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Applying the ADDIE model in training engineering for the development of teachers' professional skills: A case study of the Fes-Meknes region in Morocco

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Abstract Keeping pace with rapid advances in pedagogy and educational technologies requires structured, evidence-based professional development for teachers. In Morocco, national priorities emphasize competency-based upskilling and the integration of Information and Communication Technologies in Education (ICTE). The ADDIE instructional design model Analysis, Design, Development, Implementation, and Evaluation offers a rigorous framework to engineer training aligned with these priorities. This study investigates the effect of ICTE training engineered with the ADDIE model on high-school teachers' professional skills in the Fes-Meknes region. We employed a quantitative survey using descriptive and analytical procedures to examine associations between training components and competency development. Results show that nine primary independent variables were significantly associated with the dependent outcome ($p < 0.005$). The model's coefficient of determination ($R^2 = 0.755$) indicates that ADDIE-based ICTE training explains a substantial share of variance in teachers' professional skills, supporting a strong predictive relationship. Substantively, the findings point to improvements across technological, pedagogical, and communicative competences when training is systematically designed, iteratively refined, and consistently evaluated. These results position ADDIE not merely as a procedural blueprint but as a leverage point for measurable gains in teacher performance. Policy-wise, embedding ADDIE-engineered ICTE programs within regional professional development pathways could accelerate the implementation of competency-based reforms and inform resource allocation through continuous evaluation feedback. Limitations include the single-region scope, self-reported measures, and the cross-sectional design, which constrain causal inference. Future longitudinal and experimental studies should test durability and transferability across contexts. Overall, the study provides robust, practice-oriented evidence that structured training engineering via ADDIE can advance instructional quality at scale.

Keywords: ICTE training engineering, instructional design, teachers' professional skills, teacher training, Morocco

1. Introduction

The concept of development was implemented in the field of formation from 1960--1970. In France, this term came to the end of the year in 1960, paralleling the education sector in the education domain (Llorent-Bedmar, 2014). The formalization of the use of TIC in the formation process of the most advanced development, in the integration of the apprentices in the programs of perfection of the teachers, so that the basics on the models such as the ADDIE model do not have certain approaches to conception on it. there is a demand for the integration of information and communication technologies (ICTE) in the training of sensing agents and constant augmentation (El Ouesdadi & Rochdi, 2022).

According to (Idrissi et al., 2024), these contemporary programs include a wide variety of ICTE modules, and computer numbers and educational teachers need to be developed. Furthermore, the opening of educational systems to ICTE has considerably increased, with teachers integrating various modules into their teaching practices (El Kartouti & Juidette, 2022). Additionally, the triple pandemic of COVID-19 has to be replaced by educational activities presented in line formations, marking a transition in numerical formats. In contrast to the courses of transmission in the line, the establishments on the delivery of major devices find programs accepted in the provincial capital due to the establishment It works in engineering (Syam & Ermawati, 2024a). With previous advances and future developments in the educational domain,

of public establishments (Valishvili et al., 2022). The principals who take part in the training are doing in the face of the limited perceptions of the application in the line, but they use the technology to provide auxiliaries with a large pool of ICTE skills and investments in the programs for optimal piloting in these institutions(Derakhshan et al., 2023a). In this context, Morocco is implementing training plans within the framework of the GENIE project to (Hamdani, 2024):

- Complex and difficult-to-understand information for teachers, particularly in robotics, should be simplified.
- Dynamic methods have been developed to replace the passive use of technology.

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- Stimulate intellectual curiosity.
- Foster intellectual autonomy and promote a critical evaluation of evidence, theories, and concepts within a thematic framework.

This exploratory study evaluates the impact of ICTE training engineering according to the ADDIE model on the professional development of teachers in different stages, such as analysis, design, development, implementation, and evaluation.

2. Conceptual Framework

Educational policy is supposed to ensure easy access to education and therefore to improve quality (D'ambrosio & Boriati, 2023). Above all, achieving this goal requires the development of teachers' professional skills through continuous training in ICTE (Pedrosa, 2024a). The framework of education in the 21st century, which includes the key elements of collaborative education, the use of information technologies for knowledge creation and collaboration, and the stimulation of critical and imaginative thinking to solve concrete problems, is integrated (Lee, 2023). According to (Cheng, 2024), teachers are able to integrate new technologies into their teaching, thus enabling the dissemination and sharing of knowledge in the classroom. Thus, training engineering, through models such as the ADDIE model (analysis, design, development, implementation, and evaluation) (Spyropoulou & Kameas, 2025), has become an important element in structuring these modern educational processes. On the same voice of reflection (Rizal et al., 2024). announces that the training of teachers in engineering is based on very specific frameworks to ensure the effectiveness of educational programs or that the ADDIE model is particularly appropriate in this case and provides a systematic structure for pedagogical design, such as.

A. Analysis (Needs Analysis)

The first step of the ADDIE model, the analysis, aims to identify teacher training needs (Widyastuti & Susiana, 2019). In teacher training engineering, this step consists of measuring the gap between teachers' current skills and the requirements of modern education (Van den Beemt et al., 2020). Marushkevych et al. (2021) emphasize the importance of this step by specifying that the analysis must include both the strategic orientations of educational institutions (top-down approach) and the needs expressed by teachers themselves (bottom-up approach). This iterative process is the way to design training programs as close as possible to what is happening on the ground and what teachers want (Spatioti et al., 2022a).

