI awareness in terms of various demographic variables, Ünal (2025) found that teachers' AI awareness differed significantly according to the variables of branch and duration of technology use; however, no significant differences were found regarding gender, age, seniority, education level, school type, or participation in in-service training. Specifically, it was noted that information technology and science teachers exhibited higher awareness than teachers in other branches. Consequently, the research emphasized the importance of branch-based in-service training programs in increasing teachers' AI awareness. In another study conducted by Güler (2025), it was determined that faculty members working at universities possessed high AI awareness; among the dimensions of association, belief, and attitude, theoretical knowledge, and practical knowledge, the highest awareness was found in the "Theoretical Knowledge" dimension, while the lowest was in "Belief and Attitude." Furthermore, awareness differed significantly by age, academic title, and field, with faculty members in engineering and the sciences exhibiting higher levels. When studies in the literature are evaluated overall, it can be argued that developing teachers' AI awareness is critical to ensuring an innovative, ethical, and pedagogically grounded integration of AI in education.

Artificial intelligence literacy

While there is no universally accepted definition of AI literacy, one of the most frequently referenced definitions in the literature was provided by Long and Magerko (2020, p. 2). According to this definition, AI literacy is explained as "a set of competencies that enables individuals to evaluate AI technologies critically; communicate and collaborate effectively with AI; and use AI as a tool online, at home, and in the workplace." This definition is closely related to the concept of "AI readiness," which refers to the processes of understanding, applying, and integrating AI-based technologies across education and beyond (Luckin et al., 2022). Furthermore, the Digital Education Council (2025) defines AI literacy as the competency to use AI tools effectively and ethically, to evaluate the resulting outputs, to position humans at the center of AI processes, and to adapt to the evolving AI ecosystem at both personal and professional levels. This framework emphasizes five core dimensions that support individuals' skills in understanding, interacting with, and critically evaluating AI: 1) Understanding AI and data, 2) Critical thinking and judgment, 3) Ethical and responsible use, 4) Human-centeredness, emotional intelligence, and creativity, and 5) Domain expertise. Other studies also address AI literacy through a series of fundamental dimensions such as "understanding," "applying," "evaluating," "creating," and "addressing ethical concerns" (Chen & Zhang, 2025; Kalantzis & Cope, 2025; Ng et al., 2021).

These various approaches demonstrate that AI literacy is not limited to technical knowledge alone; it also encompasses higher-order cognitive skills such as critical thinking, ethical awareness, and creativity. In general, AI literacy refers to understanding AI technology's capabilities and limitations, and how it can be used to solve real-world problems (Kong et al., 2023). In other words, AI literacy involves not only technical proficiency but also the ability to integrate these technologies into one's life in an ethical, conscious, and responsible manner. This is because AI literacy concerns individuals' capacity to integrate AI technologies into their daily lives, use them ethically and effectively, select appropriate AI applications, reflect on the results, and evaluate them critically (Wang Rau & Yuan, 2022). Moreover, AI literacy is critical, especially for future teachers, for sustainable development and individual entrepreneurial orientation (Rieckmann et al., 2017; Zhao et al., 2024). This significance necessitates that teachers possess the required knowledge and skills in AI to effectively use AI technologies in the classroom (Selwyn, 2019). Indeed, the development of these competencies in teachers contributes not only to students' effective use of technology but also to their ability to apply technology responsibly and sustainably (Polat et al., 2025).

Aims and Research Questions

The digital generation expects technology-enhanced learning experiences, which necessitates the effective integration of AI into instructional processes (Zhou et al., 2024). Therefore, it is of paramount importance for teachers to ensure the equitable and responsible use of AI by developing pedagogical strategies. In this context, identifying teachers' AI awareness and literacy is vital for assessing their current state and guiding their professional development. Accordingly, the purpose of this study is to examine the relationship between teachers' AI awareness and their AI literacy. Within the scope of this objective, the study investigated whether teachers' AI awareness and AI literacy differ according to various variables (gender, seniority, educational level, branch, school level, knowledge of AI use, frequency of AI tool use, and daily duration of AI tool use) and determined the relationship between teachers' AI awareness and their AI literacy. The specific research questions (sub-problems) addressed in this study are as follows:

1. What are the levels of AI awareness among teachers?
2. What are the levels of AI literacy among teachers?
3. How do teachers' AI awareness vary according to the variables of gender, seniority, educational level, branch, school level, frequency of AI tool use, and daily duration of AI tool use?
4. How do teachers' AI literacy vary according to the variables of gender, seniority, educational level, branch, school level, frequency of AI tool use, and daily duration of AI tool use?
5. Is there a significant relationship between teachers' AI awareness and their AI literacy?
6. How does teachers' AI awareness predict their AI literacy?

Methodology

Participants and context

The study participants are 888 teachers from various branches (Mathematics, Science, Information Technology, etc.) working in public primary and secondary schools in a province in Türkiye's Western Black Sea Region during the 2024-2025 academic year. These teachers were selected from a population of approximately 2,000 teachers serving throughout the province. In selecting participants, the convenience sampling method was employed, with ease of access and feasibility of implementation taken into account. Demographic information regarding the research sample is presented in Table 1.

Table 1. Demographics of the sample group

Variable	Category	N	%
Gender	Female	530	59.7
	Male	358	40.3
Education level	Undergraduate	748	84.2
	Graduate	145	16.4
Seniority	1-5 years	82	9.2
	6-10 years	126	14.2
	11-15 years	214	24.1
	16-20 years	129	14.5
	21-25 years	139	15.7
	26-30 years	107	12.0
	30 years and above	91	10.2
Branch	Physical Education	35	3.9
	Other (Information Technology and Vocational Courses)	83	9.3
	Religious Culture and Ethics	44	5.0
	Visual Arts, Technology Design, Music, etc.	52	5.9
	English (Middle School/High School)	89	10.0
	Preschool	52	5.9
	Science (Middle School/High School Physics, Chemistry, Biology)	72	8.1
	Mathematics (Middle School/High School)	75	8.4
	Special Education	41	4.6
	Psychological Counselor and Guidance	25	2.8
	Primary	171	19.3
	Social Studies, History, Geography, etc.	57	6.4
	Turkish/Turkish Language and Literature	92	10.4

School level	Preschool	55	6.2
	Elementary	208	23.4
	Middle	361	40.7
	Secondary	264	29.7
Frequency of AI tool use	Never	140	15.8
	Rarely	397	44.7
	Once a month	22	2.5
	Once a week	190	21.4
	Almost every day	139	15.7
Daily duration of AI tool use	None	366	41,2
	1-2 hours	474	53,4
	3-4 hours	43	4,8
	4 hours and above	5	0,6

Approximately 60% of the participants are female, and 40% are male, with their seniority distribution predominantly (24.1%) falling within the 11-15 years range. The highest participation rate is among primary teachers (19.3%), while the lowest is among school counselors (2.8%). 84.2% of the participants have an undergraduate degree, while 16.4% have a graduate degree. The highest participation rate is among teachers at the middle school level (40.7%). Regarding AI use, a large proportion of participants (44.5%) reported having "limited knowledge." Similarly, the proportion of those who state they rarely use AI tools is also high (44.7%). While 41.2% of participants do not use AI tools at all, the majority (53.4%) reported using AI tools for 1-2 hours per day.

Data collection

The "AI Literacy Scale," adapted into Turkish by Eniş-Erdoğan and Ekşioğlu (2024), and the "AI Awareness Level Scale for Teachers," developed by Ferikoğlu and Akgün (2021), were utilized as data collection tools. The AI Awareness Level Scale for Teachers consists of 51 items across four sub-dimensions: Association, Belief and Attitude, Theoretical Knowledge, and Practical Knowledge. It was determined that this four-factor scale explained 70.27% of the total variance. The scale items are designed in a 5-point Likert-type format, ranging from "Strongly Agree" to "Strongly Disagree." The internal consistency coefficient for the scale's reliability was 0.986.

The validity and reliability of the AI Literacy Scale—originally developed by Wang et al. (2023) and adapted into Turkish by Eniş-Erdoğan and Ekşioğlu (2024)—were tested through factor analysis and internal consistency coefficients. Exploratory factor analysis (EFA) results indicated that the scale consists of four dimensions, consistent with the original version, and the total variance explained was 82.873%. The goodness-of-fit indices for the scale were calculated as follows: RMSEA = 0.078, NFI = 0.944, TLI = 0.952, CFI = 0.967, IFI = 0.967, and GFI = 0.931. The Cronbach's Alpha value for the scale was 0.861. This scale comprises 12 items across four sub-dimensions: Awareness, Usage, Evaluation, and Ethics. It is a 5-point Likert-type scale ranging from "Strongly Disagree" to "Strongly Agree.".

Internal consistency coefficients were recalculated in the present study to ensure the reliability of the instruments for this specific sample. While the original internal consistency coefficient for the AI Awareness Level Scale was reported as 0.986, it was 0.912 in this study. Similarly, the internal consistency coefficient for the AI Literacy Scale, which was 0.861 in the original adaptation, was calculated as 0.804 in the current study. The Cronbach's Alpha internal consistency coefficients obtained from both the original studies and the current research were high and consistent. These results indicate that the data collected through these scales are reliable for the sample group under investigation.

Data collection procedure

This research was conducted with the approval obtained from the Bartın University Social and Human Sciences Ethics Committee (Date: March 12, 2025; Decision No: 2025-SBB-0178). The study's data were collected via an online form created in Google Forms. This form included items from the AI Awareness Scale and the AI Literacy Scale, along with questions to collect participants' demographic information. The average completion time for the form was approximately 14 minutes. Participation in the study was strictly voluntary.

Data analysis

Before the analyses, the normality of the data obtained from both scales was examined using kurtosis and skewness coefficients. The kurtosis and skewness values for the AI Literacy Scale were calculated as 0.041 and -0.227. For the AI Awareness Level Scale for Teachers, the kurtosis was 0.652, and the skewness was -0.235. The fact that these values fall within ±1.96 standard errors indicates that the data follow a normal distribution (Tabachnick & Fidell, 2013).
Descriptive statistics, Independent Samples t-test, One-Way Analysis of Variance (one-way ANOVA), Correlation, and Simple Linear Regression analyses were utilized for the data analysis. The homogeneity of variances was analyzed using Levene's test. When variances were homogeneous, the Bonferroni post hoc test was preferred to account for differences in group sample sizes. Conversely, when variances were heterogeneous, the Welch test, which is robust to unequal variances and provides reliable results across different group sizes, was applied; for multiple comparisons, the Games-Howell post hoc test was used. Significant findings were interpreted by calculating their respective effect size values (Cohen's *d* and Eta Squared). For Cohen's *d*, values of 0.2, 0.5, and 0.8 were considered small, medium, and large effects. For Eta Squared (η^2), values of 0.01 were interpreted as a small effect, 0.06 as a medium effect, and 0.14 as a large effect size (Green & Salkind, 2005). Descriptive analyses were employed to determine the participants' AI awareness and AI literacy. By examining the mean and standard deviation values, AI awareness and literacy were classified based on the scores obtained from the 5-point Likert-type scales: values between 1.00 and 1.80 were categorized as "Very low," 1.81 to 2.60 as "Low," 2.61 to 3.40 as "Moderate," 3.41 to 4.20 as "High," and 4.21 to 5.00 as "Very high."

