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Integrating Intelligent-Technological Pedagogical and Content Knowledge (Intelligent-TPACK) and Tripartite Models to Examine Teachers' Knowledge and Attitudes Toward Artificial Intelligence (AI)

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ABSTRACT

Artificial Intelligence (AI) technologies have transformed educational practices, yet their effective integration in K–12 classrooms, particularly in the Moroccan context, remains underexplored. This study aims to examine teachers' knowledge and attitudes toward AI integration using the Intelligent-Technological Pedagogical and Content Knowledge (Intelligent-TPACK) framework and the Tripartite Model of Attitudes. A total of 204 Moroccan teachers participated in a survey. Collected data were analyzed through Exploratory and Confirmatory Factor Analyses, followed by Structural Equation Modeling (SEM) using SmartPLS. Results confirmed the validity of both models and revealed that Intelligent Techno-Pedagogical Knowledge (ITPK) is the strongest predictor of teachers' affective, behavioral, and cognitive attitudes toward AI. Ethical considerations significantly influenced cognitive attitudes, indicating reflective rather than resistant views toward AI adoption. These findings suggest that integrating pedagogical and ethical awareness into teacher training programs can foster positive attitudes and responsible AI use, supporting national education reforms aligned with Sustainable Development Goal 4 on quality education.

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1. INTRODUCTION

The quality of an educational system largely dependson the improvement of the teaching level (Gorani, 2021). In Morocco, continuous educational reform has aimed to modernize teaching and learning processes through two major initiatives: the *National Charter for Education and Training and the Strategic Vision 2015–2030* (Biyouda & Zahid, 2021). These reforms highlight the importance of integrating information and communication technologies (ICTs) into schools by providing multimedia classrooms, digital resources, and teacher training programs (Nejjari & Bakkali, 2017). However, as global education systems move beyond ICT toward Artificial Intelligence (AI) integration, understanding how teachers perceive and apply AI in pedagogical contexts becomes essential.

While ICT tools continue to be integrated into classrooms to enrich learning environments, there is a growing interest in exploring how AI technologies can further transform teachers' pedagogical practices. Nevertheless, the successful implementation of AI in classrooms depends not only on technological infrastructure but also on teachers' competence and attitudes toward AI use. In Morocco, where digital transformation remains in progress, examining teachers' knowledge and attitudes towards AI adoption is particularly important to ensure equitable and effective educational reform.

This study integrates two theoretical perspectives: the Intelligent-TPACK framework (Celik, 2023) and the Tripartite Model of Attitudes (Breckler, 1984). The Intelligent-TPACK model extends the traditional TPACK framework (Mishra & Koehler, 2006) by including ethical knowledge, emphasizing that effective AI integration requires not only technological and pedagogical expertise but also ethical awareness. Meanwhile, the Tripartite Model conceptualizes attitudes as comprising affective, behavioral, and cognitive components, providing a multidimensional understanding of how teachers feel, act, and think about AI integration.

Despite the growing global attention to AI knowledge among teachers, few studies have validated these frameworks within the Moroccan context, where educational culture and infrastructure differ from those of developed countries (Yang *et al*., 2025; Al-Abdullatif, 2024). Therefore, this study seeks to: (1) validate the Intelligent-TPACK framework for Moroccan K–12 teachers; (2) examine the Tripartite Model of Attitudes toward AI in education; and (3) analyze how knowledge components predict teachers' affective, behavioral, and cognitive attitudes. The novelty of this research lies in being the first empirical validation of both frameworks in Morocco, contributing cross-cultural insights into AI integration in teacher education. Ultimately, this study supports Morocco's educational vision and aligns with Sustainable Development Goal 4, which emphasizes inclusive and quality education through technological innovation and teacher empowerment.

2. LITERATURE REVIEW

2.1. Intelligent-TPACK Framework

The Technological Pedagogical and Content Knowledge (TPACK) framework was developed to conceptualize teachers' integrated knowledge of content, pedagogy, and technology. It consists of seven sub-dimensions that have inspired several derivative models proposed by later researchers (Mishra & Koehler, 2006; Archambault & Barnett, 2010; Chai *et al*., 2010; Ali, 2023). To better capture teachers' knowledge for instructional AI integration, the traditional TPACK framework was extended with ethical aspects, resulting in the Intelligent-TPACK scale (Celik, 2023). This framework includes five distinct components:

(i) ITK: aims to measure technological knowledge related to the use of AI-based technologies in everyday life.
(ii) ITPK: aims to measure techno-pedagogical knowledge related to AI technologies.
(iii) ITCK: aims to measure content-focused technological knowledge related to understanding how AI knowledge and content interact and influence each other.
(iv) ITPACK: aims to measure content-oriented techno-pedagogical knowledge; it involves understanding pedagogical techniques that utilize AI technologies constructively to teach specific content.
(v) Ethics: aims to measure the degree to which educators take ethical considerations into account while utilizing AI technologies in the classroom (Celik, 2023).

These components collectively form the first theoretical framework for the present study, allowing for the examination of teachers' knowledge about AI technologies applied in K–12 education. Previous studies applying the Intelligent-TPACK framework have been primarily conducted in developed contexts such as China and Saudi Arabia (Yang *et al*., 2025; Al-Abdullatif, 2024). However, to the best of our knowledge, no research has yet examined its validity or relevance within Moroccan educational systems where technological infrastructure and pedagogical practices may differ significantly.

