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Rethinking Vocational Training in the Era of Digital Transformation: The Role of Training Needs Analysis in Strengthening Training–Employment Alignment.

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Abstract

Vocational training systems are increasingly challenged by rapid economic, technological, and social transformations, particularly those induced by digitalization and artificial intelligence. In this evolving context, strengthening training–employment alignment has become a strategic imperative for improving workforce preparedness and enhancing the responsiveness of training institutions. This study investigates the role of training needs analysis in supporting the adaptation of vocational training systems and reinforcing their alignment with labor market requirements in the era of digital transformation. A quantitative research design was adopted. Data were collected through a structured questionnaire administered to 55 trainers from the OFPPT. The reliability of the measurement instrument was confirmed through a satisfactory Cronbach's alpha coefficient (0.77). The data were analyzed using descriptive and inferential statistical techniques, including Pearson correlation coefficients and chi-square tests of independence. The findings reveal statistically significant positive relationships between the consideration of labor market needs and the evolution of training programs, as well as between the regular analysis of occupational changes and the adaptation of training content. The results further demonstrate the positive contribution of digital tools, particularly artificial intelligence, in enhancing the responsiveness, relevance, and anticipatory capacity of vocational training systems. This study contributes to the field of training engineering by highlighting the transition from static and reactive approaches toward more dynamic, data-informed, and predictive models of training needs analysis. It also offers practical implications for vocational training stakeholders by emphasizing the importance of adopting flexible, forward-looking, and technology-driven strategies to strengthen training–employment alignment.

Keywords: Training needs analysis; Vocational training; Employability; Digital transformation; Artificial intelligence.

1. Introduction

Over the past decades, Morocco has undertaken a continuous process of reforms aimed at modernizing its education and training system, within a context characterized by profound economic, technological, and social transformations. In this perspective, vocational training is increasingly considered a strategic lever for development, contributing to economic competitiveness, social inclusion, and the enhancement of human capital, as highlighted by the foundational works of human capital theory (Mincer, 1958; Schultz, 1963) (El Bouhali et al., 2024). In the Moroccan context, this orientation is particularly significant, as vocational training directly contributes to improving productivity and fostering economic growth. Within this dynamic, public authorities have devoted particular attention to vocational training, positioning it at the core of public policies. As emphasized by the National Vocational Training Strategy (2021), this system is expected to play a key role in aligning qualifications with the requirements of the productive system, thereby promoting employability and facilitating youth integration into the labor market. This strategic orientation is notably based on the development of a "demand-driven" training supply, as well as on the implementation of mechanisms for identifying economic and social skills needs. Furthermore, the literature highlights that vocational training constitutes a complex field. According to Crouch et al. (1999), it lies at the intersection of educational, economic, and social logics, involving a plurality of actors and regulatory frameworks (Bouatlaoui & Ouasri, 2025). In Morocco, vocational training has undergone a progressive evolution, transitioning from an initial system focused on regulating school flows to a structured system oriented toward professionalization and training–employment alignment (Bedoui & Faraj, 2018). Since independence, vocational training in Morocco has held a strategic position as a lever for development. In this regard, the creation of the Office of Vocational Training and Labor Promotion (OFPPT) in 1974 marked a decisive step in structuring the national vocational training system, enabling the training of intermediate-level professionals to meet labor market needs. However, for a long time, these systems remained primarily focused on initial training, with limited consideration given to mechanisms for anticipating skill needs, thus restricting their capacity to adapt to economic transformations (Bedoui et al., 2018). Gradually, vocational training has evolved into a strategic function integrated within human resource management policies. It now mobilizes a wide range of stakeholders and pursues diversified objectives, including enhancing employability, strengthening organizational competitiveness, and developing competencies. This evolution reflects a shift toward a systemic approach, in which training goes beyond the mere

transmission of knowledge to embrace a competency-based logic aligned with labor market requirements (Bedoui & Faraj, 2018). Nevertheless, despite these advances, the field remains marked by tensions related to the quality, relevance, and alignment of training programs with labor market needs (Initial Vocational Training Report, 2019). Indeed, several studies highlight the persistence of mismatches between the competencies developed within training systems and those required by employers. As noted by Azzouzi (2023), companies often consider that graduates do not fully possess the required skills, reflecting a misalignment between training frameworks and professional realities. This observation points to limitations in the design and updating of competency frameworks, which are nonetheless considered key instruments within the competency-based approach.

In this context, competency frameworks occupy a central position in training engineering, as they define the knowledge, skills, and attitudes expected in relation to occupational requirements. However, the absence or inadequacy of such frameworks in certain contexts compromises the quality of training systems and their ability to meet labor market expectations (Azzouzi, 2023). These challenges are further intensified in a context marked by digital transformation. The emergence of digital technologies, artificial intelligence, and data analytics tools is profoundly transforming occupations, organizational structures, and required competencies. As highlighted by Ridoini et al. (2024), the digitalization of human resource management not only enables the automation of administrative processes but also enhances talent management and anticipates skill needs through advanced analytical approaches. This transformation requires training systems to become more flexible, adaptive, and forward-looking (Ridoini et al., 2018). From this perspective, training needs analysis emerges as a fundamental stage in training engineering. It represents the starting point for designing relevant and effective training programs. As emphasized by Akkacha et al. (2020), any training initiative must be based on a rigorous identification of skill needs in order to ensure coherence with organizational strategic objectives and labor market requirements. Otherwise, training systems risk producing limited outcomes in terms of employability and performance. Thus, training engineering is grounded in a comprehensive and systemic approach that integrates multiple dimensions—strategic, organizational, and pedagogical—and mobilizes a diversity of stakeholders in the design, implementation, and evaluation of training systems. It constitutes a key lever for ensuring training–employment alignment, particularly in a constantly evolving environment (Akkacha et al., 2020). Against this backdrop, a major research question emerges: To what extent does training needs analysis contribute to the alignment between vocational

training systems and labor market requirements in the era of digital transformation? In this perspective, the present study aims to analyze the adaptation of vocational training systems in the context of digital transformation, with a particular focus on the role of training needs analysis in training–employment alignment, based on the perceptions of trainers from the Office of Vocational Training and Labor Promotion (OFPPT). Accordingly, this research is structured around three main hypotheses. The first hypothesis posits that the consideration of training needs analysis is positively associated with the alignment between training programs and labor market requirements. The second hypothesis assumes that the regular analysis of job evolution contributes to the adaptation of training content to labor market transformations. Finally, the third hypothesis suggests that the integration of digital tools, particularly artificial intelligence, into the training needs analysis process enhances the adaptation of vocational training systems to labor market requirements.