Results

Teachers' AI awareness and AI literacy levels

Regarding the research questions, "What are the levels of AI awareness among teachers?" and "What are the levels of AI literacy among teachers?", the results obtained for the sub-dimensions of the AI Awareness Level Scale and the AI Literacy Scale are presented in Table 2.

Table 2. Descriptive statistics for the scales

Scales and Sub-Dimensions	Kolmogorov-Smirnov				
	Statistic	df	Sig.	Skewness	Kurtosis
AI Awareness					
Practical Knowledge	0.056	888	0.000	-0.660	1.186
Belief and Attitude	0.041		0.001	-0.129	-0.76
Association	0.056		0.000	-0.213	0.269
Theoretical Knowledge	0.056		0.000	-0.461	0.902
AI Literacy					
Awareness	0.142		0.000	0.096	-0.121
Usage	0.117		0.000	0.102	-0.669
Evaluation	0.130		0.000	-0.618	0.589
Ethics	0.134		0.000	-0.358	-0.851

The skewness and kurtosis values for the sub-dimensions of the scales used as data collection instruments range from -1.5 to +1.5. This finding indicates that the data about the sub-dimensions of the scales follow a normal distribution (Tabachnick & Fidell, 2013). The statistical results for determining participants' AI awareness and AI literacy are presented in Table 3.

Table 3. Information regarding teachers' AI awareness and literacy

Sub-Dimensions	M	Sd.	Level	N
AI Awareness				**888**
Practical Knowledge	3.93	0.64	High	
Belief and Attitude	3.46	0.80	High	
Association	3.43	0.78	High	
Theoretical Knowledge	3.63	0.75	High	
Total	3.61	0.66	High	
AI Literacy				**888**
Awareness	3.66	0.70	High	
Usage	3.65	0.76	High	
Evaluation	3.61	0.91	High	
Ethics	4.03	0.78	Very High (at limit)	
Total	3.74	0.63	High	

Participants' overall AI awareness is at a "high" level. Regarding the sub-dimensions of the scale, the practical knowledge dimension (M = 3.93) had the highest mean, followed by theoretical knowledge (M = 3.63), belief and attitude (M = 3.46), and association (M = 3.43). It is observed that the participants' awareness is "high" across all sub-dimensions. Similarly, the participants' AI literacy was found to be at a "high level" (M = 3.74). Upon examining the sub-dimensions, the ethics dimension (M = 4.03) had the highest mean, followed by awareness (M = 3.66), usage (M = 3.65), and evaluation (M = 3.62).

Distribution of teachers' AI awareness levels

Under this heading, the variations in participants' AI awareness was examined across gender, educational level, seniority, branch, school level, AI knowledge, frequency of AI tool use, and daily duration of AI tool use. An independent-samples t-test was conducted to determine whether there was a significant difference in participants' AI awareness across gender groups. The test results revealed that participants' AI awareness scores did not show a significant difference according to their gender ($t_{(886)} = -0.984$, $p = 0.325 > 0.05$). When the mean AI awareness of the teachers was examined by gender, it was determined that the awareness means of female teachers (M = 3.59, SD = 0.64) and male teachers (M = 3.64, SD = 0.69) were quite similar to each other. The variation in participants' AI awareness by educational level was also analyzed using an independent-samples t-test. The results obtained are presented in Table 4.

Table 4. AI Awareness scores according to educational level

Level	N	M	SD	t	df	*p*	Cohen's *d*
Undergraduate	748	3.58	0.65	-2.778	886	0.006*	0.17
Graduate	140	3.75	0.71				

*$p < 0.05$

As a result of the analysis, a statistically significant difference was identified in the total mean AI awareness scores of the participants regarding the educational level variable, favoring teachers with a graduate degree ($t_{(886)} = -2.778$, $p = 0.006 < 0.05$). The effect size for this difference was found to be at a small level (Cohen, 1988). For the variables of seniority and branch, an ANOVA was used to examine whether there was a significant difference in participants' AI awareness scores. The analysis results indicated no significant difference in AI awareness scores by seniority ($F_{(6, 881)} = 1.526$, $p = 0.167 > 0.05$) or branch ($F_{(12, 885)} = 0.926$, $p = 0.520 > 0.05$). To examine the frequency of AI tool use, an ANOVA was conducted to determine whether participants' AI awareness scores differed. The test results revealed a significant difference in participants' AI awareness based on their frequency of use ($F_{(4, 883)} = 23.566$, $p < 0.001$, $\eta^2 = 0.096$). The effect size of this difference was interpreted as medium (Green & Salkind, 2005). The relevant findings are presented in Table 5.

Table 5. AI awareness scores according to the frequency of AI tool use

Frequency of Use	N	M	SD	F	*p*	Difference	η^2
Never (1)	140	3.34	0.72	23.566	0.00*	1-2,1-3,1-4,1-5,	0.096
Rarely (2)	397	3.51	0.63			2-4, 2-5, 4-5	
Once a month (3)	22	3.83	0.46				
Once a week (4)	190	3.71	0.59				
Almost every day (5)	139	3.99	0.63				
Total	888	3.61	0.66				

**p < 0.05*

Post hoc test results indicated that participants who never use AI tools (M = 3.34) had significantly lower awareness scores than those in all other groups. Furthermore, the awareness of teachers who use the tools rarely (M = 3.51) was significantly lower than those of teachers who use them once a week (M = 3.71) and almost every day (M = 3.99). The group with the highest awareness score consisted of participants who used AI tools almost every day. An ANOVA was conducted to examine whether participants' AI awareness scores differed as a function of daily AI tool use duration. The relevant findings are presented in Table 6.

Table 6. AI awareness scores according to daily duration of AI tool use

Daily duration of AI tool use	N	M	SD	F	*p*	Difference	η^2
None (1)	366	3.41	0.63	20.07	0.00*	1-2, 1-3	0.063
1-2 hours (2)	474	3.73	0.65				
3-4 hours (3)	43	3.89	0.68				
4 hours and above (4)	5	3.85	0.71				
Total	888	3.61	0.66				

**p < 0.05*

A significant difference was identified in participants' AI awareness regarding the daily duration of use ($F_{(3, 884)} = 20.07$, $p < 0.001$, $\eta^2 = 0.063$), with a medium effect size (Green & Salkind, 2005). According to the results of the Bonferroni post-hoc test, the awareness scores of teachers who do not use AI tools at all (M = 3.41) were significantly lower than those of teachers who use them for 1-2 hours (M = 3.73) and 3-4 hours (M = 3.89). In contrast, no significant difference was found between the groups using the tools for 1-2 hours, 3-4 hours, or 4 hours and above. This finding suggests that daily interaction with AI contributes to the development of awareness up to a certain level; however, this increase does not continue to a statistically significant degree beyond 3-4 hours of use. Whether there was a significant variation in participants' AI awareness scores across the school-level variable was examined using an ANOVA. The relevant findings are presented in Table 7.

Table 7. AI awareness scores according to school level

School level	N	M	F	*p*	Difference	η^2
Preschool (1)	55	3.54	3.020	0.029*	3-4	0.01
Elementary (2)	208	3.60				
Middle (3)	361	3.68				
Secondary (4)	264	3.53				
Total	888	3.61				

**p < 0.05*

A significant difference was identified in the participants' AI awareness regarding the school level variable ($F_{(3, 884)} = 3.02$, $p = .029 < 0.05$, $\eta^2 = 0.01$), and the effect size for this difference was found to be at a small level (Green & Salkind, 2005). According to the results of the Bonferroni multiple-comparison test, a significant difference was observed only between teachers at the middle school and secondary school levels ($p = 0.020$), in favor of those at the middle school level. Consequently, AI awareness among middle school teachers was significantly higher than among secondary school teachers.

Distribution of teachers' AI literacy levels

In this section, it was examined whether teachers' AI literacy varies across gender, educational level, seniority, branch, school level, AI knowledge, frequency of AI tool use, and daily duration of AI tool use. An independent-samples t-test was conducted to determine whether there was a significant difference in participants' AI literacy scores based on gender. The test results revealed that participants' AI literacy scores did not differ significantly by gender ($t_{(886)} = -1.710$, $p = 0.088 > 0.05$). The mean scores of females (M = 3.71) and males (M = 3.78) teachers were quite similar. Accordingly, it can be stated that gender is not a decisive factor in teachers' AI literacy. An independent-samples t-test was performed to investigate whether participants' AI literacy differed by educational level. The findings are presented in Table 8.

Table 8. Teachers' AI literacy scores according to educational level

Education level	**N**	**M**	**SD**	**t**	**Df**	***p***	**Cohen's *d***
Undergraduate	748	3.71	0.61	-3.21	886	0.002*	-0.33
Graduate	140	3.91	0.71				

**p < 0.05*

Teachers' AI literacy differs significantly by educational level. Levene's test indicated that the variances were not homogeneous ($F_{(1, 886)} = 5.29$, $p = 0.022$). Consequently, the assumption of equality of variances was bypassed, and Welch's t-test results were considered. According to Welch's t-test, a significant difference in teachers' AI literacy scores by educational level was identified ($t_{(179.24)} = -3.21$, $p = 0.002 < 0.05$). While the difference is statistically significant, the effect size is small ($d = -0.33$). The mean score of teachers with a graduate degree (M = 3.91, SD = 0.71) is significantly higher than that of teachers with an undergraduate degree (M = 3.71). This result indicates that teachers with graduate-level education have more advanced AI literacy. Whether there was a significant variation in participants' AI literacy scores across seniority levels was investigated using an ANOVA. Relevant findings are presented in Table 9.