B. Design (pedagogical planning)

The planning step corresponds to training engineering in the ADDIE model. Here, the teacher designs a strategy on the basis of the results of the needs analysis (Maulina et al., 2021). As Zhang et al. (2024) described, this stage includes setting learning objectives, selecting appropriate teaching methods, and planning assessments. The challenge is the formalization of training needs, which is a complex process that must consider both the internal environment of the institution and its external context (Karthikeyan et al., 2024). Detailed planning during this phase reduces the need for adjustments during the implementation phase (Lai et al., 2024).

C. Development (Creation of Resources)

A development phase in the ADDIE model is the creation of teaching resources on the basis of the plan developed in the previous stage (Sasmito et al., 2022). This phase, which marks the transition from planning to production, focuses on the development of teaching materials adapted to the identified objectives (Reinbold, 2013a). According to Moral et al. (2023), this phase includes formative assessments to ensure that the materials meet the desired standards and outcomes. The goal is the production of teaching materials that help teachers learn and thus achieve training objectives.

D. Implementation/Dissemination and Delivery of Training

In the ADDIE model, the implementation phase is a critical stage for testing and adjusting the educational content in a real environment (Samsudin et al., 2021). This means a period where the training engineer exposes the developments to the field, observes their effectiveness and makes modifications in real time (C. Budoya et al., 2019). Feedback from trained teachers is crucial for adapting content and teaching methods to maximize the effectiveness of training (Alodwan & Almosa, 2018). As noted by (Constancio et al., 2018), "pedagogical activities must always be reviewed for relevance to the training", and this can be achieved only through continuous re-evaluation.

E. Evaluation-Measuring Effectiveness

Evaluation, the last phase of the ADDIE model, is multidimensional and continuous throughout the training process (Jonnalagadda et al., 2022). It aims to measure the extent to which the objectives set have been achieved, to assess the competence of teachers and to improve future training (Abuhassna et al., 2024). Although this phase is most often neglected due to a lack of time or resources, it is certainly an important step that guarantees the quality and relevance of training programs (H. Kim et al., 2024). Albeanu & Popentiu-Vladicescu (2019) support the idea that evaluation should be introduced from the beginning of the design process to continuously improve teaching practices. In view of the various elements studied,

both with regard to the application of the ADDIE model in training engineering for the development of teachers' professional skills and with the aim of responding to the following hypotheses:

H1: The application of the ADDIE model in training engineering contributes significantly to the development of teachers' professional skills.

H2: The integration of the ADDIE model improves the effectiveness of continuing education programs in ICT for teachers.

F. Specific Hypotheses (by phase of the ADDIE model)

- Analysis phase (needs analysis)

H3: An in-depth analysis of teachers' training needs allows a better match between training and expectations in the field.

H4: A mixed approach (top-down and bottom-up) in needs analysis improves the relevance of training in educational engineering.

- Design phase (pedagogical planning)

H5: A clear definition of educational objectives and teaching methods in the design phase improves teacher engagement and learning.

H6: Detailed planning reduces the need for adjustments during the implementation phase and optimizes the effectiveness of training.

- Development phase (creation of resources)

H7: The use of adapted and interactive educational resources in teacher training promotes better acquisition of skills.

H8: The introduction of formative assessments during the development phase improves the quality of teaching materials and teacher satisfaction.

- Implementation phase (implementation)

H9: Experimenting with training content in a real environment improves its effectiveness and adaptation to teachers' needs.

H10: Taking teacher feedback into account during implementation optimizes the quality and impact of training.

- Evaluation phase (measuring effectiveness)

H11: Continuous evaluation throughout the training process can significantly improve the quality of training provided.

3. Materials and Methods

3.1. Data collection

To determine the sample size, Slovin's formula was applied to ensure an appropriate representation of the population (Tavakol & Dennick, 2011). Given the large number of high school teachers working in the Fez-Meknes region, Morocco, a sample size of approximately 209 respondents was deemed sufficient to represent the population with a 5% margin of error at the 95% confidence level. A voluntary selection method was employed, where participants were given the choice to participate or decline to study the relationship between ICT training engineering, on the basis of the ADDIE model, and secondary school teachers' professional development in the Fez-Meknes region.

Data collection was conducted via a questionnaire developed in consultation with teachers from the higher school department working in the Fes-Meknes region, resulting in 219 responses. Prior to the main data collection, a pilot study was conducted with 20 high school teachers from the Fez-Meknes region who were not included in the final sample. The purpose of this pilot study was to assess the clarity, relevance, and comprehensiveness of the questionnaire items. Feedback from the pilot participants led to several refinements, including rewording ambiguous questions, expanding response options, and improving the overall layout for better respondent understanding. The data collected during the pilot phase were excluded from the main analysis to ensure the integrity of the study results. The main data collection spanned two months, from October 18, 2024, to December 11, 2024. Of the 239 responses received, 219 were considered valid (88.9% of the total), whereas 20 were excluded because of incomplete or inconsistent data. Only the valid responses were analyzed to maintain the reliability, validity, and appropriateness of the data for hypothesis testing.