From a theoretical perspective, this research is anchored in the field of training engineering and seeks to enrich existing studies by linking training needs analysis with the contemporary challenges of digital transformation. It contributes to a deeper understanding of training–employment alignment mechanisms by mobilizing competency-based approaches and needs analysis models, while integrating the emerging role of artificial intelligence in training processes. From a practical standpoint, this study is of particular relevance to vocational training stakeholders, including policymakers, educational managers, and trainers. It helps identify key levers for improving the adaptation of training systems to labor market requirements, highlighting the central role of training needs analysis and the growing importance of digital tools in training engineering processes. As such, the findings can contribute to guiding training practices and policies toward more flexible, anticipatory, and market-oriented systems. To achieve these objectives, this study adopts a quantitative approach, based on a questionnaire administered to 55 OFPPT trainers. The aim was to collect their perceptions regarding the adaptation of training systems in the digital era, the evolution of competencies, training engineering processes—particularly training needs analysis—and the integration of labor market needs into training design. The collected data were analyzed using SPSS software, through both descriptive and inferential statistical analyses (correlation analysis and Chi-square tests), allowing for the testing of research hypotheses and the examination of relationships between variables. In the discussion section, the empirical findings will be confronted with theoretical contributions in order to validate or challenge the proposed hypotheses, and to derive insights and recommendations aimed at improving training–

employment alignment within the Moroccan vocational training context in the era of digital transformation. Prior to this empirical analysis, a literature review will be conducted to examine the theoretical foundations related to training needs analysis, training engineering, and the adaptation of training systems to labor market requirements in a digital context. Accordingly, the first part of this article is devoted to the literature review, while the second part focuses on the empirical study, presenting the adopted methodology, the sample, and the main findings along with their interpretation.

2. Literature review

Vocational training systems are currently evolving in a context marked by profound economic, technological, and organizational transformations driven by globalization, labor market restructuring, and more recently, digital transformation. These changes continuously redefine the competencies required by employers and increase pressure on training institutions to adapt their programs in order to reduce persistent mismatches between training provision and employment needs (Peretti, 2013). As a result, training–employment alignment has become a central concern for both policymakers and practitioners, raising questions regarding the capacity of training systems to anticipate occupational change and respond effectively to emerging labor market demands. In this perspective, vocational training can no longer be limited to the transmission of stable technical knowledge. It is increasingly expected to promote employability, support professional mobility, and prepare learners for occupations undergoing continuous transformation. This evolution has reinforced the strategic importance of training engineering, understood as a framework for structuring, managing, and regulating training systems in accordance with socio-economic requirements (Kébir, 2022). Beyond technical planning, training engineering is progressively viewed as a mechanism through which institutions can improve curriculum responsiveness and strengthen their connection with labor market realities. However, although the literature broadly recognizes the importance of training–employment alignment, many studies remain descriptive or normative, often emphasizing policy objectives without sufficiently examining the operational mechanisms through which alignment can be effectively achieved. In particular, limited empirical attention has been devoted to the role of training needs analysis as a strategic instrument for improving the responsiveness of vocational training systems, especially in contexts undergoing rapid digital transformation. This gap justifies the relevance of the present study.

2.1 Training Needs Analysis as a Foundation of Training Engineering

Far from being limited to mere pedagogical design, training engineering is part of a systemic approach that integrates needs analysis, design, implementation, and evaluation of training actions, within a logic aimed at optimizing skills development and overall performance (Ardouin, 2010; Ardouin, 2013). It reflects the professionalization of training practices, seeking to align organizational needs, individual expectations, and environmental changes, thereby giving it a dynamic, contextualized, and strategic character (Ardouin, 2013). From this perspective, it serves as a mediating tool between labor market transformations and the adaptation of training systems.

At the core of this approach, training needs analysis occupies a fundamental and structuring role, as it determines the relevance and effectiveness of training systems (Ardouin, 2013). The foundational work of Barbier and Lesne (1977, 1986) demonstrates that a need cannot be reduced to an expressed demand, but rather corresponds to an objective gap between an existing situation and a desired one, thus anchoring training design within a rigorous methodological framework. It is also important to note that "training needs are in fact derived from three distinct sources, whose synthesis is oriented toward action. These sources stem from organizational projects (new products, new organizational structures, productivity gains, etc.), from individuals' conscious expectations, and from their actual level in relation to the gap to be filled. We are therefore simultaneously dealing with three distinct dimensions: organizational logic, individual motivation, and pedagogy" (Peretti, 2013). This perspective suggests that training needs result from the articulation of three complementary logics—organizational, individual, and pedagogical—whose convergence enables the definition of relevant training actions. This conception is further developed by Parmentier (2008), who emphasizes that the precise identification of needs is a key condition for the relevance of training systems, while El Gorani (2016, 2021) highlights its essential role in ensuring coherence between training objectives, targeted competencies, and labor market requirements.

In this perspective, needs analysis is not limited to a diagnostic function but is embedded in a broader logic of competence development, understood as the ability to mobilize resources effectively in complex situations (Le Boterf, 2008). It therefore contributes to the construction of training systems in connection with transformations in work and evolving occupations. Training engineering thus relies on rigorous needs analysis to ensure coherence and alignment with socio-economic contexts (Ardouin, 2013). Similarly, training is increasingly viewed as a

strategic investment enabling both organizations and individuals to adapt to economic and technological changes (Blandin, 1990; Meignant, 2006). Training systems based on in-depth needs analysis contribute to the development of both individual and organizational competencies, thereby strengthening the adaptability of training systems (Ferhaoui, 2021).