Table 9. AI literacy scores according to the seniority variable

Seniority	**N**	**M**	**F**	**p**	**Difference**	**η^2**
1-5 years (1)	82	3.96	3.81	0.001	1-6, 1-7	0.025
6-10 years (2)	126	3.75				
11-15 years (3)	214	3.76				
16-20 years (4)	129	3.80				
21-25 years (5)	139	3.71				
26-30 years (6)	107	3.60				
30 years and above (7)	91	3.59				
Total	**888**	**3.74**				

**p < 0.05*

AI literacy differs significantly according to the seniority variable ($F_{(6, 881)} = 3.82$, $p = 0.001 < 0.05$). Bonferroni multiple comparison test results indicate a significant difference between teachers with 1-5 years of seniority and those with 26-30 years and over 30 years of seniority. When the mean differences are examined, the difference favors teachers with less seniority. However, the effect size was small ($\eta^2 = 0.025$). Whether there was a significant variation in participants' AI literacy scores across the branch variable was investigated using an ANOVA. The relevant findings are presented in Table 10.

Table 10. AI literacy scores according to the branch variable

Branş	**N**	**M**	**F**	***p***	**Difference**	**η^2**
Physical Education (1)	35	3.80	2.69	0.001	2-6	0.036
Other (Information Technology and Vocational Courses) (2)	83	3.94				
Religious Culture and Ethics (3)	44	3.58				
Visual Arts, Technology Design, Music, etc. (4)	52	3.88				
English (Middle School/High School) (5)	89	3.78				
Preschool (6)	52	3.53				
Science (Middle School/High School Physics, Chemistry, Biology) (7)	72	3.63				
Mathematics (Middle School/High School) (8)	75	3.78				
Special Education (9)	41	3.94				
Psychological Counselor and Guidance (10)	25	3.67				
Primary (11)	171	3.75				
Social Studies, History, Geography, etc. (12)	57	3.64				
Turkish/Turkish Language and Literature (13)	92	3.64				
Total	888	3.74				

$*p < 0.05$

AI literacy differs significantly according to the branch variable ($F_{(12, 875)} = 2.69$, $p = 0.001 < 0.05$). According to the results of the Bonferroni test. However, this difference is significant between preschool teachers and teachers in other branches (p = 0.014), favoring preschool teachers. The effect size ($\eta^2 = 0.036$) indicates that this difference is small. This finding suggests that teachers' AI literacy differ across branches. In this framework, it can be argued that early childhood teachers, in particular, should be supported in integrating technology and AI. To examine the frequency of AI tool use, an ANOVA was conducted to determine whether participants' AI literacy scores differed significantly. The relevant findings are presented in Table 11.

Table 11. AI literacy scores according to the frequency of AI tool use

Frequency of AI tool use	**N**	**M**	**F**	***p***	**Difference**	**η^2**
Never (1)	140	3.35	58.085	0.000*	1-2, 1-3, 1-4, 1-5, 2-3, 2-4, 2-5, 4-5	0.21
Rarely (2)	397	3.59				
Once a month (3)	22	4.02				
Once a week (4)	190	3.94				
Almost every day (5)	139	4.24				
Total	888	3.74				

$*p < 0.05$

Levene's test indicated that the variances were not homogeneous ($p < 0.05$). Therefore, Welch's test results were utilized as the basis for the analysis. According to the analysis results, participants' AI literacy differed significantly based on the frequency of AI tool use ($F_{(4, 136.66)} = 58.085$, $p < 0.05$). Games-Howell multiple comparison test results revealed that the literacy scores of teachers who "never used" AI tools (M = 3.10) were significantly lower than all other groups. Additionally, those who used the tools "almost every day" (M = 4.00) exhibited significantly higher literacy scores compared to those who used them "once a week" (M = 3.85). When the mean differences were examined, it was observed that as the frequency of AI tool use increased, teachers' AI literacy scores rose markedly. Consequently, the difference in literacy between teachers who used AI tools more frequently was not only statistically significant but also had a large effect size ($\eta^2 = 0.21$). Whether there was a significant variation in participants' AI literacy scores regarding the daily duration of AI tool use was investigated using an ANOVA. The relevant findings are presented in Table 12.

Table 12. AI literacy scores according to the daily duration of AI tool use

Daily duration of use	N	M	F	*P*	Difference	η²
None (1)	366	3.50	34.737	0.000*	1-2, 1-3	0.10
1-2 hours (2)	474	3.88				
3-4 hours (3)	43	4.12				
4 hours and above (4)	5	4.03				
Toplam	888	3.74				

*$p < 0.05$

Participants' AI literacy differs significantly according to the daily duration of AI tool use ($F_{(3, 884)} = 34.74$, $p < 0.05$). Bonferroni multiple comparison test results indicate that participants in the "None" range (M = 3.50) possess significantly lower AI literacy scores than those who use AI tools for "1-2 hours" (M = 3.88) and "3-4 hours" (M = 4.12) ($p < 0.05$). Upon examining the mean scores, it is observed that participants using AI tools for 3–4 hours daily have the highest AI literacy scores. In contrast, those who do not use them at all have the lowest. The significant difference between participants' daily AI usage durations and their AI literacy scores was found to have a medium effect size. This finding suggests that the duration of AI tool use has a positive and medium-level effect on teachers' literacy. An ANOVA was conducted to investigate whether there was a significant difference in participants' AI literacy scores across school levels. The relevant findings are presented in Table 13.

Table 13. AI literacy scores according to the school level variable

School level	N	M	F	*p*	Difference	η²
Preschool (1)	55	3.54	4.185	0.006	1-3	0.014
Elementary (2)	208	3.76				
Middle (3)	361	3.80				
Secondary (4)	264	3.67				
Toplam	888	3.74				

*$p < 0.05$

A significant difference with a small effect size (Cohen, 1988) was identified in participants' AI literacy for the school-level variable ($F_{(3, 884)} = 4.19$, $p = 0.006 < 0.05$, $\eta^2 = 0.014$). According to the results of the Bonferroni multiple comparison test, this difference was found between preschool teachers and middle school teachers, favoring the latter ($p = 0.022 < 0.05$). Upon examining the mean scores, it was determined that the AI literacy scores of preschool teachers (M = 3.54) were significantly lower than those of middle school teachers (M = 3.80).

Relationship between teachers' AI awareness and AI literacy levels

A Pearson correlation analysis was conducted to examine the relationship between participants' AI awareness and AI literacy. The findings are presented in Table 14.

Table 14. Relationship between AI awareness and AI literacy

Awareness_Literacy	**Pearson r**	0.626*
	p	0.000*
	N	888

*$p < 0.01$

There is a significant positive relationship between the participants' AI awareness and their AI literacy ($r = 0.626$, $p < 0.01$). In this context, the variance in participants' AI awareness scores can explain approximately 39.1% [$(0.626)^2 = 0.391$] of the change in their AI literacy scores.

Prediction of Teachers' AI Literacy by AI Awareness

A Simple Linear Regression analysis was conducted to reveal how AI awareness predicts AI literacy. The relevant results are presented in Table 15.

Table 15. Prediction of AI literacy scores by AI awareness scores

Variable	β	SH β	R	t	R^2	%95 CI
Fixed	1.601	0.091				1.423
AI Awareness	0.592	0.025	0.626	23.924	0.392	0.544

$*p < 0.05$

There is a significant relationship between participants' AI awareness scores and AI literacy scores ($\beta = 0.626$, $R^2 = 0.392$); furthermore, AI awareness is a significant predictor of AI literacy scores ($F_{(1, 886)} = 572.369$, $p < 0.05$). Participants' AI awareness explains 39.2% of the variance in their AI literacy scores, indicating that the model possesses high explanatory power (Cohen, 1988). The significance test of the coefficient for the primary predictor variable ($\beta = 0.592$) also demonstrates that AI awareness is a significant predictor ($p < 0.05$). The regression equation is as follows:
AI literacy score = (0.592 × AI awareness) + 1.601

In conclusion, AI awareness positively and significantly affects AI literacy scores. In other words, as AI awareness increases, participants' AI literacy also increases significantly.

Discussion and Conclusion

This study examined whether there is a significant relationship between teachers' AI awareness and their AI literacy. Furthermore, it sought to determine how these levels vary according to variables such as gender, seniority, educational level, branch, school level, frequency of AI tool use, and daily duration of AI tool use. The results indicated that teachers' AI awareness is generally high. Upon examining the sub-dimensions, the highest mean was observed in the practical knowledge dimension, suggesting that teachers have a relatively higher awareness of how AI can be used in classroom applications. Indeed, Ünal (2025) stated that teachers' AI awareness was highest in the practical sub-dimension; thus, the results of this study support that finding.

Another significant finding regarding AI awareness is the predominance of "undecided" responses concerning AI's potential for personalized instruction. Specifically, the "undecided" responses were in the majority for items such as "AI systems identify students' personalities, strengths, and weaknesses well," "Through AI, we can better learn students' personal needs," and "AI individualizes education." This situation may be attributed to teachers' lack of a clear conviction regarding AI's potential to support individualized instruction. Consequently, these results suggest that while teachers recognize AI at a general level, they may lack sufficient knowledge and experience with the specific opportunities AI offers for personalized instruction, or a clear idea of how to leverage them. Effectively integrating AI into instructional processes offers critical opportunities such as personalized learning, monitoring student progress, enhancing assessment and feedback, and improving the overall learning experience (Kamalov et al., 2023). Therefore, while high AI awareness are positive for recognizing AI's transformative potential, the weight of "undecided" responses indicates a need for applied professional development support to effectively realize this potential (Re et al., 2024).

Similarly, this study determined that teachers' AI literacy is generally high. This result is consistent with previous research demonstrating high AI literacy among teachers (İçen, 2024; Muzaffer & Ünal, 2025; Yüreğilli Göksu & Göksu, 2024). Regarding sub-dimensions, the ethics dimension had the highest mean, followed by awareness, usage, and evaluation, respectively. Indeed, Muzaffer and Ünal (2025) also emphasized that teachers' AI literacy is particularly high concerning the ethical dimension.

Regarding gender, no statistically significant differences were found in AI awareness or literacy. This overlaps with findings in the literature (Çayak, 2024; İçen, 2024; Muzaffer & Ünal, 2025; Ünal, 2025), suggesting that gender is not a decisive variable. However, the reporting of significant gender-based differences in some studies (İçen, 2024; İçöz & İçöz, 2024; Yüreğilli Göksu & Göksu, 2024) indicates a lack of consensus in the field, suggesting that results may vary across samples.

