

Article

Executive Function and Ethical Digital Citizenship: A Sustainable Framework for Smart Education in Primary Learners

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Abstract

Although digital transformation has expanded classroom technology access, the integration of ethical development within digital learning environments remains limited. This study investigates the relationship between executive functions and ethical digital citizenship among primary school students aged 6–12 years. Key contributing factors examined include smart education, digital literacy, ethical competency, teacher agency, institutional support, and executive function. Empirical data were collected from 387 primary school teachers and administrators within the Office of the Basic Education Commission network via online and printed questionnaires, capturing educators' professional observations and proxy-reports of their students' behavior. Using partial least squares structural equation modeling (PLS-SEM), the study tested seven hypotheses. Results indicate that smart education directly influences digital literacy, a relationship significantly moderated by teacher agency. Furthermore, digital literacy directly impacts ethical competency, with institutional support serving as a critical moderator. Finally, executive functions demonstrated a significant, direct impact on students' ethical competency. By highlighting the interconnected roles of these six factors, this study provides a novel, evidence-based framework that policymakers can utilize to effectively foster ethical digital citizenship among young Thai learners.

Keywords: smart education; digital literacy; ethical digital citizenship; ethical competency; executive function; teacher agency; institutional support

1. Introduction

Education is central to equipping the next generation with the competencies required to navigate today's intersecting sustainability crises and rapid digital transformations [1,2]. Within contemporary digital learning environments, educational institutions face mounting pressure to adapt their curricula to foster both cognitive growth and holistic success [3]. In particular, the proliferation of artificial intelligence (AI) has underscored the urgent need for cross-disciplinary skills. Cultivating these capabilities is essential, serving as a fundamental prerequisite for building a sustainable future aligned with the Sustainable Development Goals (SDGs) [4].

Recent shifts toward online and virtual learning, accelerated by global health emergencies such as COVID-19, have broadened educational access while simultaneously exacerbating social inequalities and emotional distress among students [5,6]. In early childhood contexts, integrating information and communication technology (ICT) introduces distinct



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pedagogical challenges, and effective implementation depends heavily on teachers' professional experience [5,7]. This points to a need for professional development that goes beyond simply encouraging frequent digital tool use, instead reshaping educators' underlying pedagogical attitudes toward dynamic, technology-enhanced creative learning [5,8].

Alongside these pedagogical shifts, the rapid integration of advanced technologies introduces ethical and privacy dilemmas that are exacerbated by insufficient guidance on responsible digital resource use. Technological advancements offer unprecedented opportunities for personalized learning and operational efficiency, particularly for nations transitioning to digital economies like Thailand [9]. However, ubiquitous internet access and the proliferation of personal digital devices are fundamentally disrupting traditional educational paradigms, altering both student cognition and instructional methods [7,8]. While AI applications suggest substantial educational benefits, their pervasive influence can inadvertently facilitate dishonest behaviors, such as assignment plagiarism or exam cheating [7,10]. Furthermore, the expanding smart education infrastructure often lacks necessary ethical guidelines [9]. The growing reliance on the Internet of Things (IoT), wearable health trackers, and virtual assistants exposes young, vulnerable students to severe data privacy and security risks [11–14]. Addressing these threats requires proactive government and institutional strategies that prioritize the safe, ethical, and responsible application of emerging technologies [6].

To address this gap, the present study investigates the structural factors that drive ethical digital citizenship among primary school students aged 6–12. Because young learners lack the cognitive maturity to reliably self-report on abstract ethical concepts, the study relies on structured professional observations and proxy-ratings provided by educators and school administrators. Specifically, it models the effects of smart education on digital literacy and ethical competency, evaluates the moderating roles of teacher agency and institutional support, and examines the direct effect of executive function on ethical competency. By delineating these interrelated variables, this research offers a validated framework to help educational policymakers refine smart education ecosystems and cultivate ethical competencies in the next generation.

2. Literature Review

2.1. Key Constructs and Relationships

2.1.1. Ethical Digital Citizenship

Digital citizenship is a multifaceted concept encompassing the skills, attitudes, and actions required to navigate the digital world responsibly and ethically. More specifically, ethical digital citizenship (EDC) emphasizes the appropriate use of technology, focusing on moral behavior, critical thinking, and positive online interactions [15,16]. To foster these qualities, UNESCO established a five-pillar model for inclusive and ethical digital citizenship: digital literacy, digital security and resilience, digital participation and decision-making, digital emotional intelligence, and digital creativity and innovation [17].

Practicing EDC within digital communities requires safe, ethical, and respectful participation. Young students must understand digital ethics, maintain respectful behavior, protect their personal information, and know when to seek adult guidance for unfamiliar online issues. Effective digital participation emphasizes equitable interaction and positive social influence through information and communication technology. Meanwhile, digital emotional intelligence focuses on emotional awareness in online interactions, fostering self-regulation and empathy [18]. One underexplored area concerns how students perceive their own learning experiences, an understanding that is crucial for developing the nuanced judgment, critical thinking, and problem-solving skills needed to interpret and engage with AI-generated content [4]. Furthermore, interdisciplinary collaboration among educators

and personnel who create AI ethics content is essential [8]. Such collaboration deepens students' understanding of ethical implications and promotes responsible AI use.

Ongoing digital transformations have vastly expanded global access to educational resources via online platforms and digital libraries, allowing for ubiquitous information retrieval [19]. These tools actively assist students in organizing information, make summaries, and understand the material better, which makes them more efficient and better at learning [20].

This accessibility democratizes education by creating opportunities for individuals without access to traditional facilities, ultimately advancing social well-being and sustainable development [21,22]. Consequently, educators must actively cultivate both pedagogical strategies for digital citizenship and technological expertise to teach effectively in this rapidly evolving landscape [23,24].

2.1.2. Ethical Competency

Ethical competency extends beyond personal morality. It is a fundamental national resource. Academic research highlights ethical human capital as a key driver for economic survival and national leadership in the AI era [4,10]. While AI systems excel at processing information and executing repetitive tasks, human ethical decision-making remains distinct and irreplaceable. Together with empathy and social responsibility, it is essential to society's continuous progress and well-being [10,25]. Therefore, cultivating these qualities in younger generations is a strategic necessity for securing national stability in a digital society. Ethical competency comprises three main components: identifying ethical issues, making appropriate decisions, and demonstrating empathy and responsibility in a digital context [26]. Furthermore, situational elements, such as contextual adaptability and communication skills, are equally vital [27]. Empirical evidence suggests that elementary students require systematic, hands-on experiences, such as task-focused group discussions that encourage peer feedback and explore human complexities, to develop moral reasoning [26,27]. Through teacher-guided reflection and situational learning, students aged 6–12 gradually build ethical foundations and practice fairness across both online and offline environments [26]. Thus, developing ethical competencies is crucial for navigating the complexities of today's technology-driven world.