2.2. Tripartite Attitudes Model

The Tripartite Model of Attitudes was developed in 1960 to explain the multidimensional nature of attitudes. It delineates the concept of attitude into three components: affect, behavior, and cognition (Breckler, 1984). Derived from the initial letters of these components, the tripartite model is commonly known in psychology as the ABC model (Dilling & Vogler, 2023). According to the theory, the combination of these three elements constitutes the primary structure of attitudes. An attitude is defined as an individual's disposition to react with a certain degree of favorableness or unfavorableness toward an object, behavior, person, institution, or event, or toward any discernible aspect of the individual's world. Adopting this definition, the present study uses the Tripartite Model of Attitudes as a framework to measure teachers' attitudes toward AI technologies (Donat *et al*., 2009).

The affective component can be gauged through physiological indicators or verbal expressions of emotions. It encompasses feelings that drive attitudes toward specific objects, including subjective responses such as trust, distrust, liking, and disliking (Dilling & Vogler, 2023). Affect is a crucial and multifaceted aspect of attitudes, often fluctuating independently of cognitive processes.

The behavioral component reflects an individual's tendency to act or decide in a certain way based on previous experiences. It is associated with behavioral purpose expressions that show readiness to engage in specific actions. Researchers often observe overt actions to measure this component, while verbal responses regarding behavioral intentions have also been found to be strong predictors of actual behavior (Dilling & Vogler, 2023).

The cognitive component refers to a set of ideas and beliefs about the object of attitude. It emerges when individuals process information about the attitude object, leading them to form particular evaluations and judgments. This component represents an individual's belief about whether the outcomes of their actions will be positive or negative (Dilling & Vogler, 2023).

In this study, these three components are analyzed as outcome variables using the following indicators:

(i) Affective (A): three items assessing teachers' emotional responses to AI technologies.

(ii) Behavioral (B): three items assessing teachers' actions and intentions regarding AI use in the classroom.
(iii) Cognitive (C): three items assessing teachers' thoughts and beliefs about AI in education.

3. METHODS

The present study employed a cross-sectional research design. The selection of participants was based on their affiliation with K–12 educational institutions, a criterion considered essential for effectively addressing the research objectives. A total of 204 teachers voluntarily completed the questionnaire. To describe the sample composition, **Table 1** presents participants' demographic characteristics, including gender, sector, age group, and educational cycle.

Table 1. Demographic characteristics.

Characteristic	Frequency (n)	Percent
Gender		
Male	69	34%
Female	135	66%
Sector		
Private	93	46%
Public	111	54%
Age group		
Over 50 years	21	10.3%
Between 41 and 50 years	53	26%
Between 31 and 40 years	97	47.5%
Under 30 years	33	16.2%
Educational cycle		
Vocational secondary	31	15.2%
Secondary	44	21.6%
Primary school	119	58.3%
Kindergarten	10	4.9%

Based on the Intelligent-TPACK framework and the Tripartite Model of Attitudes, a questionnaire was designed to measure both teachers' knowledge and their attitudes toward the integration of AI technologies in education. Participants were informed that their data would be used solely for research purposes and that no personally identifiable information would be disclosed. Participation was entirely voluntary.

A quantitative approach was adopted, and data were collected using a questionnaire consisting of seven sections. The first section gathered demographic data, while the remaining six collected information about teachers' knowledge and attitudes toward the use of AI in the classroom. Responses were recorded using a five-point Likert-type scale to enable quantitative assessment of both constructs. Data analysis was performed using SPSS and SmartPLS software.

To analyze the quantitative data, a two-step procedure was implemented. First, factor analysis was conducted to examine the distribution and dimensionality of the data. Second, Structural Equation Modeling (SEM) was performed to validate the relationships among the study variables and test the formulated hypotheses. Finally, the predictive power of the model was evaluated using the $PLS_{predict}$ procedure.

This study aimed to validate both the Intelligent-TPACK framework and the Tripartite Model of Attitudes within the Moroccan context. Accordingly, the following research questions were proposed:

(i) RQ1: To what extent is the Intelligent-TPACK framework a valid model for assessing teachers' knowledge related to the use of AI technologies in Moroccan education?
(ii) RQ2: To what extent is the Tripartite Model of Attitudes valid for assessing teachers' attitudes toward the integration of AI technologies in the Moroccan educational context?
(iii) RQ3: To what extent do the components of the Intelligent-TPACK model influence teachers' attitudes toward the use of AI technologies in education?

Building on prior literature, increased knowledge about a technology leads to more positive attitudes toward its use, which in turn shapes behavioral intentions and actual practices (Davis, 1989). Drawing from the theoretical foundations of the Intelligent-TPACK framework and the Tripartite Model of Attitudes, the following hypotheses were developed (Celik, 2023; Koehler & Mishra, 2009; Mishra & Koehler, 2006; Breckler, 1984):

(i) H1a: ITPK influences Attitudes.
(ii) H1b: ITPACK influences Attitudes.
(iii) H1c: Ethics influences Attitudes.
(iv) H1d: ITCK influences Attitudes.
(v) H1e: ITK influences Attitudes.
(vi) H2a: ITK influences ITPK.
(vii) H2b: ITK influences Ethics.
(viii) H2c: ITK influences ITCK.
(ix) H3: ITPK influences ITPACK.
(x) H4a: Ethics influences ITPK.
(xi) H4b: Ethics influences ITPACK.
(xii) H4c: Ethics influences ITCK.
(xiii) H5: ITCK influences ITPACK.