2.2 Digital Transformation and the Renewal of Training Needs Analysis Practices

Today, the world is experiencing rapid transformations in occupations driven by digitalization and artificial intelligence, leading to continuous changes in competency frameworks and requiring training systems capable of anticipating labor market needs. However, despite its central role, training needs analysis presents limitations when based on traditional approaches. Conventional methods, such as surveys, interviews, and observations, often produce static data that are poorly suited to the rapid evolution of jobs and skills (Hakima et al., 2020). These approaches tend to focus on expressed or immediate needs, rather than adopting a prospective and strategic perspective (Akkacha, 2020). This lack of an anticipatory dimension limits the ability of training systems to prepare learners for emerging skills and to respond to structural labor market transformations. In this context, several studies highlight the need to integrate workforce planning and competency forecasting mechanisms in order to anticipate future needs and enhance training–employment alignment (Brémaud, 2010; Parmentier, 2008; Lévy-Leboyer, 2009).This issue is particularly relevant in national contexts such as Morocco, where vocational training plays a crucial role in the socio-professional integration of young people. The work of Goumari, Jaouhari, and Belfaqui (2025) shows that vocational training positively contributes to graduate employability, in line with the assumptions of human capital theory (Becker, 1964; Schultz, 1961; Denison, 1964). However, these authors emphasize that such integration remains dependent on macroeconomic, social, and organizational factors, highlighting the limitations of systems focused solely on ex post evaluation of outcomes (Azaizi & Berbou, 2024; El Ghrasli et al., 2025). These findings underscore the need to strengthen mechanisms for anticipating skill needs (Goumari et al., 2025).

In this context, digital transformation emerges as a structuring factor in the reconfiguration of skill needs and training engineering practices. The integration of technologies such as artificial intelligence, Big Data, and automation profoundly transforms professional activities, work organization, and required competencies. The literature highlights that these technologies improve decision-making, optimize organizational processes, and enhance overall performance, while fostering more analytical and strategic human resource management

practices (Azaizi & Berbou, 2024; El Ghrasli et al., 2025). Recent studies emphasize the potential of these technologies to renew training needs analysis practices. The integration of adaptive learning platforms and real-time feedback systems enhances learner engagement and skill acquisition, while aligning training systems with dynamic market needs (Agrawal, 2025). Similarly, the use of generative artificial intelligence contributes to transforming required competencies, particularly by strengthening cognitive and social skills (Gulati et al., 2025). Moreover, the use of Big Data makes it possible to identify gaps between acquired and required competencies, optimize learning pathways, and improve training–employment alignment (Aljohani et al., 2022). These developments reflect a shift from a static to a dynamic, continuous, and anticipatory approach to needs analysis.

Nevertheless, despite their potential, these technologies do not replace the fundamental principles of training engineering. As emphasized by Le Boterf (1999), competence also relies on human expertise, contextualization, and adaptability—dimensions that cannot be fully automated. Furthermore, the integration of artificial intelligence raises ethical, organizational, and technical challenges, particularly in terms of data protection, governance, and system reliability (Springer, 2022; UNESCO-UNEVOC, 2021). These limitations suggest that digital transformation acts more as a factor of reconfiguration than as a substitute for existing approaches. Thus, the literature converges on the idea that training needs analysis is the cornerstone of training engineering, while also highlighting the limitations of traditional approaches in addressing anticipatory requirements in a context of digital transformation. Although digital technologies offer promising perspectives for enhancing the precision and dynamism of this analysis, their integration remains partial and requires appropriate methodological frameworks. Therefore, the key challenge lies not only in adopting new technologies but also in articulating them with the foundations of training engineering. In this context, it becomes relevant to empirically examine the role of training needs analysis in adapting training systems and enhancing training–employment alignment, taking into account the perceptions of field actors, particularly OFPPT trainers.

3. Methodological Framework

3.1 Epistemological Positioning and Research Design

This study is grounded in a positivist epistemological paradigm, which assumes that social phenomena can be objectively observed, measured, and analyzed through empirical procedures.

Within this perspective, reality is considered external to the researcher and can be apprehended through rigorous methodological tools and systematic observation. Positivism is particularly relevant when the objective of research is to identify relationships between variables, test hypotheses, and generate evidence-based conclusions (Thiétart, 2007; Voss, 1999).

In line with this positioning, the present research adopts a quantitative hypothetico-deductive design. The hypotheses were formulated on the basis of prior theoretical contributions related to training engineering, training needs analysis, digital transformation, and training–employment alignment. These theoretical assumptions were subsequently subjected to empirical verification using data collected from field actors. Such a design is especially relevant for examining statistically significant associations between the consideration of training needs, the responsiveness of training systems, and the integration of digital technologies within vocational education environments (Ghanouane & Benkaraache, 2023).

3.2 Methodological Approach and Research Design

Consistent with the adopted epistemological positioning and deductive logic, this study relies on a quantitative methodological approach aimed at empirically testing theoretically derived hypotheses through measurable and statistically analyzable data. The quantitative approach is particularly appropriate for examining relationships between variables and producing robust empirical evidence through statistical procedures (Thiétart, 2007; Voss, 1999). From this perspective, the present research is both analytical and confirmatory in nature, as it seeks to validate hypotheses derived from the theoretical framework by examining the interrelationships between variables associated with training needs analysis, training system responsiveness, digital transformation, and training–employment alignment. Furthermore, the study follows an analytical cross-sectional survey design, whereby data were collected at a single point in time from respondents operating in the vocational training sector. This approach offers a solid methodological basis for empirically assessing the conceptual relationships advanced in the study.

3.3 Population, Sampling Method, and Sample Characteristics

The target population consisted of trainers working within institutions affiliated with OFPPT. This population was selected because trainers occupy a strategic position in the vocational training ecosystem, being directly involved in curriculum implementation, competency development, learner supervision, and continuous interaction with labor market realities. The

OFPPT, established under Law No. 1-72-183, is a public institution endowed with legal personality and financial autonomy, operating under the supervision of the governmental authority in charge of labor. Since its creation in 1974, it has become the leading national operator in vocational training in Morocco. Its principal mission is to contribute to human capital development by training a qualified workforce capable of responding to labor market demands and adapting to economic and technological transformations. Its institutions provide diversified training programs covering several qualification levels, including specialized technician, technician, qualification, and specialization. These programs are based on an integrated pedagogical approach combining theoretical instruction, practical training, and workplace internships, with the objective of strengthening training–employment alignment (Ibourk & Ghazi, 2024). The study relied on a non-probability convenience sampling strategy. Participants were selected according to their accessibility and willingness to participate in the survey. The questionnaire was disseminated through professional online communication channels. Following data screening and verification procedures, 55 valid questionnaires were retained for statistical analysis. Although convenience sampling does not allow strict probabilistic generalization, it remains methodologically relevant for generating empirically grounded insights from informed practitioners directly concerned by the phenomenon under investigation.