Regarding professional seniority, a significant difference with a small effect size was found in AI literacy, favoring teachers with less seniority. In contrast, no significant difference was detected for AI awareness. However, the observed downward trend in awareness scores with increasing seniority may be explained by high-seniority teachers' more limited experience with digital interaction. Kaplan and Haenlein (2019) and Kaya (2017) found that teachers with less experience are more open to technological innovations and use educational technology more intensively. This could also be related to the potential slowing of cognitive processes with age and the increasing need to adapt to new information (Cangöz, 2009). Conversely, conflicting results in the literature regarding seniority and technology use (Şengür, 2020) suggest that widespread digitalization and easier access to technology may now enable teachers to develop AI awareness regardless of their seniority.

In terms of educational level, both AI awareness and literacy differed significantly, favoring teachers with graduate degrees (small effect size). This is consistent with Ferikoğlu (2021), who emphasized that as educational levels increase, so does the level of monitoring and mastering current technological developments. However, some research suggests that education level has no significant effect on AI awareness (Erdoğan & Demirtaş, 2021; Ünal, 2025), suggesting that these competencies may be more closely related to individual motivation, interaction frequency, and institutional integration strategies than to degree level alone.

Regarding the branch variable, no significant difference was found in AI awareness, but a small, significant difference was identified in AI literacy, favoring preschool teachers. This may be explained by preschool teachers working with younger age groups, which limits the integration of AI tools. Variations in AI literacy across branches are closely related to the instructional level and the technology requirements. For teachers to develop competence, the inclusion of theoretical and applied digital content during undergraduate education is vital (Lindsey, 2015). Consequently, lower literacy in branches where AI use is not yet widespread (such as Preschool or Religious Culture and Ethics) may reflect current curricula.

For the school level, a significant difference was found in favor of middle school teachers in both awareness and literacy (small effect size). This contradicts studies suggesting AI awareness is independent of school type (Aksu, 2024; Ünal, 2025) and shows that diverse results can be reported in the literature.

Regarding the frequency of AI use, significant differences were found in awareness (medium effect) and literacy (large effect), favoring teachers who use AI tools almost every day. The marked increase in literacy scores with greater usage frequency suggests that experience-based practice is critical. This aligns with research reporting higher literacy among frequent users (Muzaffer & Ünal, 2025) and emphasizes that AI literacy develops through direct experience and application rather than just theoretical knowledge (Ravi et al., 2023; Zhao et al., 2022).

Similarly, daily usage duration showed significant differences with a medium effect size for both awareness and literacy. Teachers using AI for 3–4 hours daily exhibited the highest levels, while non-users had the lowest. The finding that growth plateaus after 4 hours underscores the importance of qualified, balanced interaction with technology. This is consistent with Ünal (2025), who identified significant differences in awareness based on usage duration.

Furthermore, this study identified a significant positive relationship between AI awareness and AI literacy. AI awareness was a significant predictor of AI literacy, accounting for 39% of the total variance. This indicates high explanatory power for the model (Cohen, 1988) and suggests that AI awareness is a fundamental component in developing AI literacy.

Implications

This research was conducted with 888 teachers in a province in Turkey's Western Black Sea Region. Although the sample size is sufficient, the use of convenience sampling and the single-province focus limit the generalizability of the results. Future research should involve larger, stratified samples across different geographical regions in Turkey. Given that AI research in Turkey often focuses on undergraduate students (Aruğaslan & Çivril, 2021; Tekin, 2023), this teacher-centered study provides a significant contribution to the literature.

The results reveal that while teachers' AI awareness and literacy are relatively high, they experience clear indecision regarding the pedagogical opportunities AI offers. While they recognize potential impacts, they lack a clear vision for integration. This underscores the need for supportive mechanisms to translate knowledge into applied competence. In this context, it is recommended that pre-service education be supported with application-based training focusing on branch-specific AI integration for personalized learning. Similarly, for in-service teachers, professional development programs should be structured around Intelligent Tutoring Systems (Kamalov et al., 2023) that emphasize monitoring learning processes, identifying student errors in real time, and providing individualized feedback. Such programs will help teachers internalize the role of AI in education in a more meaningful and functional way.

Declaration of generative AI use

For the translation and localization of content, Grammarly Edu was employed. Human translators subsequently reviewed and adjusted the translations to ensure accuracy, cultural appropriateness, and contextual relevance. The final text was thoroughly reviewed and approved by the authors to ensure it accurately reflects the intended research outcomes and ethical standards. The authors also assessed and addressed potential biases inherent in the AI-generated content. The final version of the paper is the sole responsibility of the human authors.

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The Relationship Between Autonomy, Funding, And Instructional Barrier Perceptions in Pisa Countries: A Comparison of Canada, Singapore And Estonia

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Abstract

The purpose of this study is to examine the patterns of relationships between school autonomy, quality assurance systems, hindrances to a school's instructional activities, source of school funding, and school location in high-performing countries (Singapore, Estonia, and Canada) and middle- and low-performing countries in the PISA 2022 exams. The PISA 2022 school data were used for this study. Singapore, Estonia and Canada were selected as the three high-performing countries along with 26 countries with average scores and 28 low-performing countries were included in this study. Results revealed that in the countries included in the study, school autonomy ranges from high to low in Estonia, Canada and Singapore. In all three countries and in other countries of the world participating in the PISA exam, the proportion of decisions made within the school is higher than the proportion of decisions made by local and central governments. In each of the three high-performing countries in PISA, a single relationship pattern emerged for all three education systems among all variables examined. According to this pattern, there was a negative relationship between school autonomy and school funding coming from the government, and a moderate positive relationship between school funding coming from students and parents.

Keywords: School autonomy, quality assurance system, school funding, PISA.

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Introduction

The Programme for International Student Assessment (PISA) is a triennial international comparative assessment of student learning, coordinated by the Organisation for Economic Co-operation and Development (OECD). First administered in 2000, PISA measures the competencies of 15-year-old students in three core domains—mathematics, reading, and science—focusing on how well students can apply their knowledge to real-life challenges. By 2022, PISA had completed its eighth assessment cycle (delayed from 2021 owing to the COVID-19 pandemic) and included more than 80 countries and economies. In the 2022 cycle, mathematics was the major domain, with OECD mean scores of 472 in mathematics, 476 in reading, and 485 in science (OECD, 2023). Singapore ranked first among all participating education systems, with scores of 575 in mathematics, 543 in reading, and 561 in science—more than two standard deviations above the OECD average. Estonia was the highest-performing European country, with scores of 510 in mathematics, 511 in reading, and 526 in science. Canada also ranked above the OECD average in all three domains, scoring 497 in mathematics, 507 in reading, and 515 in science (OECD, 2023). These three countries were selected for the present study because of their consistently high PISA performance and their structurally distinct educational governance systems. Understanding the school-level factors—such as school autonomy, quality assurance systems, and instructional resource conditions—that underpin such performance is the central motivation of this research.

School autonomy refers to the degree of independence the school's personnel enjoy in making valid and rational decisions about educational practices, policies, management, administration, and other educational operations. The concept of school autonomy was first articulated in Europe in the 19th century as a way of ensuring academic freedom which, later, was justified by religious and philosophical considerations in the first half of the 20th century (European Commission/EACEA/Eurdiyce, 2007).

Contemporary to this, the concept of "school autonomy" started to be discussed more widely in the literature especially in the late 1990s with a wider application when the school development efforts started developing against the rigid system of centralized administration (Barrera et. al., 2009). The researchers argued that an administrative design in which the main decisions about the school are made by the school personnel provides more consistent answers to increase student achievement in particular and raise school performance in general (Amelsvoort & Scheerens, 1997; Supriadi et al., 2021; Yuki & Igei, 2020).

While 'school autonomy' generally refers to shifting decision-making authority from central sysem to individual schools—giving them autonomy to adapt to their policies to address their needs—the term is used differently across studies and policies such as school development (Hashim et al., 2023), and planning of school management processes, restructuring and reform, self-management and decentralization in decision-making (Cheng et al., 2016). However, in general, school autonomy refers to the distribution of authority between decentralized or centralized administration and the level of independent decision-making and implementation by students, teachers and school administration (Pearson & Moomaw, 2005). Arcia et al. (2011) reiterated school autonomy as a form of school governance in which schools are given decision-making authority over their own activities, including the hiring and firing of staff and the evaluation of teachers and pedagogical practices.

School reform efforts are based on the findings that a school autonomy approach can promote innovation and quality teaching and improve school performance (Bulkley et al., 2010; Hallinger & Heck, 2010; Robinson et al., 2009; Yuki & Igei, 2020). The basic approach supported by advocates of school autonomy is that school administrators and teachers, who can analyze the needs and capacities of schools and students' local and cultural dynamics better and more closely than the central administration, will be more successful in developing policies and practices to improve educational quality. As a matter of fact, there is a considerable amount of research in the literature on the positive relationship between the autonomous structure of schools and student achievement (Caldwell, 2016; Cheng et al., 2016; Feri et al., 2016). Studies (Hanushek et al., 2013; OECD, 2013) point to a positive relationship between schools' ability to organize curricula according to students' needs, evaluate student achievement, and give administrative authority and initiative to school administrators for school improvement.

On the other hand, Fink and Brayman (2006) found a significant relationship between the autonomy of school leaders and the formation of effective working teams towards the school's goals. Fink and Brayman (2006) found that school leaders need significant autonomy to encourage and empower teachers to work together in order to improve the quality of teaching and learning activities in schools and to achieve significant results in educational achievement. Others found school autonomy as a critically important aspect for enhancing organizational learning (Marks & Louis, 1999) to sustain organizational performance, collective work, and performance of teachers and administrators. To do otherwise is to repeat dysfunctional professional development practices that are centrally determined and often not needs-focused.

Research findings (Clark, 2009; Galiani et al., 2008; Siddle & Koelble, 2012; Hanushek et al., 2013) suggest that empowered and autonomous school administrations lead to better educational outcomes. Decentralization, school autonomy and empowering local communities and institutions have been at the forefront of education policy debates for many years. As countries implemented these reforms, emerging evidence suggested that higher levels of governance quality were strongly associated with better educational outcomes (Bloom et al., 2015). Having more managerial responsibility at the school level means that a school should be accountable to national and local authorities, as well as to local stakeholders. On the other hand, the autonomous structure of schools necessitates an accountable and transparent organizational structure. Otherwise, it is not possible to predict the consequences of an arbitrary and unevaluated functioning. In this respect, accountability is defined as accepting responsibility for one's actions and being accountable for them. The main indicators of accountability in terms of school management can be listed as the level of compliance with rules and regulations, reporting to those who have supervision and control authority over the school, and linking rewards and sanctions to expected results (Heim, 1996; Rechebei, 2010).