Accordingly, the conceptual research model developed for this study is illustrated in **Figure 1**.

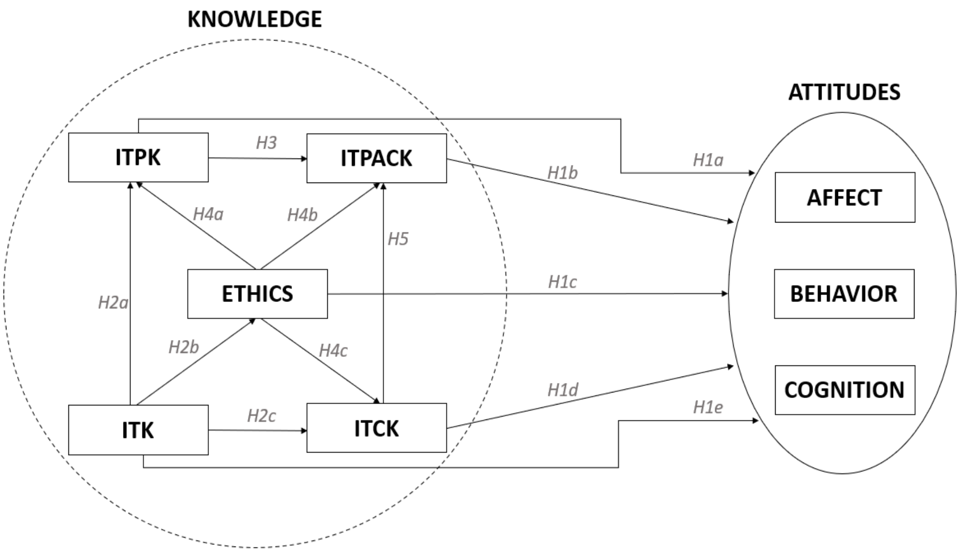

Figure 1. Conceptual research model (authors)

4. RESULTS AND DISCUSSION

4.1. RQ1: Validity of the Intelligent-TPACK Model

Using Principal Component Analysis (PCA) with Varimax rotation, five distinct components were extracted (see **Table 2**). These align with the Intelligent-TPACK model developed to assess teachers' technological, pedagogical, content, and ethical competencies related to AI integration (Celik, 2023). The extracted factors correspond to the five dimensions of the model (ITK, ITPK, ITCK, ITPACK, and Ethics), confirming the theoretical consistency between the original model and the data obtained in this study.

Table 2. Exploratory Factor Analysis and Reliability Metrics.

Factor	Items	α	KMO	Score (Component Matrix)	Eigenvalues	Variance	Communalities
ITK	ITK1	0.77	0.75	0.74	2.39	59.66%	0.55
	ITK2			0.78			0.61
	ITK3			0.80			0.64
	ITK4			0.77			0.59
ITPK	ITPK2	0.86	0.85	0.72	3.49	58%	0.52
	ITPK3			0.71			0.50
	ITPK4			0.83			0.68
	ITPK5			0.75			0.55
	ITPK6			0.80			0.63
	ITPK7			0.77			0.60
ITCK	ITCK1	0.65	0.50	0.75	1.49	75%	0.86
	ITCK2			0.75			0.86
ITPACK	ITPACK4	0.69	0.69	0.84	2.14	71%	0.71
	ITPACK5			0.88			0.77
	ITPACK6			0.81			0.66
Ethics	Ethic1	0.86	0.78	0.85	2.86	71%	0.72
	Ethic2			0.90			0.80
	Ethic3			0.84			0.71
	Ethic4			0.79			0.62

Table 2 presents the results of the exploratory factor analysis and reliability metrics for the Intelligent-TPACK model. The Cronbach's alpha (α) values for all dimensions exceeded the minimum acceptable threshold of 0.70, demonstrating internal consistency. The highest reliability was observed for ITPK (α = 0.86) and Ethics (α = 0.86), indicating excellent internal consistency across these dimensions.

The Kaiser–Meyer–Olkin (KMO) measures also showed satisfactory sampling adequacy, with ITPK (KMO = 0.85) and Ethics (KMO = 0.78) exceeding the recommended value of 0.70. These results confirm that the dataset is suitable for factor analysis. The eigenvalues further support the factor structure, with ITPK explaining 58% of the variance and Ethics accounting for 71%, reflecting a substantial portion of total variance explained by each construct.

Overall, the findings confirm that the measurement model is reliable and valid for assessing teachers' AI-related knowledge. The alignment of extracted components with the theoretical Intelligent-TPACK dimensions supports the structural validity of the model in the Moroccan educational context (Celik, 2023).

4.2. RQ2: Validity of the Tripartite Model of Attitudes

The Principal Component Analysis (PCA) for the attitude model identified three principal components representing the constructs of Affect, Behavior, and Cognition. During the refinement process, items A1, B3, and C1 were excluded due to weak correlations with their corresponding components, indicating low factor loadings and potential inconsistency with the theoretical structure of the Tripartite Model of Attitudes (Breckler, 1984).