The survey was designed to be both simple and comprehensive, allowing respondents to easily provide detailed feedback. It targeted a broad demographic group of educators, aged 25-64 years, ensuring that the results were relevant to Morocco's educational context. Drawing on international research, the survey was carefully adapted to reflect the unique conditions of the Fez-Meknes region of Morocco. The questionnaire, designed to be culturally and contextually appropriate, was administered in French, the respondents' primary language of instruction, to ensure clear and effective communication.

3.2. Survey design and variables studied

The questionnaire was designed to measure the five phases of the ADDIE model through nine variables (X1-X9), using a 5-point Likert scale ranging from “strongly disagree” to “strongly agree.” Its development followed a multi-step process. First, items were drafted based on a synthesis of international ICTE and instructional design literature and aligned with ADDIE dimensions (Analysis, Design, Development, Implementation, and Evaluation). Content validity was then ensured through expert review by three senior teacher-trainers from the Fez-Meknes region, who examined item clarity, relevance, and coverage. A pilot test with 20 high-school teachers was subsequently conducted to verify comprehensibility and cultural appropriateness. Based on pilot feedback, minor revisions were made to wording, layout, and response options. Construct validation was supported by reliability testing, which demonstrated high internal consistency (Cronbach’s alpha = 0.819), exceeding the 0.70 acceptability threshold. This confirmed that the nine items coherently measured the intended dimensions. These steps ensured that the final instrument was valid, reliable, and appropriate for assessing the impact of ADDIE-based ICTE training on teachers’ professional competencies.

The variables studied correspond to the different phases of the ADDIE model, as follows:

• X1: Gender and Alignment with Professional Development (Analysis): Does gender influence the alignment of ICT training with teachers’ professional development needs?

• X2: Age and Adaptability to ICT Training (Analysis): What is the impact of age on teachers’ adaptability to new technologies?

• X3: Analysis of ICT Skills Needs Before Training (Analysis): Does the needs analysis carried out by the Ministry allow for the detection of skills gaps?

• X4: Relevance of training objectives (Design): Are the training objectives aligned with teachers’ professional needs?

• X5: Usefulness of Teaching Materials (Development): do the materials (videos, guides, resources) contribute to improving digital skills?

• X6: Integration of ICT Tools in Training (Development): Are ICT tools effectively integrated into training?

• X7: Implementation and Deployment of Training (Implementation): Is training effectively implemented in a real context?

• X8: Overall impact of ICT training on professional skills (Evaluation): Does training have a measurable impact on skills development?

• X9: Relationship between training materials and skills development (Evaluation): To what extent do teaching materials contribute to the overall improvement of skills?

3.3. Statistical analysis

In this study, Cronbach's alpha was utilized as a measure of internal consistency to evaluate the degree of correlation among items within the scale. This metric incorporates factors such as the number of items, the strength of interitem correlations, and the homogeneity of the variables under investigation (Tavakol & Dennick, 2011). To further assess the impact of ICTE training engineering, grounded in the ADDIE model, on the professional development of high school teachers in the Fez-Meknes region of Morocco, various statistical analyses have been conducted.

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum_{i=1}^{K} \sigma_{Y_i}^2}{\sigma_x^2}\right) \qquad (1)$$

Where:
K= is the number of items,
σ_x^2 = variance of the total score
σ_(Y_i)^2= is the variance of item i

Descriptive statistics, employing both numerical and graphical methods, were used to organize, visualize, and analyze the data systematically. These methods offer significant advantages by efficiently summarizing and presenting the characteristics of variables within a sample, depending on the level of measurement applied.

The choice of regression method was determined by the characteristics of our dependent variables and the specific aims of our research. Ordinal logistic regression was selected because several key outcome variables in our study, such as the perceived effectiveness of ICT training and the alignment of training objectives, were measured via ordinal scales, with responses organized in a meaningful order (for example, from strongly disagree to strongly agree). This statistical approach is particularly well suited for analyzing such data, as it enables us to examine the influence of multiple predictors on an ordinal outcome while respecting the inherent ranking of the response categories. For variables with binary outcomes, such as whether teachers adopted ICT tools in their teaching practice, we utilized binary logistic regression. This method is ideal for modeling the likelihood of a dichotomous event on the basis of one or more independent variables. Both ordinal and binary logistic regression are widely recognized and applied in educational and social science research for analyzing categorical data, and they yield results that are easily interpretable through odds ratios, which are valuable for informing policy and practice. Other statistical techniques, such as linear regression, were not appropriate given the categorical and noncontinuous nature of our

dependent variables. Therefore, the use of logistic regression models was essential to ensure the accuracy and robustness of our statistical analyses.