2.1.3. Smart Education

The global adoption of Smart Education (SE) has transformed basic education. By integrating AI, adaptive learning platforms, and interactive feedback systems, smart education provides a learner-centered approach that personalizes education and enhances student engagement [6]. Modern SE programs for children aged 6–12 adopt a constructivist framework, using structured digital activities to stimulate active participation [3]. Platforms that integrate AI-powered feedback with game simulation align closely with early childhood constructivist theories, promoting both individualized learning and active engagement [28]. These environments provide age-appropriate experiences that foster exploration, ethical reflection, and collaboration. Such digital knowledge-construction tools are instrumental in building effective moral reasoning skills [6,7,26]. This is consistent with Mukhlis et al. [29], who emphasize that intelligent education is crucial for developing students' digital potential, and with Falloon [8], who found that positive personal experiences, such as those provided by game-based SE systems, significantly boost learning effectiveness. Based on this literature, the researchers hypothesize the following:

H1. *Smart education has a direct effect on ethical competency in primary school learners aged 6–12.*

H2. *Smart education creates positive effects on digital literacy development for children between 6 and 12 years old.*

2.1.4. Digital Literacy

Digital literacy (DL) for children involves safely and effectively using digital devices, identifying reliable online information, maintaining respectful digital interactions, and understanding basic online privacy principles [8]. To foster these foundational competencies, school curricula must integrate essential digital skills that enable students to navigate the Internet responsibly [9]. Hands-on simulations are particularly effective. They allow children to confront ethical dilemmas, experience digital consequences, and reflect on their actions within a safe virtual space, thereby deepening their moral understanding [8]. According to Mukhlis et al. [29], a youth's digital knowledge directly influences their future application of digital ethics. Strong digital literacy also enhances rational decision-making and enables ethical technological choices [30]. Moreover, Löfving [31] identifies digital literacy as a core component in comprehending digital education systems, which, in turn, supports the development of ethical competency. Finally, classroom instruction focused on digital literacy significantly improves students' ability to recognize online dangers and use technology ethically [32]. Therefore, the researchers formulated the following hypotheses:

H3. *The development of digital literacy directly leads to the growth of ethical competency in primary learners.*

H4. *Digital literacy operates as an intervening factor that links smart education to ethical competency within digital learning environments of primary education.*

2.1.5. Teacher Agency

Teacher agency (TA) refers to educators' capacity to make autonomous instructional decisions, model ethical behavior, and adapt their pedagogy to the needs of their students [28]. Teachers with strong agency are more effective at teaching digital ethics, serving as ethical role models, and adapting their pedagogy to student needs. Core functions that define this effectiveness with young learners include setting classroom expectations, integrating learning tools, engaging in daily interactions, and planning curricula [28]. Cultivating ethical skills in children aged 6–12 years relies on teacher-led reflections and structured exercises, both online and offline, that promote fairness, honesty, and respect. In this sense, Teacher Digital Competence extends beyond traditional technical literacy. It also requires teachers to understand the complex skills students need to navigate diverse digital environments ethically and safely [10]. Prior research shows that teachers' perceptions shape their digital education practices, underscoring the need for targeted professional development, age-appropriate digital civic activities, and robust policy support [9]. Consistent with this, Chowdhury et al. [33] and Samuelsson [34] describe teachers as essential facilitators of student development within digital learning systems, while Alenezi and Alfaleh [9] emphasize their crucial role in delivering effective digital skills instruction in smart education environments. Therefore, the researchers hypothesized the following:

H5. *Teacher agency influences the relationship between smart education and digital literacy in primary classrooms for learners aged 6–12 years.*

2.1.6. Institutional Support

Institutional support (IS) encompasses organizational frameworks, such as curriculum standards, digital conduct policies, teacher training programs, and IT infrastructure, designed to facilitate ethical digital learning [1]. Through IS, primary school environments

are safeguarded to ensure safety, age-appropriateness, and alignment with broader societal goals [1,5,35]. Schools must adopt methods that cultivate both moral values and critical thinking during these formative years [1]. Open, student-centered platforms support this by fostering collaborative learning that extends beyond the classroom to involve families and communities, addressing real-world problems through meaningful projects while building interdisciplinary skills [4]. Consequently, primary school policies and teaching guidelines are fundamental to shaping ethical digital citizenship and developing future human capital. Indeed, Mukhlis et al. [29] argue that institutional support for collaborative environments is more crucial than traditional face-to-face instruction for sustaining digital learning systems and fostering digital ethics. Furthermore, Parmaxi et al. [1] identify institutional support as a necessary organizational factor for establishing digital curriculum standards, while Samuelsson [34] highlights its vitality in delivering effective digital literacy education to young learners. Therefore, the researchers formulated the following hypothesis:

H6. *Institutional support moderates the relationship between digital literacy and ethical competency in primary learners aged 6–12.*

2.1.7. Executive Function

Executive function (EF) serves as a fundamental cognitive foundation, providing a comprehensive framework to analyze student learning, moral development, and ethical technology use [36–38]. EF skill development occurs in three rapid growth cycles (18 months to 5 years; 5 to 10 years; and 10 to 14 years), aligning with neural and cerebral cortex developmental models [39]. As a general term for interconnected higher-level cognitive processes, EF encompasses working memory, sustained attention, and inhibitory control. These abilities, essential for self-regulation, problem-solving, and goal-oriented behavior, emerge in infancy and mature into early adulthood [40]. Prior research links strong EF skills to a range of positive developmental, academic, and behavioral outcomes, with lasting effects on literacy and health [41]. Acting as the brain's "air traffic control system", EF helps individuals organize information, plan, and make choices when automatic or intuitive responses are insufficient [42]. Also known as cognitive control, these top-down mental processes are necessary for concentration and deliberate action [43–45]. Because utilizing EF requires deliberate mental effort to override automatic habits, it serves as a crucial indicator of learning readiness, academic achievement, and social behavior [46]. EF development accelerates during middle childhood (ages 6–12), a crucial stage marked by the onset of formal schooling and increased academic and social demands. This development both shapes and is shaped by a complex interplay of genetic, environmental, and experiential factors [37,42]. EF can be effectively promoted through an interdisciplinary approach that combines physical and cognitive stimulation [47]. Li et al. [48] identify EF as fundamental to developing digital ethical competency, while Ahmed et al. [39] note its crucial role in cultivating ethical values throughout a student's educational journey. These findings align with Quílez-Robres et al. [49], who argued that EF is a foundational skill for ethical engagement in the digital age. Therefore, the researchers formulated the following hypothesis:

H7. *Executive function has a direct effect on ethical competency in primary school learners aged 6–12 years old.*

2.2. Key Theories and Concepts

2.2.1. Connectivism and Constructivist Learning Theory

Constructivism, rooted in the foundational work of Jean Piaget and Lev Vygotsky, frames learning as an active process of knowledge construction through experiential re-

flection Rather than passively receiving information, learners construct meaning through interactive, hands-on activities that personalize the educational experience [3]. Building on this, George Siemens introduced connectivism in 2005, positing that digital networks drive knowledge acquisition beyond individual human capacity [22,29,50]. Post-pandemic research, such as Baskara's [51] adaptation of adult connectivism principles to basic education, further highlights the theory's relevance in shaping knowledge and social norms through online collaboration. Connectivism theoretically bridges smart education (SE), digital literacy (DL), and ethical competency (EC), demonstrating how networked learning fosters ethical engagement. Guided by these theories, smart education frameworks dictate that technology-based spaces must remain student-centered, employing interactive activities and contextual feedback [3,29,35]. This approach creates adaptive environments where children can explore digital tools at developmentally appropriate levels. Empirically, as primary learners require supportive, collaborative classroom environments to build their moral reasoning, which is further reinforced by their internal self-regulatory and cognitive capacities [3,26].