Table 3 presents the results of the exploratory factor analysis and reliability metrics for the Tripartite Model of Attitudes. The eigenvalues indicate the relative importance of the three extracted factors, each explaining a substantial proportion of the variance 69% for Affect, 80% for Behavior, and 61% for Cognition. The KMO value of 0.50 reflects moderate sampling adequacy, suggesting that factor analysis is feasible though the sample size could be improved in future studies. The component matrix scores demonstrate relatively strong correlations between the items and their respective factors, confirming that each group of items represents coherent latent constructs.

Table 3. Exploratory Factor Analysis and Reliability Metrics

Factor	Items	α	KMO	Score (Component Matrix)	Eigenvalues	Variance	Communalities
Affect	A2	0.54	0.50	0.83	1.37	69%	0.69
	A3			0.83			0.69
Behavior	B1	0.74	0.50	0.89	1.59	80%	0.80
	B2			0.89			0.80
Cognition	C2	0.37	0.50	0.78	1.23	61%	0.61
	C3			0.78			0.61

The Cronbach's alpha (α) values vary across components, with the highest reliability observed for Behavior (α = 0.74), followed by Affect (α = 0.54) and Cognition (α = 0.37). Although the alpha values for Affect and Cognition are below the conventional threshold of 0.70, they are still acceptable for exploratory research in early validation stages, particularly in cross-cultural settings (Hair *et al*., 2011). Overall, the PCA results suggest that the three components are conceptually meaningful and empirically distinguishable within the Moroccan context, supporting the structural validity of the Tripartite Model of Attitudes (Dilling & Vogler, 2023).

Based on the refinement of both the Intelligent-TPACK and Tripartite models, the outer loading values of the final measurement model are presented in **Table 4**.

The outer loading values indicate that most items load strongly on their intended constructs, with coefficients exceeding the acceptable threshold of 0.70, confirming indicator reliability (Hair *et al*., 2011). However, items A3 and ITPK3 displayed loadings below the threshold, suggesting insufficient contribution to their respective constructs. Consequently, these items were removed to enhance model parsimony and overall fit.

Following this refinement, the final measurement model is illustrated in **Figure 2**, representing the validated relationships among the constructs of the Intelligent-TPACK and Tripartite frameworks within the Moroccan educational context (Celik, 2023; Breckler, 1984).

Table 4. Outer Loading Values.

	AFFECT	BEHAVIOR	COGNITION	ETHICS	ITCK	ITK	ITPACK	ITPK
A2	0.972							
A3	0.578							
B1		0.879						
B2		0.904						
C2			0.753					
C3			0.812					
Ethic1				0.844				
Ethic2				0.893				
Ethic3				0.843				

Table 4 (continue). Outer Loading Values.

	AFFECT	BEHAVIOR	COGNITION	ETHICS	ITCK	ITK	ITPACK	ITPK
Ethic4				0.798				
ITCK1					0.856			
ITCK2					0.871			
ITK1						0.741		
ITK2						0.762		
ITK3						0.800		
ITK4						0.784		
ITPACK4							0.848	
ITPACK5							0.870	
ITPACK6							0.817	
ITPK2								0.726
ITPK3								0.697
ITPK4								0.824
ITPK5								0.754
ITPK6								0.790
ITPK7								0.778

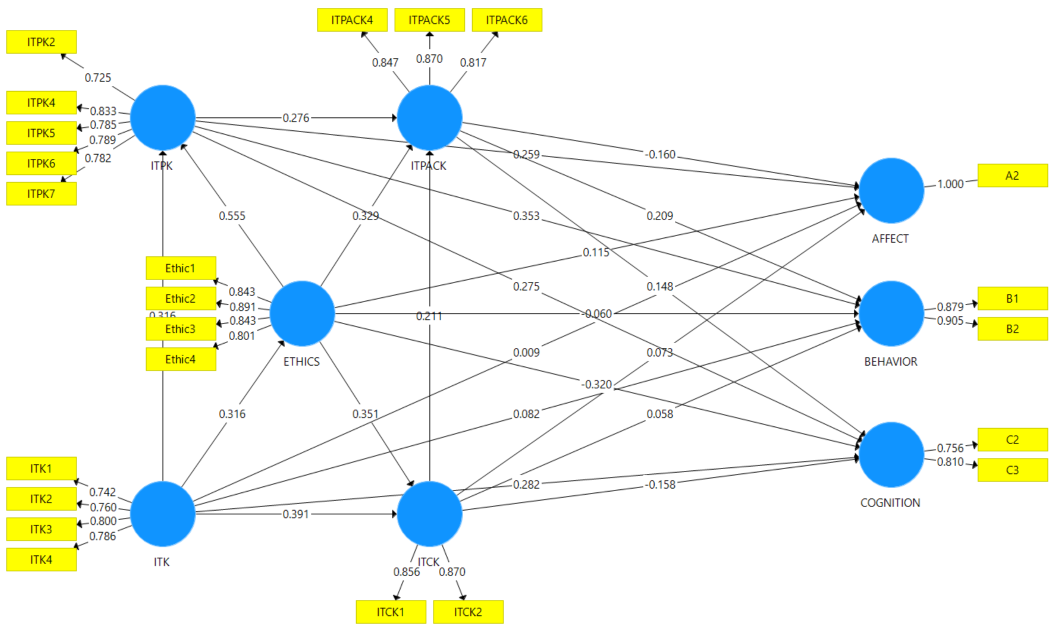

Figure 2. The measurement model

4.3. RQ3: The Effect of the Intelligent-TPACK Components on Teachers' Attitudes toward the Use of AI Technologies in Education

The analysis of the structural model was performed using SmartPLS software to test the research hypotheses and evaluate the influence of the Intelligent-TPACK components on teachers' attitudes toward AI technologies. This analysis involved the confirmatory factor analysis, collinearity assessment, estimation of path coefficients, and evaluation of explanatory, effect, and predictive powers of the model (Hair *et al.*, 2011).