Ordinal logistic regression was applied in this study to examine the relationship between an ordinal dependent variable and multiple predictor variables. This approach is particularly suitable for dependent variables with ordered categories. The proportional odds model, commonly used in ordinal logistic regression, assumes a uniform relationship across the outcome categories. The model is expressed through the log odds of the dependent variable being less than or equal to a particular category, as influenced by the independent variables. Interpretation centers on the coefficients, which indicate the direction and magnitude of these relationships, with odds ratios reflecting the change in odds for higher categories per unit increase in an independent variable. The model fit was evaluated via various tests and pseudo R-squared measures.

In addition, binary logistic regression was employed to model a binary outcome variable characterized by a Bernoulli distribution. The probability of the outcome variable equation 1, denoted by π, was modeled via the logit equation as described by (Tavakol & Dennick, 2011). The parameters of the nonlinear equation for the Bernoulli distribution were estimated via the maximum likelihood estimator (MLE). The likelihood function, defined as the product of the conditional probabilities for each observation, was logarithmically transformed to facilitate computation. Deriving the log-likelihood function yielded the gradient equations presented in Equation 1."

$$L\,(y_1, y_2, \ldots y_n,\ \beta_1, \beta_2, \ldots \beta_p) = \quad \prod_{i=1}^{n} \left(\exp\left(y_i \sum_{k=0}^{p} \beta_k\, x_{ik},\right)\right) \left(1 + \exp\left(\sum_{k=0}^{p} \beta_k\, x_{ik},\right)\right)^{-1} \qquad (2)$$

The estimated parameters β that maximize the log-likelihood are obtained by setting the gradient equations to zero. These nonlinear equations are then solved via the iterative Newton–Raphson optimization method.

4. Results

This section provides an in-depth exploration of the potential links between ICT training through the ADDIE model and teachers' professional development. It begins with the analysis of the characteristics of the variables studied, integrating frequency distributions through a descriptive analysis. The section then examines the impact of ICT training on teachers' professional development, using the chi-square test to assess these effects.

4.1. Reliability test

The study utilized a 9-item questionnaire, which demonstrated high reliability ($\hat{\alpha}$ = 0.819) and surpassed the recommended threshold of 0.70, as suggested by (Peterson, 1994). This high level of reliability underscores the robustness of the measurements, as shown in Table 1. The consistency of the alpha coefficient distribution further confirms the strong internal consistency of the measures, thereby reinforcing the validity of the data utilized in this research. Additionally, the findings revealed a significant association between the implementation of the ADDIE model in training and the enhancement of teachers' professional skills. These findings, which are consistent with established standards and prior research, enhance the credibility of the impact of ICTE training in engineering, which is based on the ADDIE model, on the professional development of high school teachers in the Fez-Meknes region of Morocco.

Table 1 Reliability test.

Cronbach's Alpha	Number of items
0.819	9

4.2. Descriptive analysis

The study surveyed 219 teachers from the Fes-Meknes region. Notably, women represented a significant majority, comprising 56.6% of the participants, reflecting broader Moroccan trends of greater female participation in the workforce (Figure 1a). In terms of age, the participants ranged from under 30 to 60 years, with a concentration between 25 and 45 years, which is typical for teacher training programs (Figure 1b). Geographically, the participants were distributed across two cities, Fes and Meknes, indicating that the study primarily involved teachers from urban areas in Morocco.

In terms of the impact of ICTE training via the ADDIE model on professional development, the responses varied: 75% strongly agreed with the positive influence, 13.2% mostly agreed, and 3.7% strongly disagreed. Additionally, when the analysis of ICTE skills needs to be conducted before training, 76.7% of the participants strongly agreed with its effectiveness, whereas only 4 participants disagreed (Figure 1c).

For the training objectives, the results varied: 35.2% strongly agreed, 42% mostly agreed, and 3.2% disagreed, suggesting differences in professional needs among teachers (Figure 1c). With respect to training materials, 37.9% moderately agreed on the usefulness of videos and guides, whereas 41.1% disagreed, questioning their effectiveness in enhancing professional skills (Figure 1c). Furthermore, the degree of integration of these tools and techniques into the training was generally moderate, with 71% mostly agreeing. Overall, 72% of the participants mostly agreed on the positive impact of ICTE training on their professional development (Figure 1c). These findings underscore the various factors influencing teachers' professional

development, including gender disparities, age-related patterns, geographic distribution, and variability in the perceived effectiveness of training materials and methods. Additionally, significant associations were observed between these variables and the overall development of teachers' skills.