Contextual relevance is the final constructivist principle in ethics education: to be effective, lessons must connect directly to students' personal experiences. Connectivism reinforces that digital ethics demand both individual and collective responsibility. Ethical development begins with intellectual knowledge construction and progresses toward moral understanding as children build these principles through direct interaction and active participation. Therefore, SE environments must transcend mere content delivery by intentionally incorporating ethical dilemmas, collaborative problem-solving, and reflective exercises. Because children develop digital ethics primarily through peer interaction rather than direct adult instruction, schools must cultivate positively supervised digital communities in which educators should guide students to co-create ethical guidelines, since rule adherence is inherently a collective effort [29]. Students aged 6 to 12 learn digital ethics best through interactive scenarios on familiar platforms rather than abstract discussions. This highlights the immense value of game-based ethics simulations, which provide safe, virtual spaces for children to confront dilemmas, experience consequences, and build moral understanding through reflection [8].

2.2.2. Socio-Technical Systems Theory (STS)

Socio-Technical Systems Theory (STS), originally introduced by Trist and Emery, posits that optimal system efficiency requires integrating technological systems with human and cultural elements. Within the digital education contexts, this framework implies that technological tools remain inefficient without policies that integrate ethical teaching methods. Consequently, schools must develop instructional support systems that align directly with their institutional structures [34]. This perspective is strongly supported by empirical research. For instance, Masri-Zada et al. [52] demonstrated that educational technology only improves outcomes when systematically supported by the social environment. Furthermore, Perrotta and Pangrazio [35] found that digital platforms fail in primary education without a human-centered approach, while Pozo et al. [5] confirmed that institutional and cultural frameworks decisively determine a technology's impact.

Smart education fundamentally requires this human-centered approach. According to STS, SE effectiveness depends on integrating technology into the school's social environment via teaching practices, relationships, and regulations. Functioning as integrated socio-technical ecosystems, SE systems encompass policies, teacher roles, and institutional support. Within this framework, teacher agency and institutional support act as the primary drivers of this transformation [34,53]. Successfully integrating digital ethics into SE requires balancing human capabilities, organizational policies, and technological tools. However,

uneven infrastructure and inadequate training often disrupt this pattern [9]. The resulting digital adoption gap exacerbates inequalities and widens achievement gaps, especially for students from lower socioeconomic backgrounds [1]. In Thailand, the lack of ethical guidelines within expanding SE programs places students at risk, as they navigate digital resources without necessary guidance [9].

2.3. Conceptual Framework

Based on the literature review, the researchers developed the conceptual framework illustrated in Figure 1 to model ethical digital citizenship (EDC) among 6–12-year-old Thai primary school students. The framework tests the relationship among six main variables: smart education, digital literacy, ethical competency, teacher agency, institutional support, and executive functions. Specifically, it examines smart education's direct influence on digital literacy, as well as digital literacy's direct impact on ethical competency. The model also assesses digital literacy's mediating role between smart education and ethical competency. Additionally, it evaluates teacher agency as a moderator between smart education and digital literacy, and institutional support as a moderator between digital literacy and ethical competency. Finally, the framework measures the direct effect of executive function on ethical competency.

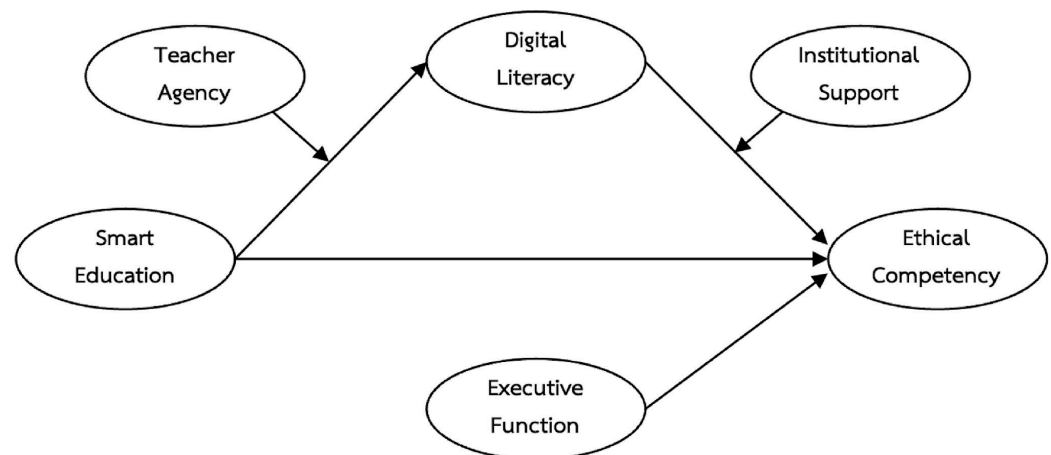


Figure 1. The proposed research framework. (Arrows indicate hypothesized direct effects and moderating pathways among variables).

3. Materials and Methods

3.1. Population and Sample

The target population for this study comprised teachers working in public, private, and international primary schools (grades 1 to 6) across Thailand. According to Thailand's education statistics [54] the formal education system employed 497,751 primary school teachers out of 833,104 total educators. To determine an appropriate sample size, the researchers applied the Krejcie and Morgan [55] formula with a 95% confidence level and a 5% margin of error, yielding a target of 384 participants. To ensure this minimum was met, additional surveys were distributed, ultimately resulting in 387 valid and complete responses. The empirical data for this study relied on educator proxy-reports rather than student self-reports, since primary school students aged 6–12 are still developing the capacity for complex cognitive reflection, executive function, and abstract ethical reasoning, factors that make direct questionnaires highly susceptible to comprehension errors and response bias. Teachers and administrators, by contrast, observe these students daily in naturalistic classroom settings. These consistent interactions provide a structured, ecologically valid basis for evaluating students' behavioral and cognitive self-regulation. Adopting this

widely accepted proxy-reporting approach ultimately ensured a more accurate assessment of the students' development. The decision to include educators from early childhood and secondary levels directly reflects the structure of the Thai educational system. Because Thai primary education generally covers children aged 6 to 11, 12-year-olds have usually already transitioned to lower secondary school. Therefore, surveying secondary school teachers was methodologically necessary to capture accurate data for the upper boundary of the demographic. Moreover, many public schools under the Office of the Basic Education Commission (OBEC) operate as integrated K–9 or K–12 institutions. Consequently, cross-level educators frequently collaborate to monitor student development, ensuring a comprehensive, multi-informant evaluation.