Research on accountability and organizational capacity suggests that schools with strong organizational capacity tend to develop internal standards of accountability for their activities; on the other hand, centrally managed schools with strong external accountability have relatively weak organizational capacity (Marks & Louis, 1999). Thus, to enhance organizational learning and achieve educational goals, schools need to be both more autonomous and more accountable for their work. To a large extent, accountability also serves as a counterweight to the greater autonomy granted to schools. However, the relationship between autonomy and accountability is multifaceted and complex. One important criterion for effective and meaningful accountability is that it requires certain levels of organizational autonomy. Without autonomy and decision-making authority, it is not reasonable to hold decision-makers to be accounted. For an accountability system to foster improvement, schools must have the autonomy to make meaningful decisions in pedagogical, managerial and organizational areas. If schools lack the decision-making capacity to address their specific challenges, development and reform efforts, it is not fair to hold them accountable for results (Quilabert, 2024).

PISA results also show that when autonomy and accountability are meaningfully and functionally integrated in schools, they lead to better learning and developmental outcomes for students (OECD, 2011a; Hanushek et al., 2013). In schools, the key elements that make effective accountability functional can only be standardized, measured and evaluated based on quality assurance systems. Quality assurance in education refers to the mechanisms and processes put in place to monitor, evaluate and improve the quality of learning, teaching, school leadership, and student outcomes. Quality assurance systems ensure that learners receive quality education, which is their fundamental right. In this respect, the strenght of accountability-linked quality assurance system ensures that schools operate efficiently and effectively, adhering to high standards in the quality and management of education.

Accountability-based quality assurance processes, which focus on rules, procedures, and performance indicators, aim to promote accountability, purposeful quality improvement and trust in the systemic functioning of the school (Caldwell & Spinks, 2013). In this respect, quality assurance systems bring consistency to procedures, reduce idiosyncratic actions and set standards and principles for quality improvement. These elements enable the benchmarking of academic standards as well as the identification and sharing of good practices in teaching, learning and assessment across educational institutions (Williams, 2016; Winstone & Carless, 2021).

Quality assurance systems, which determine the quality of an effective school autonomy, provide accountability and guarantee non-arbitrary organizational behavior. The functional aspects of quality assurance systems, such as performance indicators, standards for learning and teaching processes and outcomes, and conformity to purpose and objectives, also provide an important opportunity to determine the quality of teaching activities (Wöbmann et al., 2007; Hanushek & Raymond, 2004). Strengthening school autonomy based on quality assurance systems will ensure that the two main areas of "human resources" and "physical resources needed in the school" serve the purpose in the best way possible.

A quality assurance system that operationalizes school autonomy serves to recruit teachers and other staff who are skilled and aligned with the institutional vision and mission (Elmore, 2004). On the other hand, the quality assurance system should have the capacity to effectively improve the quality of existing human resources, as well as to foster cohesion and establish a fair career system in order to build a diverse set of rules and a good working system.

Another determinant of the quality of educational outcomes in schools is physical resources and related facilities. The quality of teaching materials, technological facilities, basic equipment and the quality of physical space across countries and schools is one of the main determinants of the quality of learning (OECD, 2017; UNESCO, 2021). With the contribution of quality assurance systems in education systems with a high level of autonomy, it is hoped that it will become more possible to establish standards among schools in terms of human resources and physical facilities, and that schools will be able to provide students with close and high-quality facilities in all aspects. This quality is expected to improve the quality of educational outcomes.

The purpose of this study is to examine the patterns of relationships between school autonomy, quality assurance systems, hindrances to a school's instructional activities, source of school funding, and school location in high-performing countries (Singapore, Estonia, and Canada) and middle- and low-performing countries in the PISA 2022 exams. Research questions were as follows:

1) To what extent do school administrations in high-performing countries and in medium and low-performing countries perceive autonomous? Does this level differ according to countries?

2) What are the descriptive statistics on existing quality assurance systems for schools in high-performing countries and in medium- and low-performing countries?

3) To what extent are there hindrances to the teaching activities of schools? Do these barriers differ significantly across countries?

4) Are there significant relationships between the geographical location of the school (being in a big or small city), the school's funding sources, the autonomy level of schools, quality assurance systems, and the issues that hinder teaching activities?

Method

Research Design

This research was designed in survey model. Descriptive statistics were calculated to measure the level of autonomy of schools, the quality assurance systems that schools have, and the issues that hinder the teaching activities of schools. Following the descriptive statistics, the correlational design was used to examine the relationships between these variables (Fraenkel et. al., 2012).

The Population and Sample

The principals of the schools in the countries/economies participating in the PISA 2022 exam were included in the study. Singapore, Estonia and Canada were selected as the three high-performing countries in the study based on the standing among the top 10 countries in the PISA 2022 exam, with average scores above 500, and were located on different continents; so, it was assumed that they would represent the high-performing countries of the world more comprehensively. In order to compare these high-performing countries with other countries, 26 countries with average scores and 28 low-performing countries were included in this study. 81 countries/economies participated in PISA 2022. The top 27 countries with the highest scores were categorized as high-performing, while countries between 28-53 were categorized as medium-performing and countries between 54-81 were categorized as low-performing (PISA 2022 Worldwide ranking, 2024). Accordingly, Singapore (first), Estonia (seventh), and Canada (eighth) were selected among the top 27. In addition to these three countries, countries with medium performance are ranked from high to low scores (Hungary, Spain, Lithuania, Italy, Norway, Croatia, Vietnam, Israel, Slovak Republic, Iceland, Serbia, Ukraine, Brunei, Greece, Chile, Romania, United Arab Emirates, Malaysia, Moldova, Bulgaria, Qatar, Kazakhstan, Mexico, Mongolia) and countries with low performance (Montenegro, Uruguay, Costa Rica, Cyprus, Peru, Colombia, Brazil, Jamaica, Argentina, Thailand, Saudi Arabia, Georgia, Azerbaijan, Panama, North Macedonia, Indonesia, Albania, Guatemala, Palestine, El Salvador, Paraguay, Jordan, Morocco, Philippines, Uzbekistan, Kosovo, Dominican Republic, Cambodia) have been included in the scope of the study.
The study included 164 schools representing Singapore, 196 schools representing Estonia, and 863 schools representing Canada. A total of 14,066 schools from countries with medium and low performance were also included in the study. High-performing countries were analyzed individually, while countries with medium and low performance were analyzed collectively. This allowed for a comparison of the education systems of high-performing countries with those of countries with medium and low performance, and an attempt to discover patterns of relationship between them. Statistics on the geographical locations of the schools from which data was collected are provided in Table 1.

Table 1

Statistics on the Geographic Location of Schools

	Singapore		Estonia		Canada		PISA Count	
Level	F	%	f	%	f	%	F	%
1) A village, hamlet or rural area (fewer than 3 000 people)			54	27,6	136	15,8	2562	18,2
2) A small town (3.000 to about 15.000 people)			48	24,5	141	16,3	2616	18,6
3) A town (15.000 to about 100.000 people)			41	20,9	155	18,0	3201	22,8
4) A city (100.000 to about 1.000.000 people)			53	27,0	264	30,6	3142	22,3
5) A large city (1.000.000 to about 10.000.000 people)	159	97			111	12,9	1601	11,4
6) A megacity (with over 10.000.000 people)							204	1,5
Missing / No Response	5	3			56	6,5	740	5,3
Total	164	100	196	100,0	863	100,0	14066	100,0

As can be seen in Table 1, since Singapore consists of a single metropolitan area, all data come from schools in the same city; in Estonia, data come from schools located in relatively small cities; and in Canada, schools in small cities as well as large cities participated.

The number of students per school in Singapore is high, and the vast majority of teachers have the necessary certification with a bachelor's degree-level education. The percentage of teachers with postgraduate degree is 22%, and the number of students per teacher is slightly above 12. In Estonia, the number of students per school is at a reasonable level, with three-quarters of teachers having a bachelor's degree and the necessary certification, and two-thirds having a master's degree or higher. The number of students per teacher is 11. There are no statistics available on the number of students per school or per teacher in Canada, but more than 90% of teachers are certified, more than three-quarters have a bachelor's degree, and 23% have a master's degree or higher. When examining other countries that participated in the PISA exam, the number of students per school is 772, three-quarters of teachers have at least a bachelor's degree and certification, 30% have a master's degree or higher, and there are 15 students per teacher.

Instruments

The PISA 2022 school data were used for this study, and school principals responded to the questions in the survey. Validity and reliability analyses were conducted for the items that form a unified structure, and the term "scale" was preferred to describe them. Validity and reliability analyses were not conducted for the items that did not form a structure together and were independent of each other, and the term "survey" was preferred to describe them. The scales used in this study and their explanations are given below.

School Autonomy Survey (SAS)

SAS consists of 12 items coded Q13 that describes who or which administrative authority makes decisions on important matters in schools. The survey response options follow as: a) principal, b) teachers or members of the school management team, c) school governing board, d) local or municipal authority, e) regional or state authority, f) national or federal authority.

Quality Assurance System Survey (QASS)

QASS consists of 11 items coded Q17 to measure whether quality assurance systems are in place in schools. The answer options are as follows: i) Yes, this is mandatory, based on district or ministry policies, ii) Yes, based on school initiatives, iii) No. The existence of quality assurance systems reflects expectations regarding the school's ability to provide quality education; in this survey, a total "yes" responses score (both mandatory and school-initiated) of 7 or more out of 11 items (> 63.6) of yes responses can be considered an indicator of the school's commitment to quality assurance systems.

Instruction Hindrances Scale (IHS)

IHS is a 4-point Likert scale that aims to describe the physical and human resources that hinder the achievement of educational goals in schools. The response options are: i) Not at all, ii) Very little, iii) To some extent, and iv) A lot. A high score on this scale indicates a higher level of learning hindrances in schools. It consists of 10 questions coded as Q25 in the PISA school survey guide and data set. Exploratory factor analysis conducted on the scale showed that all items were valid, and the scale explained 63.35% of the variance in two dimensions. Accordingly, the first dimension consists of items related to physical resources (05, 06, 07, 08, 09, 10) and explains 48.35% of the variance; the second dimension consists of items related to human resources (01, 02, 03, 04) and explains 15% of the variance. The factor loadings of the items in the scale range from .82 to .73; the item-total correlation values range from .65 to .51, and the Cronbach Alpha coefficient is .87. After modifying items SC017Q07JA and SC017Q08JA in the scale, improvements were achieved in the fit indices of confirmatory factor analysis (CFA). In the CFA results for IHS, the standardized factor load values are between .84 and .57 for the first dimension and between .75 and .66 for the second dimension. In the IHS model, the fit indices were, x^2/ df = 29,68; CFI: 0.86; GFI: 0.945; AGFI: 0.887; IFI: 0.86; SRMR: 0.052; RMSEA: 0.160, indicating mixed model fit: GFI and SRMR are within acceptable ranges, whereas χ^2/df, CFI, IFI and RMSEA fall outside conventional cut-offs (the high χ^2/df partly reflects the large sample size).

