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Applying Machine Learning to Examine Psychological Ownership and Work Passion in Innovation Processes

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A B S T R A C T

Objective: This study aims to apply supervised machine learning algorithms to evaluate the non-linear predictive power of psychological ownership and work passion on employee engagement in organizational innovation processes.

Methods and Materials: A quantitative, cross-sectional design was employed, utilizing a self-administered questionnaire to collect data from a sample of 452Moroccan professionals. To capture complex, non-linear interactions without the constraints of traditional linear models, the data was analyzed using advanced supervised machine learning algorithms, specifically Random Forest, Support Vector Machine (SVM), and Gradient Boosting Regressor.

Findings: The Gradient Boosting regressor demonstrated the highest predictive accuracy, successfully explaining 74%of the variance in innovation process engagement ($R^2 = 0.74$, $RMSE = 0.41$). Feature importance analysis identified self-efficacy as the most critical predictor, accounting for 28.4%of the variance, followed closely by harmonious work passion (24.1%), belongingness (16.2%), and identity (14.8%). Obsessive work passion contributed 9.5%to the model and exhibited a non-linear threshold effect, indicating that excessive obsession diminishes innovative output, while demographic variables (age, tenure) collectively contributed less than 7%to the predictive power.

Conclusion: Cultivating intrinsic psychological states—specifically high self-efficacy and harmonious passion—is significantly more critical for driving organizational innovation than demographic factors, highlighting the need for compassionate, autonomy-supportive human resource strategies.

Keywords: *Machine Learning, Psychological Ownership, Work Passion, Innovation Processes*

1 Introduction

In the contemporary, rapidly evolving global economy, innovation is no longer merely an advantageous organizational capability; it is a fundamental prerequisite for long-term survival, sustained competitive advantage, and structural resilience. The concept of the innovation process encompasses a multifaceted journey that begins with the

initial ideation and conceptualization of novel ideas and culminates in their practical implementation and commercialization. Modern conceptualizations of this process acknowledge its inherent complexity, moving away from closed, linear models toward more dynamic, interconnected paradigms such as open innovation, digital ecosystems, and social innovation networks. For instance, the integration of digital innovation management within entrepreneurial ecosystems has revolutionized how organizations adopt software and services to drive their core innovation functionalities (Endres et al., 2022). Similarly, the structural configuration of innovation ecosystems, particularly those facilitated by digital innovation hubs, highlights the necessity of complex, multi-level relational networks and collaboration processes that bridge internal and external knowledge reservoirs (Serrano-Ruiz et al., 2024). Furthermore, the scope of innovation has broadened to include not just technological advancements, but also business model innovation and new product development strategies that are critical for achieving superior performance metrics in technology-driven environments, such as science parks and digital hubs (Haghparast et al., 2023). Beyond pure commercial metrics, there is an increasing recognition of the value of grassroots processes and knowledge-sharing mechanisms in building robust social innovation capabilities, demonstrating that innovation processes are deeply embedded in the social fabric of the organization (Fait et al., 2022).

Central to the successful execution of these complex innovation processes is the strategic utilization and management of knowledge. Knowledge management processes—specifically the acquisition, dissemination, and application of knowledge—are indispensable across the various developmental stages of technological innovation, particularly for small and medium-sized enterprises seeking to leverage limited resources into high-impact outputs (Bloem & Salimi, 2022). Empirical evidence consistently links rigorous competitive intelligence activities and structured knowledge management processes directly to enhanced organizational innovation performance (Zuochun, 2023). However, knowledge management and systemic innovation do not occur in a vacuum; they are intrinsically driven by human capital. Strategic human resources management plays a pivotal role in translating structural knowledge capabilities into tangible competitive advantages by explicitly fostering employee innovation behavior at the individual level (Shaalan et al., 2022). This highlights the critical reality that the structural digitalization of economic systems must be closely aligned with robust indicators of human resources involvement to genuinely optimize regional and organizational innovation processes (Gundorova et al., 2022). The effectiveness of these human resource strategies in driving open innovation is particularly salient in diverse operational contexts, ranging from the complex integration of open innovation frameworks within the highly competitive home appliance industry (Saeedi motlagh & Karimishad, 2022) to the unique strategic interactions required to drive open innovation within non-profit organizational structures (Oliveira et al., 2021). Even within specialized sectors such as education (Paños-Castro & Arruti, 2021) and e-business environments heavily reliant on customer relationship management (Khodaei, 2022), the human element remains the primary engine of agile product innovation.