3.2. Research Tool

A 5-point Likert scale questionnaire, ranging from 1 (strongly disagree) to 5 (strongly agree), served as the primary research instrument. Based on the conceptual framework, the 21-item survey assessed six key constructs. The Smart education (SE) construct was measured using three items (B1–B3) addressing AI-driven personalized instruction and gamified learning. Digital literacy (DL) was measured using three items (C1–C3) covering technical ability and information verification. Executive function (EF) was measured using three items (D1–D3) addressing working memory and inhibitory control in digital contexts. Ethical competency (EC) was measured using three items (E1–E3) addressing moral sensitivity and ethical decision-making. Finally, the moderating variables included teacher agency (TA, four items; F1–F4) and institutional support (IS, five items; G1–G5). A panel of qualified experts evaluated the instrument for content validity, confirming that all items exceeded the standard 0.5 criterion. Additionally, initial scale reliability was verified using Cronbach's alpha as detailed in Table 1.

Table 1. Questionnaire reliability.

Variable	No. of Items	Cronbach's Alpha	Reliability Level
Smart Education (SE)	3	0.912	Very High
Institutional Support (IS)	5	0.938	Very High
Teacher Agency (TA)	4	0.921	Very High
Digital Literacy (DL)	3	0.904	Very High
Executive Function (EF)	3	0.916	Very High
Ethical Competency (EC)	3	0.927	Very High

3.3. Data Collection

Data were collected using both online (Google Forms; Web-based application; Google LLC, Mountain View, CA, USA) and printed questionnaires. Digital surveys were distributed primarily through the national teacher and OBEC network, while printed questionnaires were distributed to schools with limited digital access. Participation was strictly voluntary, and informed consent was obtained from all 387 respondents prior to data collection. In accordance with Mahasarakham University's ethical guidelines for human research, all participant data were kept confidential. Importantly, rather than directly measuring student self-reports, the survey instrument captured educators' professional perceptions and structured classroom observations regarding their students' digital ethics, digital literacy, and executive functioning.

3.4. Data Analysis

The primary data were analyzed using descriptive statistics, including frequency, percentage, mean, and standard deviation. For inferential statistical analysis, the researchers

employed partial least squares structural equation modeling (PLS-SEM) via SmartPLS 4 (SmartPLS GmbH, Oststeinbek, Germany). In the first step, the measurement model was evaluated to ensure the observed variables appropriately reflected the latent constructs through validity and reliability. Internal consistency was confirmed using Cronbach's alpha and Composite Reliability (CR) coefficients with a minimum threshold of 0.70 applied to all variables. Convergent validity was assessed via the Average Variance Extracted (AVE), requiring values above 0.50 to confirm that each construct explained the majority of the indicator's variance. Discriminant validity was verified using both the Heterotrait–Monotrait (HTMT) ratio and the Fornell–Larcker criterion. Additionally, multicollinearity was assessed using the Variance Inflation Factor (VIF), with values below 5.0 indicating an acceptable linear fit free from multivariate correlation issues. In the second step, a structural model was analyzed to test the seven hypotheses and determine the influence of each path within the conceptual framework. The strength and direction of these relationships were evaluated using path coefficients (statistical significance set at $p < 0.05$), while the model's predictive power was measured via the coefficient of determination (R^2) and the effect size (f^2). Additionally, model fit was determined using the Standardized Root Mean Square Residual (SRMR < 0.08) and the Normed Fit Index (NFI > 0.80), while predictive relevance was mapped via Stone–Geisser's Q^2 benchmarks to evaluate weak (>0.02), moderate (>0.15), and strong (>0.35) framework capacities.

4. Results

To address the potential risk of common method bias (CMB) arising from data collection, the researchers first performed Harman's single-factor test. Using principal axis factoring, the analysis examined whether a single latent factor could explain the majority of the variance across the measurement items. The extraction results revealed that the first factor accounted for 48.229% of the total variance. Because this value falls below the typical 50% threshold, common method bias is unlikely to be a significant concern, supporting the robustness of the subsequent structural model analysis [56].

The statistical analysis results are presented in three sequential phases: descriptive analysis, measurement model evaluation, and structural equation model analysis.

4.1. Descriptive Analysis

4.1.1. Participants Analysis

The analysis of the basic information of the participants in this research is detailed in Table 2.

As detailed in Table 2, primary school teachers in grades 1–6 comprised the largest respondent group ($n = 148$, 38.3%), followed by secondary school teachers ($n = 132$, 34.1%), early childhood teachers ($n = 36$, 9.3%), other groups ($n = 35$, 9.0%), educational administrators ($n = 27$, 7%), and curriculum specialists ($n = 9$, 2.3%). Regarding professional experience, 41.9% ($n = 162$) of the participants had five years or less, 41.1% ($n = 159$) had 6 to 15 years, and 17.1% ($n = 66$) had more than 15 years. The majority of respondents worked in suburban areas (45.0%), followed by urban (43.4%) and rural (11.6%). The sample overwhelmingly represented public schools under the Office of the Basic Education Commission (OBEC) (93.8%), with minor representation from international or bilingual schools (3.2%) and private schools (1.5%). Regionally, 85.2% of participants were located in Thailand's Eastern region. Most participants worked in mid-to-large schools, with 40.3% at institutions serving between 2001 and 3000 students and 38.8% at schools serving between 1001 and 2000 students.

Table 2. Participant analysis.

Variables	Items	Frequency	Percent
Role	Primary school teachers (grades 1–6)	148	38.3
	School administrators/principals	27	7.0
	Curriculum specialist	9	2.3
	Secondary school teachers	132	34.1
	Early childhood teachers	36	9.3
	Others	35	9.0
Experience	0–5 years	162	41.9
	6–15 years	159	41.1
	More than 15 years	66	17.1
Work location	Urban	168	43.4
	Suburban	174	45.0
	Rural	45	11.6
School types	OBEC (Public General School)	363	93.8
	Private School (OPEC)	6	1.5
	Bilingual/International School	12	3.2
	Others	6	1.5
Regions	Central part	24	6.2
	Northern part	3	0.8
	North-eastern part	30	7.8
	Eastern part	330	85.2
Number of Students	1000 or below	75	19.4
	1001–2000	150	38.8
	2001–3000	156	40.3
	3001 or above	6	1.5

4.1.2. Key Variables Analysis

The descriptive statistical analysis of the key variables in this research, including the mean and standard deviation, is shown in detail in Table 3.

Table 3. Descriptive statistics for all research variables.