As shown in **Table 5**, the Variance Inflation Factor (VIF) values were computed to assess potential multicollinearity among the predictor variables. All VIF values were below the threshold of 5, confirming that multicollinearity was not an issue in the model and that all variables could be retained for further analysis.

The results confirmed that collinearity does not pose a threat to the model's validity.

Table 5. Variance Inflation Factor (VIF) Values.

Variable	VIF	Variable	VIF	Variable	VIF
A2	1.000	ITK1	1.452	ITPK2	1.507
B1	1.539	ITK2	1.564	ITPK4	2.278
B2	1.539	ITK3	1.669	ITPK5	1.787
C2	1.055	ITK4	1.555	ITPK6	1.829
C3	1.055	ITPACK4	1.761	ITPK7	1.907
Ethic1	2.480	ITPACK5	1.977		
Ethic2	3.073	ITPACK6	1.565		
Ethic3	2.129	ITCK1	1.317		
Ethic4	1.741	ITCK2	1.317		

The path coefficients (β) obtained from the Structural Equation Modeling (SEM) analysis are summarized in **Table 6**. These coefficients show the magnitude and direction of the relationships among the constructs, while the p-values indicate the statistical significance of each relationship (Hair *et al*., 2011; McIntosh & Gonzalez-Lima, 1994).

As indicated in **Table 6**, ITPK, ITCK, and ETHICS are the most influential constructs. ITPK significantly predicts affective, behavioral, and cognitive components of attitudes, confirming its mediating role between knowledge and attitude formation. Conversely, ITK and ITPACK have limited direct effects on attitudinal outcomes.

Table 6. Structural Equation Modeling (SEM) Analysis.

Relationship	B	M	STDEV	T	P	Significance
ETHICS → AFFECT	0.115	0.113	0.102	1.126	0.260	Insignificant
ETHICS → BEHAVIOR	-0.060	-0.058	0.105	0.567	0.570	Insignificant
ETHICS → COGNITION	-0.320	-0.322	0.089	3.608	0.000	Significant
ETHICS → ITCK	0.351	0.348	0.065	5.399	0.000	Significant
ETHICS → ITPACK	0.329	0.325	0.088	3.749	0.000	Significant
ETHICS → ITPK	0.555	0.557	0.061	9.072	0.000	Significant
ITCK → AFFECT	0.073	0.069	0.082	0.893	0.372	Insignificant
ITCK → BEHAVIOR	0.058	0.059	0.089	0.656	0.512	Insignificant
ITCK → COGNITION	-0.158	-0.164	0.099	1.603	0.109	Insignificant
ITCK → ITPACK	0.211	0.209	0.074	2.857	0.004	Significant
ITK → AFFECT	0.009	0.010	0.083	0.103	0.918	Insignificant
ITK → BEHAVIOR	0.082	0.078	0.073	1.113	0.266	Insignificant
ITK → COGNITION	0.282	0.286	0.080	3.522	0.000	Significant
ITK → ETHICS	0.316	0.317	0.068	4.607	0.000	Significant
ITK → ITCK	0.391	0.394	0.066	5.948	0.000	Significant
ITK → ITPK	0.316	0.316	0.053	5.948	0.000	Significant
ITPACK → AFFECT	-0.160	-0.164	0.090	1.777	0.076	Insignificant
ITPACK → BEHAVIOR	0.209	0.211	0.103	2.028	0.043	Significant
ITPACK → COGNITION	0.148	0.151	0.110	1.353	0.176	Insignificant
ITPK → AFFECT	0.259	0.264	0.106	2.437	0.015	Significant
ITPK → BEHAVIOR	0.353	0.353	0.106	3.339	0.001	Significant
ITPK → COGNITION	0.275	0.278	0.102	2.698	0.007	Significant
ITPK → ITPACK	0.276	0.282	0.098	2.817	0.005	Significant

To evaluate the model's explanatory strength, **Table 7** presents the R^2 values of the endogenous constructs. R^2 values between 0.10 and 0.50 are considered acceptable in social science models (Shmueli *et al*., 2019).

As shown in **Table 7**, the constructs ITPK and ITPACK demonstrate the highest explanatory power, while AFFECT has the weakest value, suggesting that other external variables may influence teachers' emotional responses toward AI.

Table 7. Coefficient of Determination (R^2 Values).

Endogenous Construct	R^2	R^2 Adjusted	Interpretation
AFFECT	0.09	0.07	Weak
BEHAVIOR	0.30	0.28	Acceptable
COGNITION	0.17	0.15	Acceptable
ETHICS	0.10	0.09	Acceptable
ITCK	0.36	0.35	Acceptable
ITPACK	0.47	0.46	Acceptable
ITPK	0.52	0.51	Acceptable

The strength of each predictor's contribution was further assessed using effect size (f^2). The values in **Table 8** indicate how the removal of a variable affects the R^2 of the dependent variable.