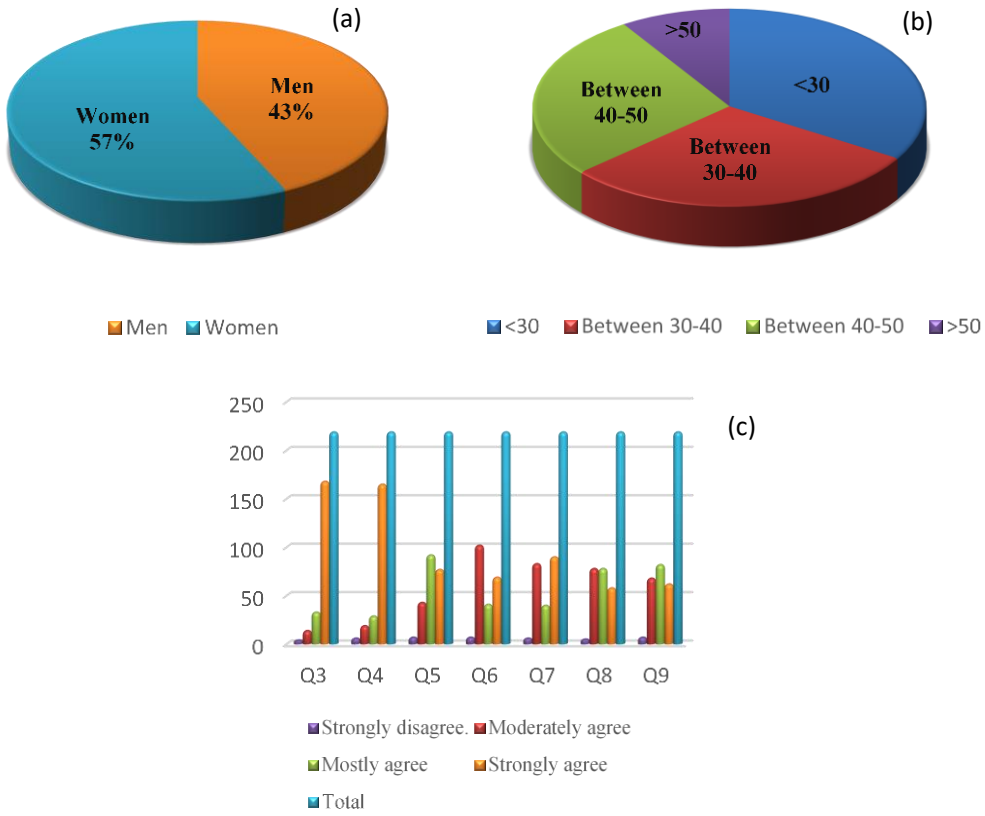

Figure 1 Descriptive analysis of a) sex, b) range age, and c) variables from X3--X9.

4.3. Correlation matrix

A Pearson correlation matrix was utilized to explore the interrelationships among the 9 questions posed in the study. The analysis included 9 selected variables, such as age, gender, diploma level, and years of teaching experience, to identify potential correlations influenced by these independent factors. The Pearson correlation matrix analysis (Table 2) revealed a significant positive correlation ($r > 0.80$) between X1 (gender of teachers), X4, and X5 (Aligning professional development with teachers' needs), indicating a well-coordinated relationship between gender and the alignment of professional development with teachers' needs. Similarly, strong correlations were observed between X5 and X6 (integration of digital tools), X7 (implementation of training), X8 (overall impact of training), and X9 (indicating a robust relationship between the use of teaching materials and the perceived effectiveness of ICT training on teachers' professional development), as well as between X6 and X7, X8, and X9, further emphasizing the alignment between teachers' needs, training materials, and their impact on enhancing teachers' development skills. Additionally, a notable positive correlation ($r > 0.64$) was found between X1 and X7, X8, and X9, highlighting a strong connection between gender and training materials' effectiveness in improving teachers' professional development. Conversely, X2 demonstrated a significant negative correlation with X5, X6, X7, X8, and X9 ($r < -0.80$), underscoring the role of age in adapting to new technologies in teacher training. Finally, a very strong positive correlation ($r > 0.88$) was identified between X8 and X9, suggesting a robust relationship between training materials and the overall impact of ICTE training on teachers' professional development.

4.4. Intraclass correlation coefficient

Table 3 highlights the effectiveness of ICTE training engineering, which is based on the ADDIE model, in enhancing the professional development of high school teachers in the Fez-Meknes region. The analysis demonstrates substantial intraclass correlations, with values of 0.39 for individual measures and 0.801 for average measures, suggesting that while individual assessments may show some variation, the overall evaluation remains consistently reliable. The significance of the Fisher test results ($p = 0.000$) affirms the internal consistency and robustness of the findings. Moreover, the confidence interval, which spans from 0.795--0.820, further confirms the dependability of the results. These insights indicate that the data supporting the study of the impact of ICTE training engineering, utilizing the ADDIE model, on the professional growth of teachers in the Fez-Meknes region are both credible and consistent, providing a solid foundation for the conclusions drawn.

Table 2 Correlation matrix.

	X1	X2	X3	X4	X5	X6	X7	X8	X9
X1	1								
X2	-0.49	1							
X3	-0.74	0.80	1						
X4	0.96	-0.43	-0.73	1					
X5	0.80	-0.77	-0.91	0.79	1				
X6	0.56	-0.88	-0.89	0.54	0.87	1			
X7	0.64	-0.89	-0.91	0.62	0.86	0.91	1		
X8	0.64	-0.78	-0.92	0.62	0.86	0.89	0.90	1	
X9	0.69	-0.77	-0.93	0.67	0.89	0.89	0.88	0.95	1

Table 3 Intraclass correlation coefficient.