3.4 Data Collection Instrument : Questionnaire Construction and Validation

To achieve the research objectives, a structured questionnaire was selected as the primary data collection instrument. Questionnaires are particularly suitable in quantitative research because they allow the collection of standardized data from a relatively broad sample, thereby facilitating robust statistical analysis (Bhattacherjee, 2012). The questionnaire was administered through Google Forms, which ensured efficient distribution, data collection, and processing. This mode of administration offers several advantages, including accessibility, rapid response collection, secure storage, and the minimization of manual data entry errors. The measurement instrument was developed after an extensive review of the literature related to vocational training, training needs analysis, employability, curriculum adaptation, digital transformation, and artificial intelligence. The aim was to ensure conceptual consistency between the questionnaire items and the theoretical framework of the study. The instrument was structured around five major dimensions: the consideration of labor market needs in training design, the adaptation of training programs to occupational changes, the updating of

competency frameworks and pedagogical content, the integration of digital tools and artificial intelligence, and the perceived contribution of training to employability and professional insertion. The questionnaire included multiple response formats, namely five-point Likert-scale items, multiple-choice questions, dichotomous questions, and socio-demographic variables relating to gender, age, professional experience, and teaching level.

3.5 Reliability Analysis of the Measurement Scale

To assess the internal consistency of the measurement instrument, Cronbach's alpha coefficient was calculated using R Commander. Cronbach's alpha is widely recognized as one of the most commonly used indicators of reliability in quantitative research, as it measures the extent to which a set of items consistently captures the same latent constructs. The analysis yielded an overall Cronbach's alpha coefficient of 0.77, indicating a satisfactory level of internal consistency. According to widely accepted methodological standards, coefficients above 0.70 are generally considered acceptable, whereas values approaching 0.80 indicate good reliability. Accordingly, the obtained result confirms that the questionnaire items display an adequate degree of coherence and stability for measuring constructs related to training needs analysis, training adaptation, digital transformation, and training–employment alignment. Therefore, the measurement scale can be considered sufficiently reliable for the purposes of the present empirical investigation, and the collected data provide a sound basis for subsequent descriptive and inferential statistical analyses.

3.6 Ethical Considerations

Ethical principles were respected throughout all stages of the research process. Participation in the survey was entirely voluntary and based on informed consent. Respondents were clearly informed that the study was conducted exclusively for academic and scientific purposes. Anonymity and confidentiality were fully guaranteed. No personally identifiable information such as names, contact details, or institutional identifiers was collected. Participants were free to withdraw from the survey at any moment prior to final submission without any adverse consequence. All collected data were securely stored and analyzed exclusively in aggregated statistical form. Individual responses were neither disclosed nor used for any purpose other than academic research. These procedures ensured compliance with fundamental ethical standards relating to privacy, confidentiality, autonomy, and responsible data management.

3.7 Data Processing and Statistical Analysis

The collected data were processed using IBM SPSS Statistics and R Commander. Descriptive statistics were first employed to present the socio-professional profile of respondents. Subsequently, inferential statistical techniques were used to test the proposed hypotheses and examine relationships between the study variables. Pearson correlation coefficients were applied to assess linear relationships between quantitative variables, while chi-square tests of independence were used to examine associations between categorical variables. When appropriate, Fisher's exact test and effect size indicators such as Phi and Cramer's V were also considered. This analytical strategy enabled the empirical examination of the relationships between training needs analysis, curriculum responsiveness, digital transformation, and training–employment alignment within the Moroccan vocational training context (Bhattacherjee, 2012; Thiétart, 2008).

4. Analysis and Presentation of Key Findings

The study sample consists of 55 trainers from different OFPPT institutions, providing a heterogeneous profile in terms of age, gender, professional experience, and teaching level.

4.1 Sample Characteristics

4.1.1 Age Distribution

Table 1. Age Distribution of Participants

Age Group					
		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	30–39 years	35	63.6	63.6	63.6
	40–49 years	7	12.7	12.7	76.4
	50 years and above	7	12.7	12.7	89.1
	Under 30 years	6	10.9	10.9	100.0
	Total	55	100.0	100.0	

Source: Author's elaboration based on SPSS analysis

The distribution of respondents according to the age variable shows that the majority of trainers fall within the 30–39 age group, representing 63.6% of the sample (n = 35). This predominance

reflects a strong presence of mid-career professionals, who generally possess significant experience in the field of training.

4.1.2 Gender

Table 2. Gender of Participants

Gender					
		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	Female	27	49,1	49,1	49,1
	Male	28	50,9	50,9	100,0
	Total	55	100,0	100,0	

Source: Author's elaboration based on SPSS analysis

A near-balanced gender composition is observed, with males representing 50.9% (n = 28) and females 49.1% (n = 27) of the sample. This quasi-parity ensures an equitable representation of both genders, thereby enhancing the reliability and neutrality of the findings.

4.1.3 Years of Experience

Table 3. Years of Experience of Participants

Years of Experience					
		Frequency	**Percentage**	**Valid Percentage**	**Cumulative Percentage**
Valid	**11–15 years**	**7**	**12,7**	**12,7**	**12,7**
	5–10 years	**17**	**30,9**	**30,9**	**43,6**
	Less than 5 years	**25**	**45,5**	**45,5**	**89,1**
	More than 15 years	**6**	**10,9**	**10,9**	**100,0**
	Total	**55**	**100,0**	**100,0**	

Source: Author's elaboration based on SPSS analysis

A predominance of trainers with less than 5 years of experience is observed, accounting for 45.5% of the sample (n = 25), followed by those with 5 to 10 years of experience (30.9%, n = 17). Trainers with 11 to 15 years of experience represent 12.7%, while those with more than 15

years account for 10.9%. This distribution highlights the prevalence of relatively less experienced profiles in terms of professional seniority.