Table 8. Effect Size (f^2) Summary.

Variable Relationship	Effect Type	f^2 (%)
ETHICS → ITPK	Large	57%
ITK → ITCK	Large	21%
ITK → ITPK	Moderate	18%
ETHICS → ITCK	Moderate	17%
ITK → ETHICS	Moderate	11%
ETHICS → ITPACK	Moderate	11%
ITPK → BEHAVIOR	Moderate	8%
ITPK → ITPACK	Moderate	7%
ETHICS → COGNITION	Moderate	6%
ITCK → ITPACK	Moderate	6%
ITPK → COGNITION	Small	4%
ITPK → AFFECT	Small	3%
ITPACK → BEHAVIOR	Small	3%
Remaining paths	No Effect	—

Table 8 shows that ITPK is the most influential knowledge dimension influencing the three attitudinal components (AFFECT, BEHAVIOR, and COGNITION). Although its effects remain small to moderate (i.e. 3, 8, and 4%), they underscore its central role. Ethical considerations also exert a notable effect on cognition (6%), suggesting that teachers' awareness of fairness and responsible AI use fosters more reflective and informed judgments rather than emotional or resistant responses.

Lastly, **Table 9** presents the predictive accuracy of the model, evaluated using Q^2predict, RMSE, and MAE values derived from both the PLS-SEM and linear models (Shmueli *et al.*, 2019).

As shown in **Table 9**, the PLS-SEM model outperformed the linear model in predictive accuracy, with most indicators displaying lower RMSE and MAE values and positive Q^2predict scores. According to the guidelines (Shmueli *et al.*, 2019), this result indicates medium predictive power, confirming the model's validity and generalizability.

Given that the PLS-SEM model's Q^2predict value is higher than 0 and that the majority of the indicators in the PLS-SEM analysis have lower RMSE and MAE values than the LM, we can conclude that the PLS-SEM model demonstrates a medium predictive power according to (Shmueli *et al*., 2019) guidelines. The results indicate that the PLS-SEM model performs better in terms of prediction accuracy for most constructs. Specifically, 10 out of 19 indicators for both RMSE and MAE are more predictive in the PLS-SEM model compared to the LM.

Table 9. RMSE, MAE, and Q^2predict for PLS-SEM and Linear Models.

Indicator	RMSE (PLS)	MAE (PLS)	Q^2 (PLS)	RMSE (LM)	MAE (LM)	Q^2 (LM)
A2	1.268	1.115	0.009	1.243	1.062	0.047
B1	1.204	0.984	0.077	1.224	1.002	0.046
B2	1.163	1.005	0.100	1.178	1.012	0.078
C2	1.035	0.843	0.034	1.056	0.857	-0.005
C3	0.989	0.740	0.055	0.976	0.738	0.078
Ethic1	1.119	0.926	0.051	1.121	0.921	0.046
Ethic2	1.063	0.879	0.066	1.070	0.864	0.054
Ethic3	1.173	1.008	0.081	1.190	1.003	0.055
Ethic4	1.151	0.979	0.056	1.175	0.999	0.016
ITCK1	0.694	0.552	0.230	0.686	0.542	0.246
ITCK2	0.907	0.719	0.128	0.917	0.726	0.108
ITPACK4	1.074	0.847	0.134	1.092	0.853	0.106
ITPACK5	1.079	0.827	0.098	1.080	0.836	0.095
ITPACK6	1.128	0.923	0.099	1.145	0.915	0.071
ITPK2	0.953	0.734	0.188	0.959	0.735	0.178
ITPK4	1.046	0.848	0.132	1.057	0.851	0.114
ITPK5	1.109	0.869	0.131	1.104	0.834	0.137
ITPK6	1.019	0.787	0.135	1.025	0.784	0.125
ITPK7	1.017	0.792	0.122	1.020	0.792	0.117

4.3. Hypothesis Test

The hypothesis testing was conducted to verify the relationships among the constructs of the Intelligent-TPACK framework and teachers' attitudes toward the use of AI technologies in education. Table 10 presents the path coefficients (β), t-statistics, p-values, and effect sizes corresponding to each hypothesis. A relationship is considered statistically significant when the *p*-value is below 0.05 and the *t*-value exceeds 1.96 (Hair *et al*., 2011).

As shown in **Table 10**, most hypotheses were supported, confirming the structural integrity and theoretical consistency of the Intelligent-TPACK framework.

The results summarized in **Table 10** confirm the existence of significant interrelations among several constructs within the Intelligent-TPACK model. ITPK emerges as the most influential factor affecting teachers' attitudes, significantly shaping all three components (i.e. affect, behavior, and cognition) with small but consistent effect sizes. This demonstrates that teachers' techno-pedagogical knowledge plays a crucial role in determining their emotional, behavioral, and cognitive engagement with AI technologies in classroom practice.

The behavioral dimension of attitude is also significantly influenced by ITPACK, indicating that pedagogical strategies combining technology and content have practical implications for teaching-related actions. Meanwhile, the cognitive component of attitude is affected by both Ethics and ITK, suggesting that knowledge about technology and ethical awareness jointly inform teachers' rational evaluation of AI integration.