Variables	M	SD	Interpretation
Smart Education (SE)	4.33	0.61	Highest
Digital Literacy (DL)	4.03	0.75	High
Executive Function (EF)	3.83	0.78	High
Ethical Competency (EC)	3.87	0.74	High
Teacher Agency (TA)	4.27	0.62	Highest
Institutional Support (IS)	4.24	0.70	Highest

Table 3 summarizes the means and standard deviations for all key research variables. Three variables achieved the highest overall mean scores: smart education ($M = 4.33$, $SD = 0.61$), teacher agency ($M = 4.27$, $SD = 0.62$), and institutional support ($M = 4.24$, $SD = 0.70$). The remaining variables also demonstrated high overall means: digital literacy ($M = 4.03$, $SD = 0.75$), ethical competency ($M = 3.87$, $SD = 0.74$), and executive function ($M = 3.83$, $SD = 0.78$).

4.2. PLS-SEM Analysis

4.2.1. Measurement Model Analysis

Tables 4–7 provide comprehensive details evaluating the measurement model's suitability, validity, and reliability.

Table 4. Construct reliability and validity.

Constructs	Variables	Loadings	Cronbach's Alpha	Composite Reliability (CR)	Average Variance Extracted (AVE)
Smart Education (SE)	B1	0.875	0.805	0.827	0.716
	B2	0.813			
	B3	0.849			
Digital Literacy (DL)	C1	0.866	0.853	0.855	0.773
	C2	0.905			
	C3	0.865			
Executive Function (EF)	D1	0.875	0.888	0.887	0.817
	D2	0.928			
	D3	0.907			
Ethical Competency (EC)	E1	0.841	0.873	0.877	0.799
	E2	0.939			
	E3	0.900			
Teacher Agency (TA)	F1	0.825	0.891	0.902	0.753
	F2	0.887			
	F3	0.902			
	F4	0.855			
Institutional Support (IS)	G1	0.911	0.932	0.935	0.785
	G2	0.869			
	G3	0.874			
	G4	0.867			
	G5	0.907			

Table 5. Discriminant validity by Heterotrait–monotrait ratio (HTMT) matrix.

Constructs	DL	EC	EF	IS	SE	TA	IS × DL
DL							
EC	0.807						
EF	0.872	0.867					
IS	0.604	0.554	0.619				
SE	0.448	0.376	0.407	0.503			
TA	0.525	0.557	0.562	0.772	0.525		
IS × DL	0.058	0.173	0.140	0.194	0.092	0.165	
TA × SE	0.072	0.117	0.070	0.065	0.341	0.048	0.130

Table 6. Discriminant validity (Fornell–Larcker criterion).

Constructs	DL	EC	EF	IS	SE	TA
DL	0.879					
EC	0.699	0.894				
EF	0.763	0.764	0.904			
IS	0.541	0.503	0.564	0.886		
SE	0.377	0.328	0.359	0.447	0.846	
TA	0.462	0.491	0.502	0.705	0.445	0.868

Note: Bold values on the diagonal represent the square root of the Average Variance Extracted (AVE) for each construct.

In the initial evaluation, the researchers addressed whether the observed variables appropriately reflected their respective latent constructs. As shown in Table 4, the passing criteria required factor loadings greater than 0.7, Cronbach's alpha greater than 0.7, composite reliability (CR) greater than 0.7, and average variance extracted (AVE) greater than 0.5 [57].

Table 7. Collinearity (VIF).

Variables	VIF
B1	1.950
B2	1.838
B3	1.569
C1	2.174
C2	2.548
C3	1.886
D1	2.102
D2	3.477
D3	2.991
E1	1.904
E2	3.792
E3	3.031
F1	2.407
F2	3.028
F3	2.945
F4	2.437
G1	3.726
G2	2.764
G3	2.835
G4	2.988
G5	3.535

The measurement model in Table 4 confirmed that all latent variables demonstrated strong structural integrity and met the required statistical thresholds. Smart education exhibited strong reliability and validity, with loadings ranging from 0.813 to 0.875, Cronbach's alpha of 0.805, CR of 0.827, and AVE of 0.716. Similarly, digital literacy showed loadings ranging from 0.865 to 0.905, Cronbach's alpha of 0.853, CR of 0.855, and AVE of 0.773. Executive function performed well above the minimum criteria, with loadings from 0.875 to 0.928, Cronbach's alpha of 0.888, CR of 0.887, and AVE of 0.817. Ethical competency showed loadings ranging from 0.841 to 0.939, Cronbach's alpha of 0.873, CR of 0.877, and an AVE of 0.799. Teacher agency showed loadings ranging from 0.825 to 0.902, Cronbach's alpha of 0.891, CR of 0.902 and AVE of 0.753. Finally, institutional support showed loadings ranging from 0.867 to 0.911, Cronbach's alpha of 0.932, CR of 0.935, and AVE of 0.785.

Following partial least squares structural equation modeling convention, discriminant validity was verified using the Heterotrait–Monotrait Ratio (HTMT), based on the criteria proposed by Henseler et al. [58]. To confirm that each latent variable is statistically distinct, all HTMT values should be below 0.90. As illustrated in Table 5, the model met this requirement entirely. The highest recorded correlation was found between executive function and digital literacy (0.872), followed by executive function and ethical competency (0.867). These results confirm that the latent variables represent unique, independent phenomena, establishing strong discriminant validity of the measurement model [58].

Table 6 presents the assessment of discriminant validity using the Fornell–Larcker criterion, which requires that the square root of each construct's AVE (shown on the diagonal) exceed its correlations with all other constructs (shown in the corresponding row and column) [58]. The results confirm that this condition was met for all constructs, establishing robust discriminant validity for the measurement model.

Furthermore, Table 7 details the assessment of multicollinearity within the measurement models. All variables demonstrated a Variance Inflation Factor (VIF) below the acceptable threshold of 5.0, confirming the absence of severe multicollinearity issues [59].

4.2.2. Structural Model Analysis

The results of the partial least squares–structural equation modeling analysis for this research are shown in detail in Figure 2 and Table 8.

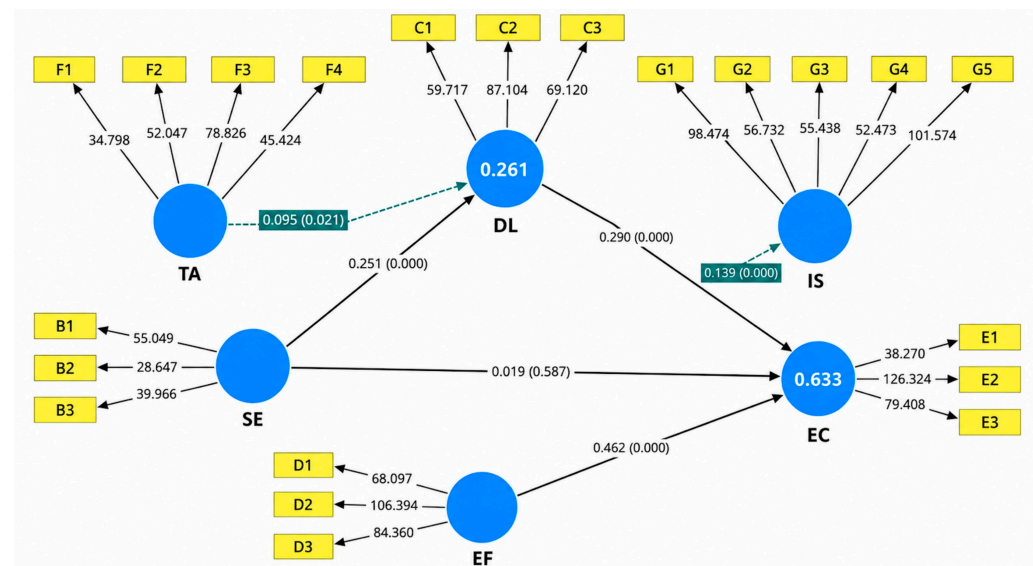


Figure 2. Final model.