Data Analysis Procedures

The analysis of the variables in the study and the calculation of scores were obtained as follows:

School autonomy was measured using 12 items coded as Q13. Table 3 shows the percentages calculated for each item in the school autonomy survey. The variable named “school autonomy” was obtained by summing the percentages related to i) principal, ii) teachers or members of the school management team, and iii) school governing board, which are indicators of school autonomy. The variable named “centralized administration” was obtained by summing the options i) local or municipal authority, ii) regional or state authority, and iii) national or federal authority. A high score in the school autonomy variable indicates that schools are autonomous and make their own decisions, while a high score in the centralized administration variable indicates that decisions regarding the school are made by the central administration and that school autonomy is low. In the 12-item SAS, the sum of school autonomy and centralized administration is 12 points, and correlation analyses were performed on the total scores.

QASS, was measured using 11 items coded as Q17 and three response options. Total scores were obtained for the response options “yes, this is mandatory, based on district or ministry policies” and “yes, based on school initiatives,” and these were included in the correlation analysis as two different variables. Since the survey consisted of 11 items, the two defined variables and the sum of the “no” options amounted to 11 points.

The IHS consists of 10 items on a 4-point Likert scale. Accordingly, instruction hindrances were calculated for each school on a scale of 10 to 40, and correlation analyses were performed on the total scores obtained from the scale.

School location is question Q1, which describes the geographical location of schools. Table 1 provides descriptive statistics for the countries included in the study regarding the geographical location of schools. In this variable, which measures the size of the city where the schools are located, the larger the city, the higher the score. The smallest location, “a village, hamlet or rural area (fewer than 3,000 people),” is scored as 1, while the largest location, “a megacity (with over 10,000,000 people),” is scored as 6.

School funding is question Q4 and consists of four options. Each option asks what percentage of school funding for an academic year is covered by the relevant option. The percentage is asked for each option, and the sum of these percentages is 100. Accordingly, the first option (SC016Q01TA) is government (includes departments, local, regional, state, and national), and the second option (SC016Q02TA) is student fees or school charges paid by parents or guardians. The responses to these options were analyzed as two different variables in the correlation analysis.

Findings

The autonomy level of schools in the Singapore education system was collected with the SAS and descriptive statistics are given in Table 2.

Table 2

Descriptive Statistics on School Autonomy in the Singapore Education System (N=164)

At your school, who is responsible for	Principal %	Teachers or members of sch. mang. Team %	School governing board %	Local or municipal authority %	Regional or state authority %	National or federal authority %
1) Appointing or hiring teachers	18.9	3				77.4
2) Dismissing or suspending teachers from employment	17.1	1.8	1.8			78.7
3) Establishing teachers' starting salaries, including setting pay scales	6.7	2.4	7.9			82.3
4) Determining teachers' salary increases	7.3	4.9	6.7			80.5
5) Formulating the school budget	32.3	27.4	7.3			32.3
6) Deciding on budget allocations	71.3	23.8	3			1.2
7) Establishing student disciplinary policies and procedures	35.4	59.8	0.6			3.7
8) Establishing student assessments policies, including [national / regional] assessments	15.2	35.4				48.8
9) Approving students for admission to the school	52.4	6.7				39.6
10) Choosing which learning materials are used	12.8	76.7				10.4
11) Determining course content, including [national / regional] curricula	4.3	29.9				65.6
12) Deciding which courses are offered	27.4	45.1	1.2			25.6
Total (Average)	25.12	26.41	2.73			45.53
Autonomy	School Level: % 54.26			Centralized Adm.: % 45.53		

Table 2 shows that 163 of the 164 school principals in Singapore responded to the questionnaire. As Singapore consists of one large city and one administration, it has become apparent that local administrations have no influence over decisions made in schools. It was found that schools in Singapore have a reasonable level of autonomy (more than half of the decisions (54.26%)). It has been found that school principals have the most influence over student admissions, teachers or members of the school management team have the most influence over the selection of learning materials, and national or federal authorities have the most influence over teachers' starting salaries. Teachers' employment, dismissal and salary increases are largely determined by the central government. Descriptive statistics regarding the level of autonomy that schools have in the Estonian education system are given in Table 3.

Table 3

Descriptive Statistics on School Autonomy in the Estonian Education System (N=196)

At your school, who is responsible for	Principal %	Teachers or members of sch. mang. Team %	School governing board %	Local or municipal authority %	Regional or state authority %	National or federal authority %
1) Appointing or hiring teachers	92.3	6.1		.5		1
2) Dismissing or suspending teachers from employment	96.9	3.1				
3) Establishing teachers' starting salaries, including setting pay scales	35.2	2.6		19.4		42.9
4) Determining teachers' salary increases	35.2	3.6		19.4		41.8
5) Formulating the school budget	65.8	9.7	1.5	21.4		1.5
6) Deciding on budget allocations	48	10.2	1	37.8		2
7) Establishing student disciplinary policies and procedures	15.3	80.1	4.6			
8) Establishing student assessments policies, including [national / regional] assessments	16.3	77.6	1			5.1
9) Approving students for admission to the school	75	10.2	5.1	9.7		
10) Choosing which learning materials are used	2	97.4				.5
11) Determining course content, including [national / regional] curricula	3.6	95.4				1
12) Deciding which courses are offered	11.2	84.7	2			1.5
Total	41.37	40.05	1.27	9.01		8.11
Autonomy	School Level: % 82.72			Centralized Adm.: % 17.12		

Table 3 shows that one of the 196 school principals included in the study in Estonia did not answer question 12, while all other principals answered all questions. Schools in Estonia are quite autonomous, with decisions regarding school operations largely made by the principal or management team, while the central administration has the most influence in determining teacher salaries. School principals in Estonia have a high degree of authority in the employment and dismissal of teachers, and as a result, it can be said that decisions regarding teacher employment are made at the school level. The school principal has influence in determining learning materials, course content, and courses to be offered in a small number of schools, while in the remaining schools, these decisions were made by the management team. Descriptive statistics regarding the level of autonomy that schools have in the Canadian education system have been provided in Table 4.

Table 4

Descriptive Statistics on School Autonomy in the Canadian Education System (N=863)

At your school, who is responsible for	Principal %	Teachers or members of sch. mang. Team %	School governing board %	Local or municipal authority %	Regional or state authority %	National or federal authority %
1) Appointing or hiring teachers	46.3	3	41.4		.2	
2) Dismissing or suspending teachers from employment	11.7	.6	70.7	.1	7.6	.1
3) Establishing teachers' starting salaries, including setting pay scales	1.6	.7	27.6	.6	59	1.4
4) Determining teachers' salary increases	1.6	.6	23.2	1.3	62.3	1.6
5) Formulating the school budget	17.5	1.7	61.4	.3	9.5	.3
6) Deciding on budget allocations	49.9	4.5	32		4.2	.1
7) Establishing student disciplinary policies and procedures	35.1	18.8	31.4	.1	5.3	.2
8) Establishing student assessments policies, including [national / regional] assessments	5.2	7.9	26.8	1.2	49.1	.7
9) Approving students for admission to the school	53.8	8.9	25.6		2.3	.1
10) Choosing which learning materials are used	13.2	53.3	10.7	.7	12.9	.2
11) Determining course content, including [national / regional] curricula	2.8	11	5.2	2.2	68.7	1
12) Deciding which courses are offered	46.1	26.4	7.8	.2	10.2	
Total	23.73	11.45	30.32	.56	24.28	.4
Autonomy	School Level: % 65.5			Centralized Adm.: % 25.24		

Table 4 shows that of the 863 school principals included in the study in Canada, between 78 and 80 did not respond to the questions, while the rest did respond. It can be stated that schools in Canada have a high degree of autonomy, with very few decisions being made at the provincial or national level. In Canada, the school principal is responsible for teacher employment, the use of the school budget, and student enrolment; the school governing board is responsible for teacher employment, teacher dismissals, and the determination of the school budget; the school management team has a high degree of influence on the learning materials to be used in schools, and the regional or state authority has a high degree of influence on determining teachers' starting salaries, salary increases and course content. Descriptive statistics on the level of autonomy of schools in the education systems of countries with below-average and average performance in PISA were given in Table 5.

Table 5

Descriptive Statistics on School Autonomy in Education Systems of Other PISA Countries (N=14,066)

At your school, who is responsible for	Principal %	Teachers or members of sch. mang. Team %	School governing board %	Local or municipal authority %	Regional or state authority %	National or federal authority %
1) Appointing or hiring teachers	37.3	5.9	5.9	7.2	16	21.3
2) Dismissing or suspending teachers from employment	36.6	5	8.7	6.8	15.9	20.5
3) Establishing teachers' starting salaries, including setting pay scales	12.6	4.1	7.3	5.9	14.6	49
4) Determining teachers' salary increases	11.4	4.5	7.1	4.4	13.7	52.3
5) Formulating the school budget	23.1	11.7	17.4	10	12.5	18.7
6) Deciding on budget allocations	22.1	11.3	22.1	11.3	11.9	14.5
7) Establishing student disciplinary policies and procedures	19.9	37.3	18.6	.9	4.1	12.5
8) Establishing student assessments policies, including [national / regional] assessments	8.8	21.8	5.4	2	11.5	43.8
9) Approving students for admission to the school	44.8	16.6	7	3.4	10.9	10.4
10) Choosing which learning materials are used	8.3	56.6	5.4	1	3.3	18.7
11) Determining course content, including [national / regional] curricula	5.3	22.4	3.4	1.8	11.2	49.4
12) Deciding which courses are offered	10.7	22	7.6	1.8	11	40.4
Total	20.08	18.27	9.66	4.71	11.38	28.46
Autonomy	School Level: % 48.01			Centralized Adm.: % 44.55		

Table 5 shows that 14,060 school principals from countries with average and below-average performance in the PISA test were included in the study, and between 894 and 961 principals did not respond to the questions, although this varied depending on the question. In countries with average and below-average PISA performance, it can be said that school autonomy and centralized management levels are similar. In countries participating in PISA, it has been revealed that school principals have high levels of authority in the employment and dismissal of teachers; the school management team has high levels of authority in student discipline policies and teaching materials used in schools; and national or federal authorities have high levels of authority in teachers' starting salaries, salary increases, assessment and evaluation policies, course content, and course selection. Descriptive statistics obtained from the QASS, which describes the existence of quality assurance and improvement systems in schools, have been presented in Table 6.