In contrast, ITCK does not have a significant effect on any attitude component, implying that content-focused technological knowledge alone is insufficient to foster positive dispositions toward AI adoption. Instead, pedagogical and ethical dimensions are more impactful in shaping teachers' readiness for technological change.

The findings further emphasize the role of ethical awareness as a central construct in AI integration. Ethics strongly influences ITPK ($\beta = 0.555$, $p < 0.001$) and exerts moderate effects on both ITCK and ITPACK, highlighting the importance of moral and responsible use of AI in education. Similarly, ITK significantly predicts ITPK, ITCK, and Ethics, reflecting its foundational role as a precursor to higher-order pedagogical and ethical competencies.

Table 10. Hypothesis Test.

Hypothesis	Dependent Variable	B	T	P	Results	Effect Size
H1a – ITPK influences Attitudes.	Affect	0.259	2.437	0.015	Significant	Small
	Behavior	0.353	3.339	0.001	Significant	Small
	Cognition	0.275	2.698	0.007	Significant	Small
H1b – ITPACK influences Attitudes.	Affect	-0.160	1.777	0.076	Insignificant	No effect
	Behavior	0.209	2.028	0.043	Significant	Small
	Cognition	0.148	1.353	0.176	Insignificant	No effect
H1c – ETHICS influences Attitudes.	Affect	0.115	1.126	0.260	Insignificant	No effect
	Behavior	-0.060	0.567	0.570	Insignificant	No effect
	Cognition	-0.320	3.608	0.000	Significant	Small
H1d – ITCK influences Attitudes.	Affect	0.073	0.893	0.372	Insignificant	No effect
	Behavior	0.058	0.656	0.512	Insignificant	No effect
	Cognition	-0.158	1.603	0.109	Insignificant	No effect
H1e – ITK influences Attitudes.	Affect	0.009	0.103	0.918	Insignificant	No effect
	Behavior	0.082	1.113	0.266	Insignificant	No effect
	Cognition	0.282	3.522	0.000	Significant	Small
H2a – ITK influences ITPK.		0.316	5.948	0.000	Significant	Medium
H2b – ITK influences ETHICS.		0.316	4.607	0.000	Significant	Small
H2c – ITK influences ITCK.		0.391	5.948	0.000	Significant	Medium
H3 – ITPK influences ITPACK.		0.276	2.817	0.005	Significant	Small
H4a – ETHICS influences ITPK.		0.555	9.072	0.000	Significant	Large
H4b – ETHICS influences ITPACK.		0.329	3.749	0.000	Significant	Small
H4c – ETHICS influences ITCK.		0.351	5.399	0.000	Significant	Medium
H5 – ITCK influences ITPACK.		0.211	2.857	0.004	Significant	Small

Note: β: Original Sample (O), t: T Statistics (|O/STDEV|), P: P Values.

Overall, the results support the conceptual structure of the Intelligent-TPACK framework in the Moroccan educational context. They demonstrate that strengthening teachers' techno-pedagogical knowledge (ITPK) and integrating ethical considerations into AI-related professional development can enhance teachers' positive attitudes toward adopting AI-based educational tools.

The final research model incorporating standardized path estimates, composite reliability coefficients, and effect sizes is illustrated in **Figure 3**. This model visually represents the validated relationships among the Intelligent-TPACK components and the attitudinal constructs that influence teachers' engagement with AI technologies in K–12 education (Celik, 2023; Hair *et al*., 2011).

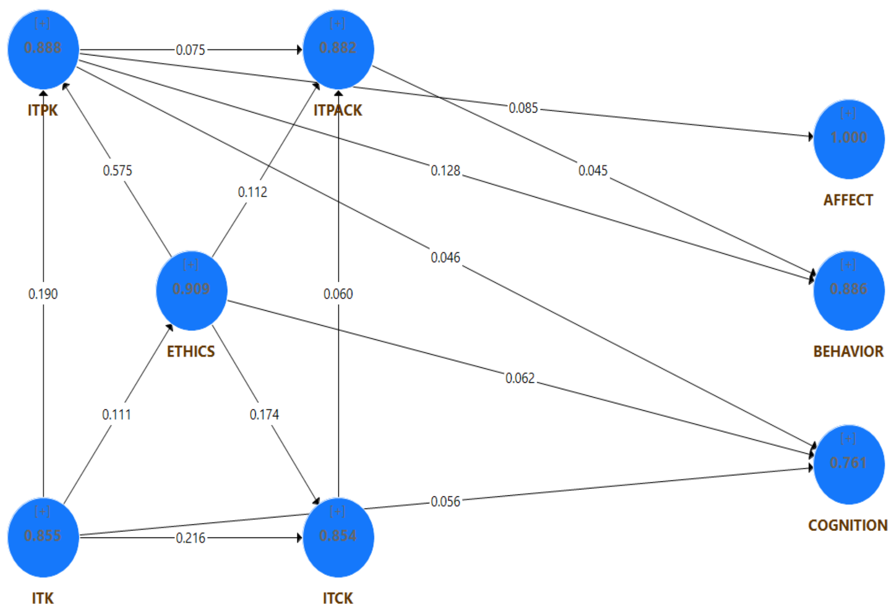

Figure 3. Research Model with Standardized Estimates.