Table 8. The effects of influential paths and hypothesis testing.

Paths (Hypothesis)	Coefficients	t Statistics	p Values	f ²	Interpretation
SE → EC (H1)	0.019	0.544	0.587	0.001	Rejected
SE → DL (H2)	0.251	4.769	0.000 ***	0.062	Supported
DL → EC (H3)	0.290	4.296	0.000 ***	0.088	Supported
SE → DL → EC (H4)	0.073	3.240	0.001 **	0.078	Supported
TA × SE → DL (H5)	0.095	2.316	0.021 *	0.014	Supported
IS × DL → EC (H6)	0.139	3.835	0.000 ***	0.040	Supported
EF → EC (H7)	0.462	6.659	0.000 ***	0.201	Supported

NOTE: *, **, and *** mean the statistical significance level at 0.05, 0.01, and 0.001, respectively.

The structural equation modeling results show that nearly all hypothesized paths are statistically significant ($p < 0.05$), except for the direct influence of smart education (SE) on ethical competency (EC). Model fit was verified using the Standardized Root Mean Square Residual (SRMR) and the Normed Fit Index (NFI). The analysis yielded an SRMR value of 0.060, which falls well within the recommended threshold of 0.08, and an NFI value of 0.801, indicating an acceptable overall model fit.

Table 8 provides empirical evidence for the complex interactions within the EDC framework. Path analysis reveals that smart education does not have a statistically significant direct impact on ethical competency, leading to the rejection of Hypothesis 1 (H1: $\beta = 0.019$, $p = 0.587$). The negligible effect size ($f^2 = 0.001$) further confirms this weak direct relationship.

However, smart education demonstrates a significant positive influence on digital literacy (H2: $\beta = 0.251$, $p < 0.001$, $f^2 = 0.062$), and digital literacy, in turn, significantly influences ethical competency (H3: $\beta = 0.290$, $p < 0.001$, $f^2 = 0.088$). Although these f^2 values fall between the 0.02 and 0.15 thresholds, and therefore indicate small effect sizes, the relationships remain statistically significant, supporting Hypotheses 2 and 3. Furthermore, digital literacy significantly mediates the relationship between smart education and ethical competency (H4: $\beta = 0.073$, $p < 0.01$, $f^2 = 0.078$), supporting Hypothesis 4. Regarding

moderation effects, teacher agency serves as a significant moderating factor between smart education and digital literacy (H5: $\beta = 0.095$, $p = 0.021$), though with a subtle practical impact as its effect size $f^2 = 0.014$ falls slightly below the conventional 0.02 threshold. Similarly, institutional support significantly moderates the influence of digital literacy on ethical competency (H6: $\beta = 0.139$, $p < 0.001$, $f^2 = 0.040$). Therefore, Hypotheses 5 and 6 are supported. Finally, executive function (EF) exerts a strong, significant direct influence on ethical competency (H7: $\beta = 0.462$, $p < 0.001$, $f^2 = 0.201$). The effect size ($f^2 = 0.201$) indicates a medium effect, confirming that executive function serves as a primary cognitive predictor within this structural framework.

Simple slope analysis (Figure 3) further illustrates the moderating effect underlying Hypothesis 5. The positive influence of smart education on digital literacy is significantly stronger when teacher agency is high (+1 SD) than when it is average or low (−1 SD), confirming that teacher agency acts as a key catalyst in promoting digital literacy.

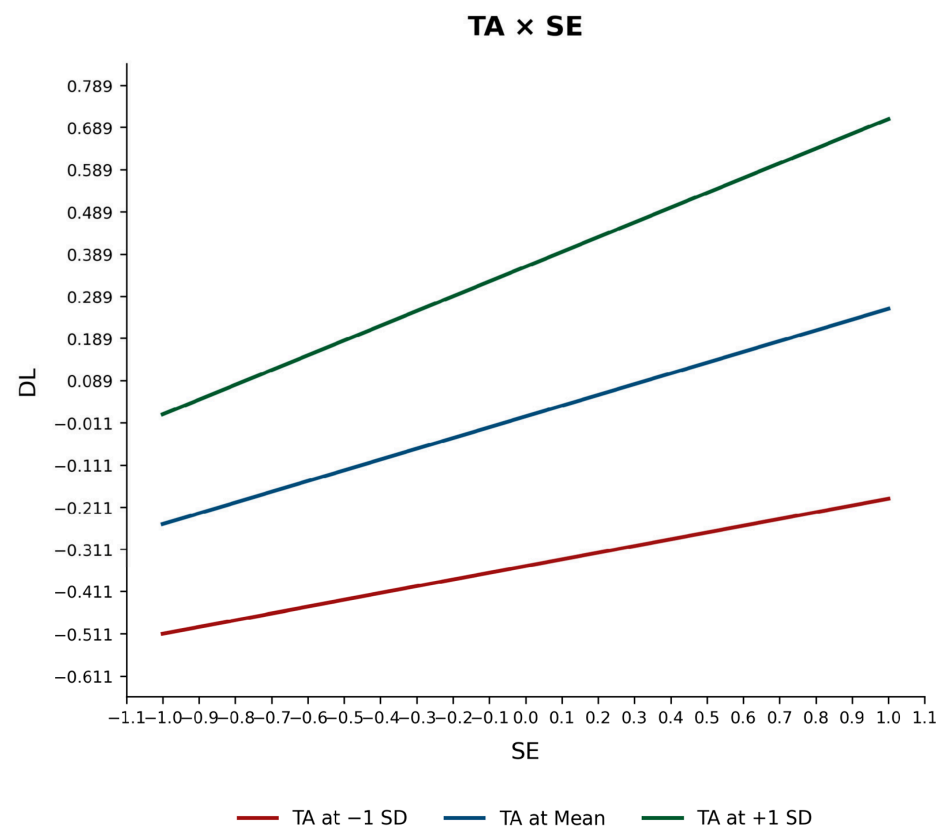


Figure 3. Simple slope analysis of the moderating effect of Teacher Agency (TA) on the relationship between Smart Education (SE) and Digital Literacy (DL).