Table 6

Descriptive Statistics on Quality Assurance and Improvements Systems in Schools

Exist at your school	Singapore (N= 164)		Estonia (N= 196)		Canada (N=863)		Other Countries (N=14.066)	
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
1) Internal evaluation / self-evaluation	99.4	0,6	99	.5	76.2	12.1	90	3.1
2) External evaluation	98.8	1.2	79.6	19.9	60.4	27.7	78.6	14.2
3) Written specific of the school's curricular profile and educational goals	100	0	97	2	82.3	6	88.3	4.4
4) Written specification of student performance standards	97.6	2.4	77.1	22.4	74.2	14.1	84.4	8.3
5) Systematic recording of data such as Teacher or student attendance and professional dev.	100	0	93.4	5.6	81.4	7.4	90.6	2.5
6) Systematic recording of students test results and graduation rates	100	0	96.5	2.6	85.1	3.9	89.5	3.7
7) Seeking written feedback from students (e. g. regarding lessons, teachers or resources)	91.5	8.5	75.5	23.5	55.4	33	72.9	20.1
8) Teacher mentoring	100	0	94.9	4.6	75.7	13.2	76.9	16.1
9) Regular consultation aimed at school improvement with one or more experts over a period of at least six months	67.1	32.9	51.1	46.9	65.4	23.2	60.6	32.5
10) Implementation of a standardized policy for mathematics subjects (i.e. school curriculum with shared instructional materials accompanied by staff development and training)	98.8	1.2	72	26.5	71.8	17.1	70	23.1

As Table 6 shows, quality assurance and improvement systems are in place in the vast majority of schools in Singapore and Estonia. Singapore has more schools with quality assurance and improvement systems than Estonia, Canada and other countries around the world, whereas Estonia has more schools with such systems than Canada and other countries around the world. It was found that other countries participating in PISA most frequently had records of student test results and graduation rates, whereas consulting with experts on school development was the least common practice. Teaching resources that hinder teaching activities were examined using IHS, and descriptive statistics on this are given in Table 7.

Table 7

Statistics on Instructional Resources Hindering Teaching Activities

Is your school's capacity to provide instruction hindered by any of the following issues?	Singapore (N= 164)		Estonia (N= 195)		Canada (N=761)		Other Countries (N=13.099)	
	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD	$\overline{X}$	SD
1) A lack of teaching staff	1.94	.81	2.79	.90	2.31	1.00	2.07	1.04
2) Inadequate or poorly qualified teaching staff	1.53	.69	2.39	.89	1.88	.86	1.80	.91
3) A lack of assisting staff	1.48	.66	2.20	.96	2.18	.91	2.11	1.10
4) Inadequate or poorly qualified assisting staff	1.24	.49	1.78	.84	1.83	.88	1.69	.95
5) A lack of educational material (e.g. textbooks, IT equipment, library or laboratory material)	1.10	.33	1.83	.84	1.52	.74	2.18	1.10
6) Inadequate or poor quality educational material (e.g. textbooks, IT equipment, library or laboratory material)	1.12	.37	1.79	.82	1.50	.73	2.10	1.05
7) A lack of physical infrastructure (e.g. building, grounds, heating/cooling, lighting and acoustic systems)	1.27	.62	1.97	1.08	1.56	.83	2.13	1.13
8) Inadequate or poor quality physical infrastructure (e.g. building, grounds, heating/cooling, lighting and acoustic systems)	1.30	.68	1.92	1.02	1.49	.79	2.09	1.10
9) A lack of [digital resources] (e.g. desktop or laptop computers, internet access, learning management systems or school learning platforms	1.09	.32	1.61	.76	1.52	.76	2.32	1.13
10) Inadequate or poor quality [digital resources] (e.g. desktop or laptop computers, internet access, learning management systems or school learning platforms)	1.15	.45	1.68	.83	1.55	.76	2.30	1.11
Total	1.32	.36	1.99	.56	1.73	.57	2.07	.77

As can be seen in Table 7, in countries with high performance in PISA, the resources that hinder teaching activities appear to be, from least to most, Singapore, Canada and Estonia. With regard to resources that hinder teaching activities, Singapore and Canada experienced resource problems at the 'not at all' level, whereas Estonia and other countries experienced problems at the 'very little' level. In high-performing countries in PISA, the lowest problem was found to be 'a lack of digital resources', while the highest problem was 'a lack of teaching staff'. It is noteworthy that in other countries participating in PISA, the lowest resource problem was 'inadequate or poorly qualified assisting staff' and the highest problem was 'a lack of digital resources'.

A One-Way ANOVA was conducted to compare the resource issues of high-performing countries in PISA, and a significant difference was found [$F_{(2,1117)} = 69.49$; $p < 0.000$]. According to this result, schools in Singapore experience lower resource issues compared to schools in Canada and Estonia, while schools in Canada experience lower resource issues compared to schools in Estonia. In Singapore, the relationships between the variables described in the findings section and the school's funding sources and geographical location were analyzed using Pearson's correlation, and the results were presented in Table 8.

Table 8

Relationships between Variables for Singapore

Variable	n	M	SD	1	2	3	4	5	6	7
1.SA	162	6.52	2.78							
2.CA	162	5.48	2.78	-1.00**						
3.MQAS	164	4.40	2.26	-.290**	.290**					
4.SIQAS	164	5.13	2.42	.309**	-.309**	-.963**				
5.IH	164	13.21	3.57	-.013	.013	-.003	.005			
6.SL	159	5.00	.000	NC	NC	NC	NC	NC		
7.SFcfG	162	74.74	27.30	-.543**	.543**	.109	-.125	.038	NC	
8.SFcfSaP	162	22.21	26.59	.538**	-.538**	-.107	.128	-.036	NC	-,972**

* Correlation is significant at the 0.01 level (2-tailed)
NC= Not computed: Due to school location is same for whole school
1: School Autonomy, 2: Centralized Administration, 3: Mandatory Quality Assurance System, 4: School Initiatives Quality Assurance System, 5: Instruction Hindrances, 6: School Location, 7: School Funding comes from Government, 8: School Funding comes from Students and Parents

As can be seen in Table 8, there is a low-level negative significant relationship between variables 1 and 3 [r (162) = -.290, p < .001]; while there is a low-level positive significant relationship between variables 1 and 4 [r (162) = .309, p < .001]. According to this result, if school autonomy scores increase, the mandatory quality assurance system decreases, whereas the school initiatives quality assurance system increases. There was a moderate negative significant relationship between variables 1 and 7 [r (160) = -.543, p < .001]; whereas there was a positive significant relationship between variables 1 and 8 [r (160) = .538, p < .001]. According to this result, if school funding comes from the government, school autonomy decreases; if school funding comes from students and parents, school autonomy scores increase. Centralized administration and school autonomy have a correlation value of -1 due to the calculation algorithm. Therefore, the relationships between centralized administration and variables 3, 4, 7, and 8 are inversely proportional to those between school autonomy and variables 3, 4, 7, and 8. According to this result, in Singapore, when centralized administration increases in a school, the mandatory quality assurance system and school funding comes from the government increase, whereas school initiatives quality assurance system and school funding comes from students and parents decrease. The relationships between the variables included in the study in Estonia were analyzed using Pearson correlation, and the results are presented in Table 9.

Table 9

Relationships between Variables for Estonia

Variable	n	M	SD	1	2	3	4	5	6	7
1.SA	194	9.96	1.40							
2.CA	194	2.04	1.40	-1.00**						
3.MQAS	191	3.66	1.93	-.120	.120					
4.SIQAS	191	4.77	2.03	.099	-.099	-.753**				
5.IH	195	19.91	5.62	-.029	.029	-.214**	.127			
6.SL	196	2.47	1.16	.050	-.050	.094	.085	.109		
7.SFcfG	195	96.88	9.97	-.194**	.194**	.038	-.040	.050	-.199**	
8.SFcfSaP	195	2.11	9.05	.195**	-.195**	-.019	.009	-.052	.184*	-.958**

* Correlation is significant at the 0.01 level (2-tailed)
1: School Autonomy, 2: Centralized Administration, 3: Mandatory Quality Assurance System, 4: School Initiatives Quality Assurance System, 5: Instruction Hindrances, 6: School Location, 7: School Funding comes from Government, 8: School Funding comes from Students and Parents

As can be seen in Table 9, in Estonia, there is a low-level negative significant relationship between variables 1 and 7 [r (193) = -.194, p = .007]; and a low-level positive significant relationship between variables 1 and 8 [r (193) = .195, p = .007]. According to this result, if school autonomy increases, school funding comes from students and parents increases, whereas school funding comes from the government decreases. It is expected that there is a high level of negative correlation between variables 3 and 4 [r (191) = -.753, p < .001]. According to this result, if the mandatory quality assurance system increases, school initiatives quality assurance system decreases. A low level of negative significant relationship emerged between variables three and five [r (190) = -.194, p = .003]. According to this result, in Estonia, if the mandatory quality assurance system increases in a school, instruction hindrances decrease. A low-level positive significant relationship was found between variables two and seven [r (193) = .194, p = .007]; a low-level negative significant relationship was found between variables two and eight [r (193) = -.195, p = .007]. According to this result, if the influence of centralized administration increases in the decisions made in a school, school funding comes from the government, whereas school funding comes from students and parents decreases. Finally, a low-level negative significant relationship was calculated between variables six and seven [r (195) = -.199, p = .005]; whereas a low-level positive significant relationship was calculated between variables six and eight [r (195) = .184, p = .010]. Accordingly, as the geographical location of the school increases (as the city grows), school funding comes from students and parents increases, whereas school funding comes from government decreases. The relationships between the variables included in the study in Canada were analyzed using Pearson correlation, and the results were presented in Table 10.