4.4. Discussion

Overall, the findings provide empirical validation of both the Intelligent-TPACK model and the Tripartite Model of Attitudes within the Moroccan educational context. The five theoretical components of the Intelligent-TPACK model were successfully confirmed through factor analysis, while the three components of the Tripartite Model were also distinctly validated. Beyond confirming the factorial structure, the path analysis further supported the hypothesized structural relationships among these constructs. Consequently, this research constitutes the first empirical validation of both frameworks in Morocco, extending their cross-cultural generalizability and confirming their conceptual robustness for understanding teachers' AI-related competencies and attitudes (Celik, 2023).

The results of hypothesis testing highlight the decisive role of pedagogical knowledge (ITPK) in shaping teachers' affective, behavioral, and cognitive orientations toward the use of AI in education. ITPK exerts a positive and significant influence across all three attitudinal dimensions, with the strongest impact observed on the behavioral component ($\beta = 0.353$, $p = 0.001$). This suggests that when teachers possess well-developed techno-pedagogical knowledge, they are more capable of managing AI-supported learning situations and therefore more confident in implementing AI tools in their teaching practice. Such findings are consistent with previous research grounded in the AI-TPACK framework, which emphasizes pedagogical knowledge as a cornerstone of effective AI integration in educational settings (Ning *et al*., 2024).

In contrast, the influence of ITPACK is more limited, affecting only the behavioral component of attitude. This implies that while integrated knowledge combining content and technology encourages teachers to experiment with AI applications, it does not necessarily alter their emotional disposition or cognitive evaluation of AI technologies. Integrated knowledge appears to function as a practical enabler rather than an emotional motivator, promoting action over perception.

The findings regarding ethical knowledge (ETHICS) reveal an intriguing and nuanced relationship. Its significant negative effect on cognitive attitudes ($\beta = -0.320$, $p = 0.000$)

suggests that teachers who are more aware of ethical concerns tend to hold a more critical and reflective stance toward AI in education. This critical view should not be interpreted as resistance but rather as evidence of ethical maturity. These findings align with research emphasizing the importance of ethical reflection in shaping responsible and sustainable AI use in educational environments. For the successful integration of AI, educators must balance ethical considerations with pedagogical and technological proficiency, ensuring that technology enhances trust, fairness, and accountability in the learning process.

The ITCK and ITK dimensions show comparatively weaker direct effects on attitudes. ITCK does not significantly influence any component of attitude, which can be attributed to teachers' still-limited exposure to AI tools and applications specifically tailored to their subject domains. This finding reflects the early stage of AI adoption in Moroccan schools, where teachers may not yet see clear subject-specific applications of AI. Meanwhile, ITK shows a significant influence only on the cognitive component ($\beta = 0.282$, $p = 0.000$), suggesting that basic technological understanding contributes primarily to the development of informed judgments rather than emotional or behavioral change. Teachers who understand fundamental AI mechanisms are more capable of critically evaluating AI's relevance and pedagogical value.

Collectively, these results underscore the interdependence between technological, pedagogical, and ethical knowledge in shaping teachers' attitude toward the integration of AI into classroom practice. They suggest that developing techno-pedagogical competence (ITPK) remains the most critical factor in promoting teachers' active engagement with AI, while ethical reflection provides the necessary moral foundation for responsible adoption.

In practical terms, the findings call upon the Moroccan educational system to strengthen teacher training programs in AI-based pedagogy and ethics. Institutional investment should focus not only on improving digital infrastructure but also on cultivating teachers' ability to design, evaluate, and manage AI-driven learning environments that align with ethical and pedagogical principles. By integrating technological expertise with ethical awareness, Moroccan educators can ensure that AI is employed to foster equitable, transparent, and learner-centered educational outcomes.

5. CONCLUSION

Artificial Intelligence (AI) has become a driving force reshaping teaching and learning practices worldwide. The findings of this study underscore the crucial need for teachers to be equipped not only with technical proficiency but also with robust pedagogical and ethical knowledge to develop positive and informed attitudes toward the use of AI in classrooms. Within the Moroccan educational context, this research provides empirical evidence validating both the Intelligent-TPACK and Tripartite Attitudes frameworks, demonstrating their relevance for understanding the interplay between teachers' knowledge dimensions and their attitudinal orientations toward AI integration.

To foster effective and responsible adoption of AI in education, professional development programs should be designed to familiarize teachers with AI technologies while supporting their ability to apply these tools within pedagogically sound and ethically grounded frameworks. Such initiatives would ensure that innovation in education enhances instructional quality without compromising human values.

While this study highlights the centrality of techno-pedagogical and ethical knowledge in shaping teachers' attitude toward AI adoption, incorporating qualitative approaches in future research could deepen the understanding of teachers' beliefs, concerns, and lived experiences regarding AI integration in K–12 settings. Furthermore, subsequent studies could apply the

TPACK-in-Context framework (Petko *et al*., 2025) to examine how specific contextual variables affect the application of AI knowledge in diverse educational environments.

In conclusion, the successful integration of AI into education requires a holistic approach that combines technological competence, pedagogical adaptability, and ethical sensitivity. Strengthening these dimensions among educators will be essential for ensuring that the advancement of AI not only transforms education but also sustains its humanistic and socially responsible foundation.

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7. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. Authors confirmed that the paper was free of plagiarism.

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