Similarly, simple slope analysis for Hypothesis 6 (Figure 4) revealed that the pathway from digital literacy to ethical competency is significantly strengthened under high institutional support (+1 SD). This demonstrates that a robust school policy environment is crucial for translating digital literacy into ethical competency.

Table 9 presents the coefficients of determination (R^2) for the dependent variables. Smart education, together with the moderating effect of teacher agency, explains 26.1% of the variance in digital literacy ($R^2 = 0.261$), representing a low to moderate effect. Conversely, the full model explains a substantial 63.3% of the variance in ethical competency ($R^2 = 0.633$), indicating moderate-to-high explanatory power. Predictive relevance was assessed using Stone–Geisser’s Q^2 values, where values above 0.02 indicate weak, above 0.15 indicate moderate, and above 0.35 indicate strong predictive relevance. The Q^2 value for digital literacy is 0.242, indicating moderate predictive relevance, while the Q^2 value

for ethical competency is 0.564, indicating strong predictive relevance for the proposed structural model.

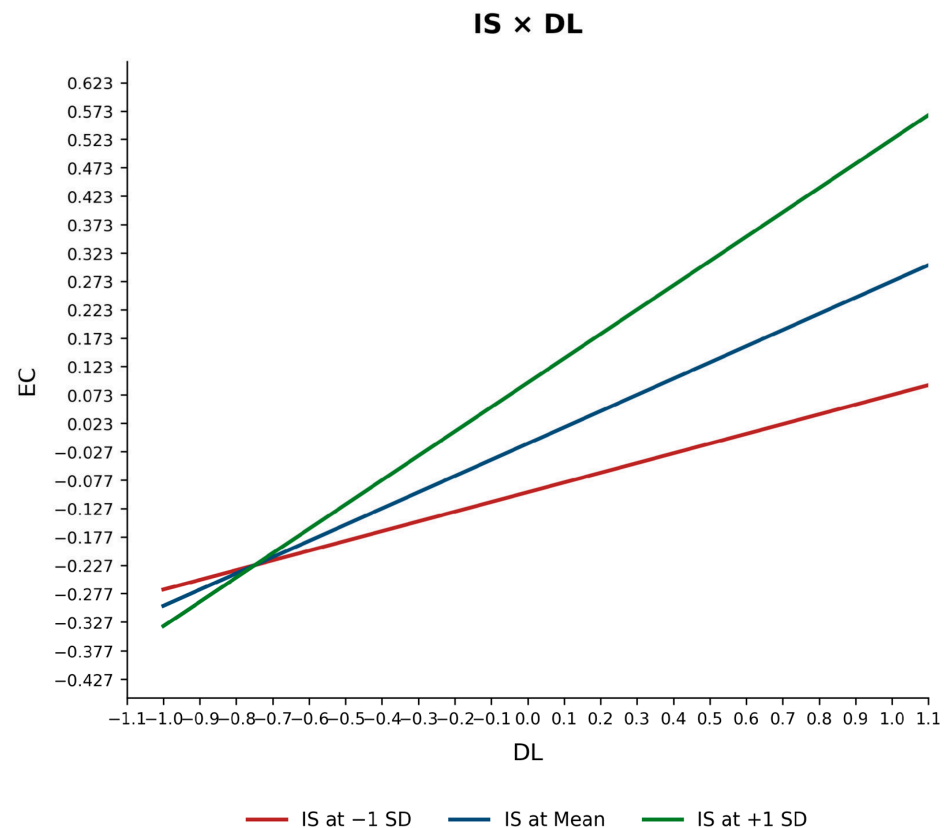


Figure 4. Simple slope analysis of the moderating effect of Institutional Support (IS) on the relationship between Digital Literacy (DL) and Ethical Competency (EC).

Table 9. Coefficient of determination (R^2) and predictive relevance (Q^2).

Dependent Variables	R^2	R^2 Adjusted	Q^2
Digital literacy	0.261	0.255	0.242
Ethical competency	0.633	0.628	0.564

5. Discussion

Analysis of the key variables revealed high to very high average scores across all constructs. This indicated that respondents (teachers, administrators, and curriculum experts) held highly positive attitudes regarding the research constructs. While this study focuses on primary school students, the findings rely primarily on these educators' professional perspectives. Feedback on ethical digital citizenship development was overwhelmingly positive, reflecting optimism about the progress of students aged 6–12. Based on the educators' observations, students were perceived to exhibit high levels of appropriate digital ethics behavior, including the abilities to critically evaluate information, make sound decisions in complex digital scenarios, and apply key ethical principles online. Regarding executive function, educators observed that students demonstrated strong self-control, enabling them to effectively manage and organize their thoughts during digital learning. For instance, respondents evaluated the students as demonstrating higher-order thinking skills and self-discipline, which facilitated their success in digital environments. Educators also rated students' ethical competencies highly, reflecting confidence in schools' ethical development programs. Teachers observed that students displayed appropriate ethical

judgment and expressed themselves responsibly in the use of digital technology. Students also demonstrated high proficiency in digital literacy. However, these ratings reflect educators' professional observations rather than direct objective measurements or standardized testing of students' digital literacy, executive function, and ethical competencies. Finally, smart education systems, teacher agency, and institutional support received the highest average scores. This highlights the successful integration of AI-driven and game-based learning, confidence in teachers' ability to guide ethical behavior, and trust in institutional support to provide robust digital infrastructure while fostering an ethical school culture.

The first hypothesis was rejected, as this study found no direct influence of smart education on the development of ethical competency among primary school students aged 6–12. This finding contrasts with the foundational paradigms of DeVries and Zan [3], who established that structured, interactive classroom environments are vital catalysts for fostering holistic moral and socio-emotional development in primary learners. It also contrasts with Schuetz and Koglin [26], who found that education systems incorporating knowledge creation tools support the development of effective moral reasoning skills. This discrepancy likely stems from differences in Thailand's basic education system compared to other countries. In Thai classrooms, advanced technological infrastructure is often utilized purely as a technical delivery system rather than a foundation for moral instruction. Unlike certain Western models that blend technology with independent moral inquiry, simply having smart education tools does not automatically foster morality. Other mediating factors must be present to develop ethical competency in these students.

Supporting Hypothesis 2, the study found that smart education significantly improves digital skills among 6–12-year-old students. This aligns with DeVries and Zan [3], who emphasized that constructivist, interactive learning environments deeply nurture children's broader intellectual and social development. It also supports constructivist principles that identify smart education as vital for building digital capacities [29], and aligns with Falloon [8], who linked learning effectiveness to positive personal experiences. Since approaches like game-based learning enhance education, institutions should prioritize integrating diverse smart education methods, such as collaborative online learning and educational games, to significantly boost Thai primary school students' digital skills.