Correlation Intraclass	Confidence interval 95% confidence interval		Fisher test			
	Boundary	Upper	Value	ddl1	ddl2	Sig.
Single measures	0.39	0.363	0.418	5.61	99	297	0.000
Medium measures	0.801	0.795	0.820	5.61	99	297	0.000

4.5. Chi-square test

The cross-tabulation presented in Table 4 illustrates the relationships between the 9 independent variables and the dependent variable (professional development of teachers by training in information and communication technologies (ICTs)) via the ADDIE model. These cross-tabulated data facilitate an analysis of how organizational commitment is associated with the different independent variables. In our study, Pearson's chi-square test was employed to determine whether the observed frequencies in each category significantly differed from the expected frequencies under the assumption of independence between the variables.

As shown in Table 4, the chi-square (χ^2) test yielded values ranging from 54.911 to 443.290, with 9 degrees of freedom for questions X1 through X9. These results indicate significant differences between the observed and expected frequencies, implying that such variations are unlikely to occur by chance. The extremely low p value of 0.000 further supports the rejection of the null hypothesis of independence, emphasizing the potential influence of ICTE training engineering, which is based on the ADDIE model, on the professional development of high school teachers in the Fez-Meknes region.

Table 4 Chi-square test.

Explanatory variables	Chi-square value	Likelihood ratio	Linear by linear associatione	Ddl	Sig
X1	54.91	74.81	43.72	9	0.000
X2	269.75	211.82	119.91	9	0.000
X3	443.29	271.07	199.21	9	0.000
X4	382.20	249.64	140.00	9	0.000
X5	254.60	137.68	68.93	9	0.000
X6	318.78	169.29	89.74	9	0.000
X7	293.55	169.60	88.91	9	0.000
X8	318.41	194.39	104.74	9	0.000
X9	330.50	185.40	95.25	9	0.000

4.6. Model adjustment

In this study, the regression analysis summarized in Table 5 underscores the robustness of the model in capturing the variability among the different variables and the influence of ICTE training engineering, which is based on the ADDIE model, on the professional development of high school teachers. The model exhibits strong predictive ability, with a coefficient of determination (R) of 0.888, reflecting a high correlation between the predicted and observed values. This robustness is further evidenced by a significant improvement in the fit of the full binary logistic regression model, as indicated by a chi-square test with a p value of 0.000 ($p < 0.05$) and a decrease in the -2LL value. The Cox and Snell R-squared (75.5%) and Nagelkerke R-squared (95%) values suggest that the model effectively explains the variation in the likelihood of hiring salaried executives. With an adjusted coefficient of determination of 0.881, the model provides an excellent fit, accounting for 87.6% of the variance through binary logistic regression.

Analysis of the logistic regression coefficients reveals significant impacts ($p < 0.05$) for all the variables, with coefficients of 8.957, -6.414, 6.173, 4.357, -9.996, 12.412, -1.399, and 6.370. Training actions and materials have pronounced effects on the development of teachers' skills, significantly influencing participation. For example, age increases the likelihood of participation in training actions (X2) by approximately 12.47 times. These findings emphasize the critical role of these factors in enhancing teachers' comprehension and skill development (Table 5).

Table 5 Results of the linear regression test.

2 Log of Likelihood	R^2 of Cox and Snell	R^2 of Nagelkerke	R squared sum of squares	R squared (Adjusted) sum of squares R^2
307.799	0.755	0.950	0.888	0.881

4.7. Assessment of regression model quality (ANOVA)

Table 6 provides an assessment of the quality of the regression model (ANOVA), highlighting the distribution of variance via the sum of squares, degrees of freedom, F statistic, and significance level. The ANOVA table shows the contribution of the multiple linear model used in the explanation of the response variable Y (acceptance of DT). On the basis of the bilateral asymptotic significance of the F value ($p = 0.000 < 0.05$), the null hypothesis ($H0$) is rejected, confirming the quality of the adjustment of the model used in the explanation of the dependent variable Y.

Table 6 Assessment of regression model quality (ANOVA).

ANOVAa						
Model		Sum of squares	ddl	Mean of squares	D	Sig.
1	Regression	54.567	9	3.517	47.258	.000
	Residual	2.059	24	.082		
	Total	56.626	34			

4.8. Non-standardized coefficients

Table 7 presents the nonstandardized coefficients of the regression model, along with their statistical significance and 95% confidence intervals. These coefficients enable the reconstruction of the linear adjustment equation, commonly referred to as the regression line equation. The column of nonstandardized coefficients (β) also provides insight into the direction of the relationship between the dependent variable (Y) and the independent variables (X), as indicated by the sign of the coefficient (+ or -). This sign is critical for interpreting whether the relationship is positive or negative.

The magnitude of these coefficients reflects the extent and direction of the relationship between the response variable, "the importance of interaction with the patient," and the explanatory variables included in the study. For example, the explanatory variable "the impact of language used in the context of care" (Q9) has a coefficient of β = -0.209, indicating an inverse relationship with the dependent variable, "the importance of interaction with the patient."

Conversely, other explanatory variables demonstrate a positive impact on the importance of interaction with the patient. Specifically, determinants such as language, the working system, and length of service in the profession contribute positively to improving care for pregnant women in maternity wards. However, challenges persist, particularly among illiterate individuals in rural areas, where language barriers can occasionally hinder effective communication between midwives and pregnant women.

Table 7 Regression variables.