4.1.4 Training Level Delivered

Table 4. Training Levels Delivered by Participants

Training Level Delivered					
		Frequency	Percentage	Valid Percentage	Cumulative Percentage
Valid	Multiple levels	24	43,6	43,6	43,6
	Qualification	2	3,6	3,6	47,3
	Technician	7	12,7	12,7	60,0
	Specialized technician	22	40,0	40,0	100,0
	Total	55	100,0	100,0	

Source: Author's elaboration based on SPSS analysis

The distribution of respondents according to the level of training provided indicates that the majority operate across multiple levels (43.6%, n = 24), followed by trainers at the specialized technician level (40.0%, n = 22). The technician (12.7%) and qualification (3.6%) levels are less represented. This distribution reflects a high degree of versatility among trainers within the sample.

4.2 Analysis of Results

4.2.1 The Consideration of Training Needs is Positively Associated with Training–Employment Alignment

Table 5. Correlation between the Consideration of Labor Market Needs and the Evolution of Training Programs

Correlation			
		Are labor market needs sufficiently considered in training design?	*Do training programs evolve in response to changes in occupations?*
Are labor market needs sufficiently considered in training design?	*Pearson Correlation*	1	,445**
	Sig. (2-tailed)		,001
	N	55	55
Do training programs evolve in response to changes in occupations?	*Pearson Correlation*	,445**	1
	Sig. (2-tailed)	,001	
	N	55	55
***. Note: Correlation is significant at the 0.01 level (2-tailed).*			

Source: Author's elaboration based on SPSS analysis

The results of the Pearson correlation analysis reveal the existence of a positive and statistically significant relationship between the consideration of labor market needs in training design and the evolution of training programs in response to changes in occupations ($r = 0.445$; $p = 0.001$; $N = 55$). This correlation, significant at the 1% level, indicates that training programs are more likely to evolve when labor market needs are effectively integrated into their design.

The moderate strength of the relationship suggests that this consideration represents an important, though not exclusive, factor in the adaptation of training programs. These findings therefore reflect a dynamic process of alignment between training systems and evolving occupational requirements, highlighting the structuring role of integrating labor market needs into training design processes.

Table 6. Relationship between the Consideration of Labor Market Needs and the Adaptation of Training Frameworks

Correlation			
		Are labor market needs sufficiently considered in training design?	*Are training frameworks adapted to new technological requirements?*
Are labor market needs sufficiently considered in training design?	*Pearson Correlation*	1	,640**
	Sig. (2-tailed)		,000
	N	55	55
Are training frameworks adapted to new technological requirements?	*Pearson Correlation*	,640**	1
	Sig. (2-tailed)	,000	
	N	55	55
***. Note: Correlation is significant at the 0.01 level (2-tailed).*			

Source: Author's elaboration based on SPSS analysis

Pearson correlation analysis indicates a positive and statistically significant relationship between the consideration of labor market needs in training design and the alignment of training frameworks with emerging technological requirements (r = 0.640; p = 0.000; N = 55). The significance at the 1% level attests to the strength and reliability of this association. Moreover, the relatively high value of the correlation coefficient reflects a strong linkage between the two variables.These results suggest that training systems that incorporate labor market needs more thoroughly are more likely to develop training frameworks that are responsive to technological changes. They therefore underscore a greater consistency between labor market expectations and the structural foundations of training programs.

4.2.2 The Regular Analysis of Occupational Changes is Positively Associated with the Adaptation of Training Content to Labor Market Transformations

Table 7. Correlation between the Analysis of Occupational Changes and the Adaptation of Training Programs to Labor Market Transformations

Correlation			
		Are occupational changes in your field regularly analyzed?	*Do training programs evolve in response to changes in occupations?*
Are occupational changes in your field regularly analyzed?	*Pearson Correlation*	1	,430**
	Sig. (2-tailed)		,001
	N	55	55
Do training programs evolve in response to changes in occupations?	*Pearson Correlation*	,430**	1
	Sig. (2-tailed)	,001	
	N	55	55
***. Note: Correlation is significant at the 0.01 level (2-tailed).*			

Source: Author's elaboration based on SPSS analysis

The results of the Pearson correlation analysis indicate a positive and statistically significant association between the analysis of occupational changes and the adaptation of training programs to labor market transformations ($r = 0.430$; $p = 0.001$; $N = 55$). The significance at the 1% level attests to the reliability of the observed relationship. The moderate value of the correlation coefficient suggests that the consideration of occupational dynamics contributes to the adjustment of training content, while remaining one among several influencing factors.

These results further suggest that the incorporation of occupational transformations into analytical processes supports greater responsiveness within training systems. They therefore point to a gradual alignment of training programs with the evolving demands of the professional environment.

Table 8. Correlation between the Evolution of Training Programs and the Consideration of Professional Field Realities in Their Design

Correlation			
		Do training programs evolve in response to changes in occupations?	***Are professional field realities taken into account in training design?***
Do training programs evolve in response to changes in occupations?	***Pearson Correlation***	1	,642**
	Sig. (2-tailed)		,000
	N	55	55
Are professional field realities taken into account in training design?	***Pearson Correlation***	,642**	1
	Sig. (2-tailed)	,000	
	N	55	55
*****. Note: Correlation is significant at the 0.01 level (2-tailed).***			

Source: Author's elaboration based on SPSS analysis

Findings from the Pearson correlation analysis point to a positive and statistically significant relationship between the evolution of training programs and the extent to which professional field realities are incorporated into their design ($r = 0.642$; $p = 0.000$; $N = 55$). The significance at the 1% level substantiates the robustness of this association, while the strength of the coefficient suggests a strong linkage.

These findings support the view that embedding professional realities within training design enhances the capacity of programs to evolve, thereby reinforcing the alignment between training systems and real-world professional contexts**.**

Table 9. Relationship between the Updating of Training Frameworks and the Adaptation of Training Programs

Cross-tabulation: Are training frameworks regularly updated? × Have training programs been modified in recent years in your specialty?				
Frequency				
		Have training programs been modified in recent years in your specialty?		
		No	Yes	Total
Are training frameworks regularly updated?	No	17	18	35
	Yes	0	20	20
Total		17	38	55

Source: Author's elaboration based on SPSS analysis

The results indicate that training programs associated with regularly updated frameworks are more likely to undergo modifications. Indeed, all respondents (20 out of 20) who reported that training frameworks are regularly updated also indicated that training programs have been modified in recent years. In contrast, among the 35 respondents who stated that frameworks are not regularly updated, 17 reported no changes in training programs, while 18 indicated the opposite. These findings suggest a trend in which the updating of training frameworks is associated with a dynamic process of program revision.