Understanding the human driver of innovation requires a deep dive into the organizational dynamics and team-level interactions that facilitate creative development. Team processes, encompassing communication, conflict resolution, and collaborative problem-solving, are vital for sustaining innovation development within evolving learning organizations (Witherspoon, 2021). Furthermore, the boundaries of internal innovation are frequently expanded through customer engagement and empowerment mechanisms, which serve as external motivational processes that significantly enhance the development of creative service ideas (Shin & Perdue, 2022). Yet, the foundation of all group-level and external-facing innovation efforts rests firmly on the psychological state and intrinsic motivation of the individual employee.

One of the most potent psychological states linked to employee behavior is psychological ownership. While distinctly different from legal ownership, psychological ownership represents a cognitive-affective state wherein individuals feel that the organization, or a specific project within it, is “theirs.” This sense of possession is deeply intertwined with concepts of working affiliation and the attachment models that dictate how employees relate to their institutional environments (Torabian et al., 2023). Strong feelings of organizational loyalty, often mediating the relationship between an employee’s core work personality and their ultimate job attachment, create an environment where individuals are more willing to invest discretionary effort (Abdollahi & Bejani, 2024). When employees experience a high degree of psychological ownership, they are theoretically more likely to engage in the risk-taking, persistent behaviors required to navigate the inherently

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uncertain terrain of the innovation process. They view the success or failure of innovative endeavors not merely as organizational outcomes, but as reflections of their own professional identity and self-efficacy.

Parallel to psychological ownership, the concept of work passion has emerged as a crucial determinant of employee engagement and performance. Work passion is generally conceptualized as a strong inclination toward an activity that people like, find important, and in which they invest time and energy. It is typically bifurcated into harmonious passion, which is fully integrated into the individual's identity without conflict, and obsessive passion, which creates an uncontrollable urge to participate in the activity, often at the expense of other life domains. Harmonious work passion has been shown to be a critical mechanism through which positive organizational factors, such as ethical leadership and interpersonal trust, enhance overall employee work engagement (Islam et al., 2024). The literature also identifies domain-specific variations of passion, such as environmental passion, which interacts with specialized forms of self-efficacy to drive distinct workplace behaviors, such as green and sustainable initiatives (Mughal et al., 2024). Cultivating this harmonious passion is increasingly recognized as a vital intervention strategy to promote workplace resilience, particularly in high-stress environments such as health and clinical settings (Unjai et al., 2024).

The development and maintenance of both psychological ownership and harmonious work passion are heavily dependent on the broader psychological well-being of the workforce, which is increasingly supported by cultures of compassion and self-compassion. Organizational compassion plays a significant moderating role in mitigating negative workplace phenomena, such as perceived organizational politics and the proliferation of detrimental workplace rumors (Mirzai & Zarei, 2024). At the individual level, brief workplace interventions focused on compassion have demonstrated significant efficacy in improving the overall well-being and psychological stability of stressed employees across various demanding professions (Healy et al., 2024). Furthermore, self-compassion—the ability to direct care and understanding inward during instances of failure or inadequacy—serves as a vital internal resource. Studies have mapped the complex network dynamics of self-compassion components, illustrating their direct impact on reducing psychological symptoms over time (Huang et al., 2023). In demanding clinical and healthcare roles, self-compassion, alongside broader self-care routines, acts as a cornerstone within the complex networks of resilience that protect professionals from burnout and acute stress (Pank et al., 2025). It enhances core work engagement by bolstering moral resilience, allowing employees to navigate complex ethical and professional challenges without losing their intrinsic drive (Liu et al., 2025). Even outside the immediate professional sphere, the moderating role of self-compassion is critical in mitigating the mediating effects of parenting burnout caused by work-family conflicts, thereby preserving the individual's cognitive and emotional bandwidth for workplace engagement (Liang, 2025). The profound psychological impact of compassion extends even to mitigating the effects of severe trauma, highlighting its foundational role in psychological recovery and stabilization (Willis et al., 2023). Thus, a workforce characterized by high self-compassion and supported by organizational compassion is inherently better equipped to sustain the passion and psychological ownership necessary for enduring the cyclical failures and ultimate triumphs of the innovation process.

Despite the rich, independent bodies of literature surrounding innovation processes, psychological ownership, and work passion, there remains a critical methodological and conceptual gap in understanding how these variables interact holistically. Traditional research in human resources and organizational psychology has predominantly relied on conventional, linear statistical techniques—such as ordinary least squares regression or structural equation modeling—to identify relationships between these constructs. While these methods are invaluable for establishing basic correlational and direct causal pathways, they frequently fall short of capturing the highly complex, non-linear, and potentially synergistic interactions that characterize real-world psychological phenomena. For example, the relationship between obsessive passion and innovation output may not be linear; it could follow an inverted U-shape where moderate obsession drives focus, but excessive obsession leads to cognitive rigidity and diminished creative capacity. Similarly, the dimensions of psychological ownership—such as self-efficacy, identity, and belongingness—likely interact with different types of work passion in multifaceted ways that simple linear equations cannot accurately model.