	$\hat{\beta}$	E.S	Wald	ddl	Sig.	Exp ($\hat{\beta}$)	95% confidence interval for Exp ($\hat{\beta}$)	
							Inf.	Sup.
X1	8.95	24.65	0.13	1	0.71	7.68	-0.03	0.29
X2	-6.41	7.84	0.66	1	0.41	12.47	-0.14	0.06
X3	6.17	7.89	0.61	1	0.43	4.46	0.81	0.99
X4	4.35	12.27	0.12	1	0.72	11.79	-0.01	0.23
X5	-9.99	38.76	0.06	1	0.796	11.63	-0.18	0.02
X6	12.42	31.52	0.15	1	0.694	13.06	0.01	0.23
X7	-1.39	25.88	0.01	1	0.95	15.24	-0.24	0.03
X8	6.37	28.46	0.05	1	0.82	16.47	-0.02	0.26
X9	0.50	1.00	0.25	1	0.60	1.64	0.23	11.71
Constante	-0.33	0.37	0.08	1	0.03	0.71	0.34	1.49

5. Discussion

These principles provide a framework for establishing a structured training system that effectively addresses the outlined objectives. The proposed training, meticulously crafted following the steps of the ADDIE model, is tailored to meet the specific needs of teachers in Morocco, particularly in the Fes Meknes region, with an emphasis on information and communication technologies in education (ICTE). The ADDIE model also facilitates the definition of targeted objectives for training teachers in the ICTE domain, ensuring coherence between instructional design and learning outcomes (C. M. Budoya et al., 2019; Reinbold, 2013b).

The study's findings validate both hypotheses, highlighting the significant connections between the ADDIE model and the development of teachers' skills, thereby reinforcing previous research. Factors such as participation in training programs, age, and others play crucial roles in enhancing teachers' professional skills (Idrissi Loukili et al., 2024; Ortiz et al., 2025). Factors such as participation in training programs, age, and prior digital literacy experience play crucial roles in enhancing teachers' professional competencies. Similar relationships were identified by (Pedrosa, 2024b), who emphasized co-regulated learning strategies in teacher education projects involving ICT integration.

Numerous studies support the efficacy of this approach. For instance, Putri et al. (2020) reported that the use of an ICT-based instructional model in accounting significantly contributes to the professional development of vocational teachers by creating an effective learning environment that benefits students. Similarly, Almomen et al. (2016) evaluated a professional development program for primary care physicians via the ADDIE model, an instructional design framework encompassing five phases: analysis, design, development, implementation, and evaluation. Their findings indicated that at least 50% of participants reported substantial improvement in their learning for 16 out of 23 topics. While feedback from focus groups was generally positive, it also highlighted areas requiring further enhancement. Comparable outcomes were observed by (Derakhshan et al., 2023b; M. C. Kim & Hannafin, 2011), who found that iterative design processes and technological scaffolding increase both teaching innovation and confidence in digital environments.

In the same context, (Spatioti et al., 2022b) investigated effective teaching practices and approaches related to the ADDIE model in distance online learning environments. The researchers employed meta-analysis as their research methodology, analyzing a total of 58 articles that referenced the ADDIE model. Of these, only 23 articles were deemed suitable for inclusion in the meta-analysis. The results indicate that the ADDIE model is adaptable and can effectively meet diverse teaching requirements across various online educational settings (Luo et al., 2024).Complementary findings by (D'Ambrosio & Boriati, 2023) highlighted the importance of continuous digital literacy development and technology-supported critical thinking in sustaining lifelong professional learning.

Additionally, the study by (Maxnun et al., 2024) aimed to develop and implement a cognitive assessment based on higher-order thinking skills (HOTS) to evaluate students' abilities in this area. The study utilized an adaptation of the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model for the development process. The research involved a sample of 30 students from the Governance and Office Automation Competency Program in Class 11 at Vocational High School 1, Kudus. The results indicated that 11 students demonstrated very good HOTS abilities, 17 at a good level, and 2 at a sufficient level. The findings suggest that the use of the ADDIE model effectively enhances student performance in developing HOTS abilities. Comparable results were noted by (Syam & Ermawati, 2024b), whose work on English-language materials confirmed the model's versatility across disciplines and contexts. Collectively, these studies consolidate the view that the ADDIE model is a flexible, evidence-based instructional design paradigm capable of promoting sustainable teacher professionalization.

These results offer practical insights into the application of the ADDIE model and are consistent with the literature, supporting the study's external validity. The rigorous methodology and solid theoretical foundation also contribute to its internal validity. However, owing to the study's specific geographical and sectoral limitations, caution is advised when generalizing the findings. This underscores the need for future research to expand the sample size and employ mixed methodologies to achieve a more comprehensive understanding. Additionally, referencing prior studies and investigating the long-term impacts on overall teacher training performance would further strengthen the theoretical framework. Overall, this research deepens our understanding of the relationship between ICTE training via the ADDIE model and the enhancement of teachers' skills while also identifying areas for further exploration.