To examine the existence of a statistically significant relationship between these two variables, a chi-square test of independence was conducted based on the following hypotheses:

- Null hypothesis (H0): There is no significant relationship between the updating of training frameworks and the adaptation of training programs.
- Alternative hypothesis (H1): There is a significant relationship between the updating of training frameworks and the adaptation of training programs.

Table 10. Chi-Square Test

Chi-Square Test					
	Value	ddl	Asymptotic Sig. (2-tailed)	Exact Sig. (2-tailed)	Exact Sig. (1-tailed)
Pearson Chi-Square	14,060[a]	1	,000		
Continuity Correction	11,878	1	,001		
Likelihood Ratio	19,529	1	,000		
Fisher's Exact Test				,000	,000
N of Valid Cases	55				
a. No cells (0.0%) have expected counts less than 5; minimum expected count = 6.18.					
b. Calculated only for a 2×2 table					

Source: Author's elaboration based on SPSS analysis

Table 11. Cramer's V Test

Measure			
		Value	Approximate Significance
Nominal by Nominal	Phi	,506	,000
	Cramer's V	,506	,000
N d'observations valides		55	

Source: Author's elaboration based on SPSS analysis

To assess the existence of a statistically significant relationship between the updating of training frameworks and program modification, a chi-square test of independence was performed. The results show a Pearson chi-square value of $\chi^2 = 14.060$, with 1 degree of freedom and a significance level of $p = 0.000$, which is below the 0.05 threshold. This result leads to the rejection of the null hypothesis of independence, thereby confirming the existence of a relationship between the two variables. The conditions for applying the test are satisfied, as no cell has an expected frequency below 5 (minimum = 6.18), ensuring the reliability of the results. Furthermore, Fisher's exact test confirms this significance ($p = 0.000$), reinforcing the robustness of the analysis. Having established the existence of this relationship, its strength was assessed using Cramer's V coefficient, which yields a value of 0.506. The interpretation of this coefficient, exceeding the threshold of 0.50, indicates a relatively strong association between

the variables. Thus, beyond statistical significance, the results also highlight the substantive importance of the relationship between the updating of training frameworks and the modification of training programs, reflecting a notable interdependence between these two dimensions.

4.2.3 The Integration of Digital Tools in the Training Needs Analysis Process is Positively Associated with the Adaptation of Vocational Training to Labor Market Requirements

Table 12. Correlation between the Use of Artificial Intelligence for Anticipating Training Needs and the Adaptation of Training Programs

Correlation			
		Can artificial intelligence tools be used to anticipate future training needs?	*Can the integration of artificial intelligence improve the adaptation of training programs to labor market requirements?*
Can artificial intelligence tools be used to anticipate future training needs?	*Pearson Correlation*	1	,633**
	Sig. (2-tailed)		,000
	N	55	55
Can the integration of artificial intelligence improve the adaptation of training programs to labor market requirements?	*Pearson Correlation*	,633**	1
	Sig. (2-tailed)	,000	
	N	55	55
***. Note: Correlation is significant at the 0.01 level (2-tailed).*			

Source: Author's elaboration based on SPSS analysis

Table 1. Correlation between the Integration of Digital Tools in Training Content and Their Capacity to Address Digital Transformations in Occupations

Correlation			
		Are digital tools used in companies taken into account in training content?	*Does training content respond to digital transformations in occupations?*
Are digital tools used in companies taken into account in training content?	*Pearson Correlation*	1	,776**
	Sig. (2-tailed)		,000
	N	55	55
Does training content respond to digital transformations in occupations?	*Pearson Correlation*	,776**	1
	Sig. (2-tailed)	,000	
	N	55	55
***. Note: Correlation is significant at the 0.01 level (2-tailed).*			

Source: Author's elaboration based on SPSS analysis

The correlation analysis reveals a positive and highly significant relationship between the integration of digital tools into training content and their capacity to address digital transformations in occupations ($r = 0.776$; $p < 0.001$). The strength of this correlation indicates that the greater the incorporation of digital tools used in professional environments, the more training systems are perceived as capable of adapting to evolving occupational demands. This finding underscores the structuring role of digitalization in the modernization of training systems by promoting stronger alignment between pedagogical content and professional realities. It further suggests that digital integration extends beyond mere content enhancement, constituting a key driver of pedagogical transformation and competency development, particularly in relation to digital and transversal skills.

In addition, a positive and statistically significant relationship is observed between the use of artificial intelligence for anticipating training needs and its contribution to improving the alignment of training programs with labor market requirements ($r = 0.633$; $p < 0.001$). This

result highlights the specific contribution of artificial intelligence to the training needs analysis process, enabling a shift from traditional approaches based on static data toward more dynamic and predictive models. Indeed, artificial intelligence allows for the processing of large volumes of labor market data, thereby facilitating the identification of emerging competencies and the anticipation of occupational changes. It also enhances the responsiveness of training systems to rapid transformations in professional environments. Taken together, these findings point to a complementary relationship between digital tools and artificial intelligence in optimizing the training needs analysis process. While digital tools contribute to aligning training content with current professional practices, artificial intelligence enables the anticipation of future needs and supports a forward-looking approach to training system design. Consequently, the integration of these technologies into training engineering emerges as a strategic lever for strengthening training–employment alignment, enhancing the relevance of training systems, and supporting the development of competencies adapted to labor market transformations. Overall, these results confirm that the integration of digital tools, particularly artificial intelligence, into the training needs analysis process constitutes a decisive factor in improving training–employment alignment. Accordingly, the proposed hypothesis is validated.

1. Discussion

The validation of the three research hypotheses highlights the central role of training needs analysis as a strategic lever for adapting vocational training systems in a context characterized by digital transformation. These findings are consistent with the theoretical foundations outlined in the literature review and provide empirical support within the Moroccan vocational training context, particularly within OFPPT.