Table 10

Relationships between Variables for Canada

Variable	n	M	SD	1	2	3	4	5	6	7
1.SA	772	8.65	1.76							
2.CA	772	3.35	1.76	-1.00**						
3.MQAS	738	5.37	2.45	-.145**	.145**					
4.SIQAS	738	2.84	2.15	.226**	-.226**	-.689**				
5.IH	761	17.33	5.66	-.103**	.103**	.002	-.086*			
6.SL	807	3.09	1.31	.104**	-.104**	-.027	.030	-.097**		
7.SFcfG	789	89.69	19.38	-.245**	.245**	.220**	-.260**	.096**	-.134**	
8.SFcfSaP	767	7.77	16.76	.287**	-.287**	-.241**	.272**	-.128**	.190**	-.925**

* Correlation is significant at the 0.01 level (2-tailed)
1: School Autonomy, 2: Centralized Administration, 3: Mandatory Quality Assurance System, 4: School Initiatives Quality Assurance System, 5: Instruction Hindrances, 6: School Location, 7: School Funding comes from Government, 8: School Funding comes from Students and Parents

As can be seen in Table 10, there is a low-level negative significant relationship between variables 1 and 3 [r (726) = -.145, p < .001]; between variables 1 and 4, there is a low-level positive significant relationship [r (726) = .226, p = .000]. According to this result, in Canada, if school autonomy scores increase, the mandatory quality assurance system decreases, whereas the school initiatives quality assurance system increases. A low-level negative significant relationship emerged between variables 1 and 5 [r (747) = -.103, p = .005]. Accordingly, as school autonomy increases, instructional hindrances decrease. A low-level positive significant relationship was found between variables 1 and 6 [r (771) = .104, p = .004]. Accordingly, as the geographical location of the school (city size) increases, school autonomy increases. A low-level negative significant relationship was found between variables 1 and 7 [r (760) = -.245, p < .001]; whereas a low-level positive significant relationship was found between variables 1 and 8 [r (738) = .287, p = .000]. According to this result, school funding comes from students and parents increases school autonomy, whereas school funding comes from government decreases it. Centralized administration and school autonomy have a correlation value of -1 according to the calculation algorithm. Therefore, the relationships between centralized administration and variables numbered three, four, five, six, seven and eight are inversely proportional to those between school autonomy and variables numbered three, four, five, six, seven and eight. According to this result, in Canada, when centralized administration increases in a school, mandatory quality assurance system, school funding comes from government and instruction hindrances increase; whereas school initiatives quality assurance system and school funding comes from students and parents decrease. Another result is the low-level negative significant relationship between variables two and six [r (771) = -.104, p = .004]. According to this, as the geographical location of the school (size of the city) increases, centralized administration decreases.

As can be seen in Table 10, there is a low-level positive significant relationship between variables 3 and 7 [r (727) = .220, p < .001]; while there is a low-level negative significant relationship between variables 3 and 8 [r (706) = -.241, p < .001]. Accordingly, in Canada, if school funding comes from the government, the mandatory quality assurance system increases; if school funding comes from students and parents, the mandatory quality assurance system decreases. A low-level negative significant relationship was found between variables 4 and 5 [r (727) = -.086, p = .020]. Accordingly, school initiatives quality assurance system reduces instruction hindrances.
As can be seen in Table 10, low-level significant relationships have emerged between variable number five and variables six [r (759) = -.097, p = .007], seven [r (748) = .096, p = .009] and eight [r (727) = -.128, p = .001]. Accordingly, as the geographical location of the school increases (as the city grows) and school funding comes from students and parents, instructional hindrances decrease. Finally, for Canada, a low-level positive significant relationship was found between variables six and eight [r (766) = .190, p < .001]. Accordingly, as the geographical location of the school increases (as the city grows), school funding comes from students and parents.

Results and Discussion

In the countries included in the study, school autonomy ranges from high to low in Estonia, Canada and Singapore (Cheng et al., 2016). In all three countries and in other countries of the world participating in the PISA exam, the proportion of decisions made within the school is higher than the proportion of decisions made by local and central governments. According to this result, it can be stated that schools have a reasonable level of autonomy, in other words, a relatively high level of autonomy on a global scale (Honig & Rainey, 2012). Compared to Singapore and Canada, school principals in Estonia were found to have a high level of authority and a high level of influence in teacher recruitment and school budget determination (Kukemelk & Ginter, 2016; Mehisto & Kitsing, 2022).

In Singapore, unlike in Estonia and Canada, teacher recruitment, termination, teacher salaries and raises are decided by the government (Schleicher, 2012). In Canada, it was concluded that the federal or central government had no influence on schools, whereas regional or state authorities had influence on determining teacher salaries, salary increases, and course content (Council of Ministers of Education, Canada, 2022). The political structure of countries, their geographical and cultural locations, and the autonomy of schools are factors that influence whether decisions are made at the central or school level. Therefore, it is possible to consider it as a normal situation that there are differences between countries in terms of school autonomy.

In Singapore and Estonia, quality assurance and improvement systems are in place in the vast majority of schools; in these two countries, quality assurance systems are present in a greater number of schools than in Canada and other countries participating in PISA (Boman, 2020). However, in the three countries included in the study and other countries participating in PISA, the existence of quality assurance and improvement systems in the vast majority of schools is a positive development. Quality assurance systems contribute to the implementation of learning and teaching activities that meet qualified and anticipated standards in schools (Révai, 2018).

In this study, factors that hinder teaching activities were among the variables examined. According to the study, Singapore was found to be the country with the lowest teaching hindrances compared to Estonia, Canada and other countries around the world. Singapore, Estonia and Canada, which were high-performing education systems in PISA, encountered lower teaching barriers compared to other countries with average and below-average performance (Greatbatch & Tate, 2019). This result can be evaluated as an indication of the relationship between the learning resources available to a school and the academic achievement of its students (Savasci & Tomul, 2013). It was concluded that the most common hindrance in the three high-performing education systems included in the sample was a shortage of teaching staff, whereas the least common hindrance was a lack of digital resources. In European countries, the United States and other developed countries around the world, teacher shortages were widespread and striking (Ladd, 2007; Sutcher et al., 2019) In other countries participating in PISA, it was found that the least common hindrance was a shortage of qualified support staff, whereas the most common hindrance was a lack of digital resources. In other countries participating in PISA, it is expected that there will be a hindrance due to the financial burden of digital resources. With the increase in national income in other countries, it will be possible to provide easier access to the greater number of digital resources needed by schools.

In each of the three high-performing countries in PISA, a single relationship pattern emerged for all three education systems among all variables examined. According to this pattern, there was a negative relationship between school autonomy and school funding coming from the government, and a positive relationship between school autonomy and school funding coming from students and parents (moderate in Singapore and low-level in Estonia and Canada). Accordingly, if school funding comes from students and parents, school autonomy will also increase (Gunnarsson et al., 2009). A relationship pattern valid for Singapore and Canada is a negative relationship between school autonomy and mandatory quality assurance system, whereas there is a positive relationship with school initiatives quality assurance system. Accordingly, school autonomy increases school-based quality assurance systems and reduces mandatory quality assurance systems. Hanushek et al. (2013) also found that schools can develop more effective quality assurance systems with strong local decision-making mechanisms that reduce centralized control and allow schools to set their own quality standards. Another relationship pattern applicable to Estonia and Canada is the relationship between school location and funding from students and parents. As the population of the city where the school is located increases, the amount of funding from students and parents decreases. Some studies and research reports highlight the funding differences between rural and urban schools in OECD countries (OECD, 2018). Especially in highly urbanized areas, the diversity of funding and the advantages of employing more qualified teachers, as well as the frequent teacher turnover in rural areas (Monk, 2007) may be reflected as negative outcomes for rural areas. It is possible to generalize this situation for Estonia and Canada in terms of research findings.

In Estonia, there is a negative and significant relationship between mandatory quality assurance systems and instructional hindrances. The presence of mandatory quality assurance systems reduces instructional hindrances in schools. Estonia's centralized quality assurance system (national curriculum, standardized assessments and school inspections) has been effective in reducing learning inequalities. It has contributed to minimizing barriers to teaching (e.g. lack of resources, teacher quality), especially in disadvantaged schools. External evaluations identified pedagogical and managerial weaknesses of schools, contributing to the elimination of instructional barriers (e.g. language barriers, special educational needs) (OECD, 2020). These findings suggest that centralized quality assurance systems and standards are contributory for Estonia.

In Canada, a negative correlation was found between school autonomy and instruction hindrances, while a positive correlation was found between school location and instruction hindrances. Accordingly, it was found that instruction hindrances have an effect on school autonomy. In Canada, school autonomy increases as the size of the city where the school is located increases. Accordingly, it is possible to conclude that school autonomy needs to be supported in small settlements as well. A negative significant relationship was found between instruction hindrances and school location and funding comes from students and parents. Accordingly, in Canada, the size of the city where the school is located and the type of school funding (from the central government or from parents/students) affect the learning obstacles that arise in schools.

When evaluating the results on school autonomy, country conditions and how the basic components of education, public school structure and institutional culture are structured become very important. In countries such as Canada and Estonia, where education components and basic governance culture and processes are standardized through quality assurance systems, the results are very good, whereas in countries with low quality in education, the results are not of the same quality (Hanushek et al., 2013; OECD, 2011b). In contrast, both international and Canadian and Estonian PISA results and experiences show that academic outcomes can be improved with more pedagogical autonomy (Bédard, 2015).

Implications

In order to increase school autonomy, in addition to securing financial support from parents and students, policy regulations are needed to prevent the central government budget allocated to education from reducing school autonomy, based on the importance of public resources in education. Quality assurance systems contribute to the quality of education provided by schools. In order to increase school-based quality assurance systems, which are an indicator of the school's commitment to providing quality education, there is a need to increase school autonomy. As the population of the city where the school is located increases, the amount of funding for schools from students and parents decreases. Therefore, it is recommended that policy regulations be made to provide parental support to schools in large cities in order to ensure school autonomy.

In Estonia, it is recommended to increase the number of school-based quality assurance systems to reduce instruction hindrances, whereas in Canada, it is recommended to increase school autonomy. In Canada, it is also recommended that regulations be implemented to reduce learning barriers in schools in large cities, based on the fact that instruction hindrances increase as the city where the school is located grows. For Canada, it is also important to maintain financial support from parents and students in terms of school funding in order to reduce instruction hindrances.

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Credit Author Statement:
Abdurrahman Ilgan: Conceptualization, Methodology, Formal Analysis, Data Curation, Writing – Original Draft Preparation, Writing – Review & Editing.

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