6. Limitations and Future Study

This study provides important insights into the effectiveness of ICTE training for engineering, structured according to the ADDIE model, in advancing the professional competencies of high school teachers in the Fes-Meknes region. By concentrating on this specific locale, the research offers a nuanced understanding of regional educational needs and practices, which may inform similar contexts. The voluntary nature of teacher participation ensured that the data captured the perspectives of those most actively engaged in professional development, thereby highlighting exemplary practices and successful outcomes. Nevertheless, several limitations should be acknowledged. The exclusive focus on the Fes-Meknes region, while enabling a thorough contextual analysis, may constrain the generalizability of the results to other regions or educational systems. The reliance on voluntary participation introduces the potential for self-selection bias, as the views of less-engaged teachers may be underrepresented. Furthermore, the primary use of survey-based data collection, although effective for

quantitative analysis, may not fully capture the complexity of teachers' experiences or the sustained impact of training interventions.

Future research should consider extending the scope to encompass a wider range of regions and adopting mixed-methods approaches, such as in-depth interviews or classroom observations, to yield richer and more comprehensive data. Improving the transparency and accessibility of the data collection process will also enhance reproducibility and foster collaborative research efforts. Addressing these limitations will enable future studies to provide a more robust and generalizable understanding of effective professional development strategies across diverse educational environments.

7. Conclusion

This study presents a comprehensive evaluation of the impact of ICTE engineering training on the professional development of high school teachers in Morocco's Fes-Meknes region. By utilizing a robust methodological framework including a validated questionnaire (Cronbach's alpha = 0.819), chi-square analysis ($p < 0.005$), and regression modeling ($R^2 = 0.906$), the findings offer strong empirical support for the effectiveness of targeted ICT training programs that are closely aligned with teachers' professional needs. The results demonstrate that such programs can significantly improve pedagogical practices and promote the integration of digital technologies within classroom settings.

The statistical analyses identify key determinants of successful professional development. The high internal consistency of the survey instrument and the substantial explanatory power of the regression model indicate that factors such as the alignment of training objectives, the relevance and quality of instructional materials, and the effective use of ICT tools are critical to achieving positive outcomes. Importantly, the regression analysis reveals that these variables account for more than 90% of the variance in training effectiveness, highlighting their central role in fostering teachers' professional growth.

In light of these results, we recommend that the Moroccan Ministry of Education adopt a data-driven, needs-based strategy for the design and implementation of ICT training initiatives. Conducting systematic needs assessments will help ensure that training content remains relevant to teachers' evolving professional contexts. Additionally, investment in the development and dissemination of high-quality, contextually appropriate teaching resources, as well as the establishment of ongoing support structures such as mentorship and peer collaboration, will be essential for facilitating the practical integration of ICT in daily teaching practice.

Moreover, institutionalizing continuous feedback and evaluation mechanisms is crucial for the ongoing refinement of training programs, allowing for adjustments on the basis of empirical data and teacher feedback. These approaches will not only maximize the immediate benefits of ICT training but also support the sustainable digital transformation of Morocco's education sector. While this research focuses on the Fes-Meknes region, its insights are applicable to other regions in Morocco and to educational systems in comparable contexts worldwide. The methodological rigor and evidence-based recommendations provided here offer a scalable framework for enhancing teacher professional development through ICT.

Future investigations should extend this work by assessing the long-term effects of ICT training, examining the roles of school leadership and infrastructure, and evaluating the efficacy of blended and fully online training modalities. By fostering sustained collaboration among researchers, policymakers, and practitioners, Morocco can continue to drive educational innovation and ensure that its teaching workforce is well prepared to navigate the challenges of an increasingly digital educational landscape.

8. Final Considerations

This study provides compelling evidence for the success of an ICT training approach based upon the ADDIE training model for teacher professional development, particularly within the context of the Fez-Meknes region of Morocco. A thorough survey questionnaire with rigorous statistical analysis demonstrated strong internal consistency of the survey instrument and revealed significant associations between ICT training and central domains of teacher competencies such as technological knowledge, pedagogical knowledge, and content knowledge.

The findings indicate that ICT training improves the instructional practices of teaching and engenders the incorporation of emerging technologies into the delivery of instruction. The large explanatory power of the regression model ($R^2 = 75.5\%$) highlights that ICT and training programs lead to considerable teacher competence development. Furthermore, the findings are valuable for education policymakers and leaders who are wanting to optimize teacher development from a professional development perspective and support the ongoing digital transformation of the education system. Importantly, the research study, and what it means, has relevance beyond the Fez-Meknes region, and the authors have relevance for other regions of Morocco and other similar educational contexts worldwide. For future research, the authors recommend continuing to research digital learning in different training approaches to improve teaching practices, using digital technologies, and supporting teachers' professional development, which represents and responds to today's educational demands.

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Ethical Considerations

This study involved a non-interventional, anonymous survey conducted with voluntary participants. All procedures followed the ethical standards of Moroccan national research regulations and the principles of the Declaration of Helsinki. Participation was entirely voluntary, and informed consent was obtained from all respondents prior to data collection. No personal or identifying information was collected, and participants could withdraw at any time without consequence. Given the non-clinical nature of the study and in accordance with institutional guidelines, formal approval from an ethics committee was not required.

Conflict of Interest

The authors declare no conflicts of interest.

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