First, the results related to the first hypothesis confirm the existence of a positive and significant relationship between the consideration of labor market needs and the adaptation of training systems. This finding is consistent with the foundational work of Barbier and Lesne (1977, 1986), who conceptualize training needs as an objective gap between an existing situation and a desired one, thereby constituting the starting point for any relevant training intervention. It also corroborates the contributions of Parmentier (2008) and El Gorani (2021), who emphasize that the rigorous identification of needs conditions the coherence between training objectives, targeted competencies, and labor market requirements. From this perspective, the results confirm that training systems integrating labor market needs tend to be more adaptive and better aligned with evolving occupational demands. This observation aligns with the systemic

approach to training engineering developed by Ardouin (2013), which considers needs analysis as a structuring stage determining the relevance and effectiveness of training systems. It also reinforces the view of training as a strategic investment (Meignant, 2006; Blandin, 1990), which must be grounded in a precise understanding of competency needs in order to enhance employability and organizational performance (Ferhaoui, 2021). Second, the validation of the second hypothesis demonstrates that the regular analysis of occupational changes significantly contributes to the adaptation of training content to labor market transformations. This finding confirms the importance of the anticipatory dimension in needs analysis, as emphasized in the literature on competency management (Lévy-Leboyer, 2009; Brémaud, 2010). Indeed, the absence of a dynamic analysis of occupational developments represents a major limitation of traditional approaches to needs analysis, which are often based on static and immediate data (Akkacha et al., 2020). Furthermore, the results indicate that the updating of training frameworks and the consideration of professional field realities are strongly associated with the evolution of training programs. These findings are consistent with the work of Azzouzi (2023), which highlights the structuring role of competency frameworks in aligning training systems with labor market requirements. They also confirm that training engineering can only be effective when it is grounded in a close articulation between organizational, pedagogical, and professional logics, as emphasized by Peretti (2013).

Third, the findings related to the third hypothesis underscore the decisive role of digital transformation, particularly artificial intelligence, in improving the adaptation of training systems to labor market requirements. The high intensity of the observed correlations confirms that the integration of digital tools into training content constitutes a key factor in aligning training systems with evolving occupational demands. This result is consistent with recent studies highlighting the potential of digital technologies to transform training engineering practices (Ridoini et al., 2024; Agrawal, 2025). Moreover, the significant correlation between the use of artificial intelligence to anticipate training needs and the improved adaptation of training programs confirms the contributions of Aljohani et al. (2022), who emphasize the role of Big Data and artificial intelligence in identifying emerging competencies and anticipating labor market changes. These technologies make it possible to overcome the limitations of traditional approaches by enabling a more dynamic, continuous, and predictive analysis of skill needs.

However, these findings should be interpreted with caution. As highlighted by Guy Le Boterf (2008), competence cannot be reduced to the mere mobilization of technical resources, but also involves the ability of individuals to mobilize and combine knowledge in complex situations. Thus, while the integration of digital technologies is essential, it cannot replace human expertise and the contextual dimensions of competence (UNESCO-UNEVOC, 2021; Springer, 2022). Overall, these results confirm that training needs analysis constitutes the cornerstone of training engineering, while also highlighting the need to renew its approaches in a context of digital transformation. They point to a shift from a traditional, static, and descriptive approach toward a more dynamic, continuous, and forward-looking approach, integrating the contributions of digital technologies and artificial intelligence. Thus, this research makes both a theoretical and empirical contribution by demonstrating that improving training–employment alignment relies on the articulation of three complementary dimensions: rigorous needs analysis, anticipation of occupational changes, and the strategic integration of digital tools. These findings are consistent with the orientations of the Stratégie Nationale de la Formation Professionnelle (2021), which advocates for the development of a demand-driven training system based on a more accurate identification of economic and social skill needs.

2. Conclusion

The present study aimed to analyze the role of training needs analysis in the adaptation of vocational training systems and in enhancing training–employment alignment within a context shaped by digital transformation. Based on the perceptions of OFPPT trainers, the findings allowed for the validation of all the proposed hypotheses, thereby highlighting significant relationships between training needs analysis, training adaptation, and the integration of digital tools. The results first demonstrate that the consideration of labor market needs constitutes a determining factor in the evolution of training programs and the adaptation of training frameworks. This confirms that training needs analysis represents the foundation of training engineering and a key lever for ensuring coherence between training systems and socio-economic requirements. Second, the study emphasizes the importance of regularly analyzing occupational changes, which contributes to a better adaptation of training content to labor market transformations. This dimension highlights the need to embed training systems within a dynamic and anticipatory framework.

Furthermore, the findings reveal the structuring role of digital transformation, particularly artificial intelligence, in improving training–employment alignment. The integration of digital tools into training content not only enables alignment with current professional practices but also supports the anticipation of future competencies, thereby enhancing the relevance and effectiveness of training systems. From a theoretical perspective, this research contributes to the field of training engineering by highlighting the evolution of training needs analysis practices toward more dynamic approaches that integrate the contributions of digital technologies and artificial intelligence. It confirms that training needs analysis can no longer be considered a one-time step, but rather a continuous and strategic process at the core of training–employment alignment. From a practical standpoint, the findings provide important implications for vocational training stakeholders. They emphasize the need to strengthen training needs analysis mechanisms, develop monitoring systems for occupational changes, and further integrate digital technologies into training engineering processes. In this regard, training institutions, particularly OFPPT, are encouraged to adopt more flexible, adaptive, and forward-looking approaches in order to effectively respond to labor market transformations. However, this study presents certain limitations that should be acknowledged. On the one hand, it is based on trainers' perceptions, which may introduce a degree of subjectivity into the findings. On the other hand, the sample size and its focus on a specific context limit the generalizability of the

results. In this respect, several avenues for future research can be considered. It would be relevant to extend the study to other stakeholders within the vocational training system, such as learners, companies, and institutional decision-makers, in order to obtain a more comprehensive understanding of training–employment alignment. In addition, the use of mixed methods combining quantitative and qualitative approaches would allow for a deeper exploration of the underlying mechanisms. Finally, the development of predictive models based on artificial intelligence and Big Data represents a promising avenue for improving the anticipation of skill needs and enhancing the effectiveness of training systems.

Ultimately, this research demonstrates that improving training–employment alignment relies on the articulation of training needs analysis, anticipation of occupational changes, and the integration of digital technologies, thereby confirming the strategic role of training engineering in a constantly evolving environment.