To address these profound methodological limitations, the current study introduces advanced machine learning algorithms into this domain of organizational psychology. Machine learning techniques, particularly ensemble methods like Random Forests and Gradient Boosting machines, are uniquely equipped to process large datasets,

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automatically detect complex, non-linear patterns, and handle intricate interaction effects without requiring the a priori specification of rigid theoretical models. By treating variables such as psychological ownership dimensions and passion types as computational features (X_i) to predict the continuous target variable of innovation process engagement (Y), these algorithms can map the exact threshold effects and variable importance hierarchies that govern employee behavior. This computational approach allows for a shift from mere explanation to robust, out-of-sample prediction, providing organizations with actionable, data-driven insights into the specific psychological profiles that most effectively drive innovation. Therefore, the present research seeks to utilize these advanced predictive analytics to untangle the complex psychological web of the modern innovator. The aim of this study is to apply supervised machine learning algorithms to evaluate the non-linear predictive power of psychological ownership and work passion on employee engagement in innovation processes.

2 Methods and Materials

This research employed a quantitative, cross-sectional design to investigate the complex interplay between psychological ownership, work passion, and innovation processes within the contemporary corporate context. The study specifically targeted the Moroccan organizational landscape, focusing on professionals actively engaged in research and development, product design, and creative problem-solving roles across various technology and manufacturing firms based in Morocco. A purposive sampling technique was utilized to ensure that the participants had relevant, hands-on experience in innovation-driven tasks and projects. The final sample consisted of precisely four hundred and fifty-two employees who voluntarily agreed to participate in the study after being fully informed of its academic purposes. Participants represented a diverse range of age groups, educational backgrounds, and organizational tenures, providing a robust and comprehensive cross-section of the Moroccan innovation sector.

Data were gathered utilizing a meticulously structured, self-administered questionnaire composed of established, scientifically validated measurement scales that were carefully adapted for the current research context. Psychological ownership was assessed using a multidimensional scale that captured the participants' feelings of possession, belongingness, and self-efficacy regarding their specific work outputs and the broader organization. Work passion was measured through a dualistic model scale, which effectively differentiates between harmonious passion, where individuals freely and joyfully engage in their work without it overwhelming their core identity, and obsessive passion, which reflects a compulsive, uncontrollable drive to work that may ultimately conflict with other vital life domains. The innovation process was evaluated using a comprehensive assessment tool that quantified an individual's direct involvement in the distinct, sequential stages of organizational innovation, ranging from the initial generation of novel ideas to the promotion and subsequent practical implementation of those concepts. All items within the survey instrument were anchored on a standard five-point Likert scale, enabling the granular quantification of the respondents' intrinsic attitudes and workplace behaviors. Prior to the main data collection phase, the questionnaire underwent rigorous translation procedures and a pilot test among a smaller subset of Moroccan professionals to ensure linguistic clarity, cultural relevance, and optimal construct validity.

The analytical framework of this study intentionally diverged from traditional linear statistics, instead relying heavily on advanced machine learning techniques to unravel the potentially non-linear relationships and the predictive power of psychological ownership and work passion on innovation processes. Initial data preprocessing protocols involved handling any missing values through k-nearest neighbors imputation and carefully standardizing the continuous variables to ensure uniform scale contribution across the chosen machine learning algorithms. To predict innovation process outcomes, several supervised machine learning models were systematically trained and evaluated, prominently including Random Forest regressors, Support Vector Machines, and Gradient Boosting algorithms. The collected dataset was strategically partitioned into a training set, comprising eighty percent of the data, and an independent testing set, containing the remaining twenty percent, to strictly facilitate unbiased model validation. Hyperparameter tuning was continuously conducted utilizing a sophisticated ten-fold cross-validation approach to optimize the internal structural parameters of each algorithm and successfully mitigate the risk of statistical overfitting. The ultimate predictive performance of the formulated models was rigorously evaluated using standard mathematical metrics such as the coefficient of determination, denoted in this study as R^2, and the Root

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Mean Square Error, formally represented as $RMSE$. Furthermore, a comprehensive feature importance analysis was executed, particularly leveraging the inherent capabilities of the tree-based models, to definitively rank the specific psychological dimensions that contributed most significantly to the variance in innovation process engagement.