Furthermore, the results support Hypothesis 3, digital literacy directly and significantly impacts the development of ethical competency. This is consistent with Mukhlis et al. [29], who demonstrated that digital knowledge and experience are foundational to youth's current and future digital ethics. It also aligns with Savage [30], who found that strong digital literacy fosters rational decision-making and ethical technology choices. Therefore, cultivating digital literacy in primary school students is vital for their future ethical proficiency, underscoring the essential role educational institutions play in developing these skills for 6–12-year-olds.

Supporting Hypothesis 4, the study confirmed that digital literacy mediates the relationship between smart education and ethical competency. This aligns with Löfving [31], who identified digital literacy as a key component for translating digital education into tangible ethical competency, and Guitert et al. [32], who noted that digital literacy instruction helps students identify online dangers and act ethically. Ultimately, developing digital ethics requires pairing smart education systems with foundational digital experiences. A novel contribution of this research is identifying the crucial bridging role of digital skills. Without this bridge, providing smart education alone could widen social gaps and increase ethical disregard in technology use.

These findings support Hypothesis 5, revealing that teacher agency acts as a moderating variable between smart education and digital skills development. This is consistent with Chowdhury et al. [33] and Samuelsson [34], who highlighted teachers as crucial fa-

cilitators in digital learning ecosystems. It also aligns with Alenezi and Alfaleh [9], who emphasize teachers' vital role in smart education. In sum, teachers serve as essential agents of change in Thailand, ensuring that smart education systems effectively achieve their digital skills development goals.

Supporting Hypothesis 6, the data demonstrate that institutional support significantly moderates the relationship between digital literacy and ethical competency. This aligns with Mukhlis et al. [29], who argued that institutional support for collaborative learning environments, beyond traditional tutoring, is crucial for developing digital ethics. This is also consistent with Parmaxi et al. [1], who identified institutional support as a necessary organizational factor for establishing digital curriculum standards and ethical policies. Additionally, Samuelsson [34] noted that institutional support, comprising curriculum integration, ethics policy design, ethics leadership, and teacher training, is critical for digital literacy education. Therefore, robust institutional policies are essential for the success of smart education systems in Thailand.

Finally, the research provides strong empirical support for Hypothesis 7, confirming that executive function has a profound, direct influence on the ethical abilities of 6–12-year-old students. These findings align with Li et al. [48], who identified executive function as a fundamental element for digital ethical competency, and Ahmed et al. [39], who characterized these cognitive processes as crucial for cultivating ethical values. Furthermore, this aligns with Quílez-Robres et al. [49], who emphasize that executive function is a necessary foundational skill for ethical engagement in the digital age.

6. Conclusions

This study investigated the key factors driving ethical digital citizenship among Thai primary school students aged 6–12. It resulted in a structural model demonstrating the relationships among six main variables, smart education, digital literacy, ethical competency, teacher agency, institutional support, and executive functions. Specifically, the research captured educators' perspectives on the factors shaping student behavior and development. As shown in Figure 5, the results indicate that smart education directly influences digital literacy, with teacher agency moderating this relationship. Furthermore, digital literacy directly impacts ethical competency, a relationship that is significantly moderated by institutional support. Finally, executive function emerged as a crucial variable with a significant, direct impact on students' ethical competency. Ultimately, the derived conceptual framework offers a novel understanding of ethical digital citizenship for this demographic. Thai educational institutions and policymakers can utilize this model to effectively foster these vital skills in young learners.

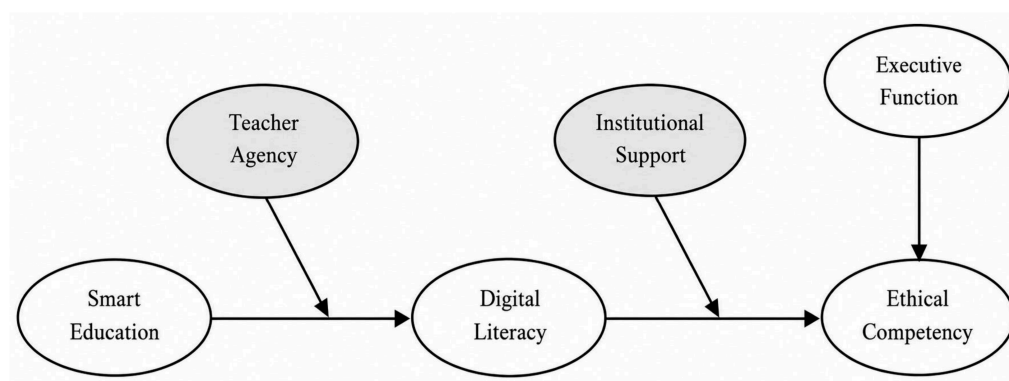


Figure 5. The Integrated Ethical Digital Citizenship (EDC) Framework for Thai Primary Learners. (Arrows indicate the directional relationships and flow between the components).

Beyond validating these structural relationships, the findings offer vital implications for educational policy. Specifically, the results demonstrate that merely equipping classrooms with smart education infrastructure is insufficient; rather, digital literacy and executive functions must be actively cultivated as essential bridges to ethical digital behavior. Despite these contributions, certain limitations within this study provide directions for future research. First, while utilizing teacher and administrator proxy reports is methodologically justified for addressing complex behaviors in young children (aged 6–12), a primary limitation is that the empirical data rely on educators' professional observations and subjective assessments rather than direct objective measurements or standardized direct testing of the students' digital literacy competencies. Consequently, the findings reflect performance as perceived through an instructional lens rather than unmediated student outcomes. Additionally, the cross-sectional design and the sample's regional concentration within Thailand's Eastern region restrict definitive causal inferences and limit broad national generalizability. Consequently, future studies should employ longitudinal designs to monitor ethical development over time. Expanding to diverse nationwide cohorts and integrating multi-informant data, such as parent reports or direct cognitive neuro-assessments, will be crucial for further validating and extending this ethical digital citizenship framework.

7. Recommendations

Thai primary education institutions can utilize the derived model (Figure 5) as a strategic guideline for developing policies, missions, and activities centered on ethical digital citizenship. The researchers suggest the following applications:

1. Institutions should enhance teachers' capabilities in social interaction, moral reasoning, and the ethical use of digital technology. Because this study confirms that teacher agency significantly boosts the impact of smart education, equipping educators to serve as ethical digital role models is essential to fostering digital literacy in primary school students aged 6–12.
2. Schools must establish robust support systems that continuously promote digital literacy. Active institutional support ensures that digital literacy initiatives effectively translate into the development of strong moral values and ethical competency.
3. Thai primary education institutions should actively integrate practices that build students' working memory, self-control, and planning skills within digital contexts. Strengthening these cognitive and self-regulatory skills will empower learners to manage online situations effectively, ultimately laying the foundation for moral and ethical behavior.

By implementing these recommendations, Thai educational institutions can significantly improve the ethical use of technology among primary school students aged 6–12, effectively addressing current gaps in the national education system.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are not publicly available due to confidentiality restrictions.

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