Références :

- Abdelmalek AZZOUZI. (2023). *Le référentiel de compétences au cœur de la formation qualifiante*. https://doi.org/10.5281/ZENODO.7581838
- Agrawal, A. (2025). *Artificial Intelligence for Skill Development : Implementing Ai in Vocational Training Programs to Enhance Employability*.
- Aljohani, N. R., Aslam, M. A., Khadidos, A. O., & Hassan, S.-U. (2022). A Methodological Framework to Predict Future Market Needs for Sustainable Skills Management Using AI and Big Data Technologies. *Applied Sciences*, *12*(14), 6898. https://doi.org/10.3390/app12146898
- Aloovi, O. A., & Sisinyize, N. L. (2024). Training Needs Assessment for managers of Technical andVocational Education and training providers in Namibia. *Social Science and Humanities Journal*, *8*(08), 4705-4720. https://doi.org/10.18535/sshj.v8i08.1285
- Ardouin, T. & ARDOUIN. (2013). Ingénierie de formation analyser, concevoir, réaliser, évaluer (Quatrième édition). DUNOD.
- AZAIZI Amira, & BERBOU Lahoucine. (2024). *Repenser La Gestion Des Ressources Humaines A L'ere De L'intelligence Artificielle*. https://doi.org/10.5281/ZENODO.11400794
- Bedoui, N., Laboratory, L., Faraj, A., & Laboratory, L. (2018). *Le développement des ressources humaines de l'éducation et de la formation*. *1*(2).
- Bilagi, A. (2022). Review of Literature on Human Resource Planning as an Ongoing Important Practice to Anticipate Future Human Resource Requirements within an Organization. *International Journal of Research Publication and Reviews*, 222-227. https://doi.org/10.55248/gengpi.2022.3.11.4
- Blandin, B. (1990). *L'INGENIERIE DE FORMATION: des projets aux actes*
- Chedi, J. M. (2017). *A Preliminary Review on Needs Analysis and Delphi Technique : Effective Tools for Data Collection*.
- El Bouhali, M., El Alaoui, A., El Alami, N., & Lakhouil, A. (2024). Impact de La Formation Professionnelle sur la Croissance Économique au Maroc : Étude

Économétrique. *International Journal of Research in Economics and Finance*, *1*(2), 50-63. https://doi.org/10.71420/ijref.v1i2.18

- EL GHRASLI, A., MZAIZ, M., & LOUX, K. (2025). L'intelligence artificielle au service de la gestion des ressources humaines : Une analyse des opportunités et des défis de déploiement. *Revue Management des Systèmes d'Information et Innovation*, *9*(2), 3-14. https://doi.org/10.34874/IMIST.PRSM/ISMI/55277

- EL GORANI Azhar. (2021). *La mise en œuvre de la stratégie nationale de la formation continue des ressources humaines dans le cadre de la réforme éducative au Maroc*. https://doi.org/10.5281/ZENODO.5529186

- FARSAD Mohamed Elmehdi, & MOKSIT Idriss. (2025). *Quelle conception de méthodologie de recherche appropriée en sciences de gestion : Positionnement épistémologique et approche de recherche*. https://doi.org/10.5281/ZENODO.15740359

- Ferreira, R. R., & Abbad, G. (2013). Training needs assessment : Where we are and where we should go. *BAR - Brazilian Administration Review*, *10*(1), 77-99. https://doi.org/10.1590/S1807-76922013000100006

- Ferhaoui, M. (2021). L'ingénierie de formation au service de la gestion et de développement des compétences. *Advanced Research in Economics and Business Strategy Journal*, *2*(1), 25-35. https://doi.org/10.52919/arebus.v2i1.13

- *Formation professionnelle initiale : Clés pour la refondation*. (2019). Conseil Supérieur de l'Éducation, de la Formation et de la Recherche Scientifique.

- Gould, D., Kelly, D., White, I., & Chidgey, J. (2004). Training needs analysis. A literature review and reappraisal. *International Journal of Nursing Studies*, *41*(5), 471-486. https://doi.org/10.1016/j.ijnurstu.2003.12.003

- Goumari, S., Jaouhari, L., & Belafquih, A. (2025). *Evaluation de l'impact de la formation professionnelle sur l'insertion des diplômés : Cas des lauréats de l'OFPPT*. *6*(4).

- Hakima, A., Salah, D., & Assya, K. (2020). *L'INGENIERIE DE FORMATION UN OUTIL STRATEGIQUE DANS LE DEVELOPPEMENT DES COMPETENCES, DES*

(103) STAGIAIRES DANS LE CADRE D'UNE FORMATION PRE-RECRUTEMENT AU SEIN DU COMPLEXE GL3Z- SONATRACH.

- Ibourk, A., & Ghazi, T. (2024). *DE LA CLASSE À LA CARRIÈRE :*
- Kamila Ludwikowska. (2018). *The effectiveness of training needs analysis and its relation to employee efficiency*. https://doi.org/10.21008/J.0239-9415.2018.077.11
- Karim, G. (2023). *Les tendances épistémologiques et méthodologiques de la recherche en management des Big Data—Une analyse sur la période 2017-2022*. *4*.
- Le Boterf, G. (2008). *Ingénierie et évaluation des compétences* (5e éd., 2e tirage 2008). Eyrolles - Ed. d'organisation.
- *Méthodologie de la recherche : Réussir son mémoire ou sa thèse en sciences de gestion*. (2008). Pearson éducation.
- Moore, M. L., Dutton, P., & Donnelly, R. R. (1978). *Training Needs Analysis : Review and Critique ^*.
- Parmentier, C. (2008). *L'ingénierie de formation*. Eyrolles-Éd. d'Organisation.
- Peretti, J.-M. (2013). *Ressources humaines* (14e éd., [à jour de la loi sur la sécurisation de l'emploi du 14 mai 2013]). Vuibert.
- Robert, N., & Mori, N. (2025). Effects of training needs assessment in enhancing employees' skills and firm performance. *Journal of Work-Applied Management*, *17*(1), 82-98. https://doi.org/10.1108/JWAM-05-2023-0046
- *Stratégie Nationale de la Formation professionnelle*. (2021).
- Touria Bouatlaoui, & Ali Ouasri. (2025). *La formation professionnelle initiale au Maroc : Etat des lieux, Dispositifs de formation, et enjeux socio-éducatifs*. https://doi.org/10.5281/ZENODO.15607734