3 Findings and Results

The primary objective of the data analysis was to evaluate the predictive capacity of psychological ownership and work passion on innovation processes among the sampled Moroccan professionals ($N = 452$). Prior to evaluating the machine learning models, preliminary data screening and descriptive analyses were conducted. The demographic profile of the participants, which is not tabulated to conserve space for predictive metrics, revealed a slightly male-dominated sample (58.4% male, 41.6%female). The average age of the respondents was $M = 34.2$years ($SD = 7.5$), with an average organizational tenure of $M = 6.8$years ($SD = 4.3$). Initial data preprocessing confirmed that there were no severe violations of normality, and the handling of missing data via k-nearest neighbors imputation affected less than 2.3%of the total dataset, ensuring the integrity of the subsequent analyses.

Table 1 presents the descriptive statistics, including the mean (M) and standard deviation (SD), along with the bivariate Pearson correlation coefficients (r) and Cronbach's alpha reliability estimates (α) for all core variables. The internal consistency for all measurement scales was robust, with αcoefficients ranging from 0.81to 0.92, well above the acceptable threshold of 0.70. The respondents reported relatively high levels of harmonious passion ($M = 4.12$, $SD = 0.68$) compared to obsessive passion ($M = 2.85$, $SD = 0.94$). Bivariate correlations indicated that overall psychological ownership was strongly and positively correlated with the aggregate innovation process score ($r = 0.64$, $p < .001$). Furthermore, harmonious passion demonstrated a strong positive association with innovation ($r = 0.58$, $p < .001$), whereas obsessive passion exhibited a weaker, albeit statistically significant, positive correlation ($r = 0.22$, $p < .01$).

Table 1

Descriptive Statistics, Scale Reliabilities, and Pearson Correlation Matrix

Variable	*M*	*SD*	1	2	3	4
1. Psychological Ownership	3.95	0.72	(0.88)			
2. Harmonious Passion	4.12	0.68	0.55**	(0.91)		
3. Obsessive Passion	2.85	0.94	0.18*	0.14*	(0.85)	
4. Innovation Process (Aggregate)	3.78	0.81	0.64**	0.58**	0.22**	(0.92)

Following the correlational analysis, the focus shifted to the machine learning predictive modeling. Three distinct supervised algorithms—Random Forest (RF), Support Vector Machine (SVM), and Gradient Boosting (GB)—were trained to predict the aggregate innovation process score based on the sub-dimensions of psychological ownership, the two distinct types of work passion, and demographic controls (age and organizational tenure). The models were evaluated on the 20%hold-out testing set. Table 2 summarizes the performance metrics of these models. The evaluation criteria included the coefficient of determination for both training (R^2_{train}) and testing (R^2_{test}) datasets, the Root Mean Square Error ($RMSE$), and the Mean Absolute Error (MAE).

The Gradient Boosting model emerged as the most robust and accurate predictive algorithm. While the Random Forest model showed signs of slight overfitting—evidenced by the discrepancy between its training variance explained ($R^2_{train} = 0.89$) and testing variance explained ($R^2_{test} = 0.68$)—the Gradient Boosting algorithm maintained strong generalization capabilities. The optimized Gradient Boosting model, utilizing hyperparameters tuned via ten-fold cross-validation (number of estimators = 250, learning rate = 0.05, maximum depth = 4), accounted for 74%of the variance in the innovation process on the unseen testing data ($R^2_{test} = 0.74$). It also yielded the lowest prediction errors ($RMSE = 0.41$, $MAE = 0.32$). The SVM algorithm, utilizing a radial basis function kernel, performed adequately but was outperformed by both tree-based ensemble methods.

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Table 2

Machine Learning Model Performance Metrics for Predicting Innovation Processes

Predictive Model	R^2_{train}	R^2_{test}	*RMSE*	*MAE*
Random Forest Regressor	0.89	0.68	0.46	0.36
Support Vector Machine (RBF)	0.67	0.62	0.51	0.40
Gradient Boosting Regressor	0.81	0.74	0.41	0.32

To unpack the "black box" of the superior Gradient Boosting model and understand the precise drivers of the innovation process among the Moroccan sample, a feature importance extraction was conducted. Table 3 delineates the relative importance scores of the predictor variables, normalized to sum to 100%. This analysis identifies which specific psychological factors most heavily influenced the model's predictive decisions.

The findings indicate that feelings of Self-Efficacy, a core dimension of psychological ownership, was the single most critical determinant, contributing 28.4%to the model's overall predictive power. This was closely followed by Harmonious Work Passion, which accounted for 24.1%of the variance. Notably, the partial dependence plots generated during the analysis (described here in-text) revealed a non-linear threshold effect for Obsessive Passion. While Obsessive Passion contributed 9.5%to the model, its effect on the innovation process was only marginally positive up to a moderate threshold ($M \approx 3.0$ on the scale), beyond which its predictive influence plateaued and slightly degraded, suggesting that excessive obsessive passion does not yield higher innovation output. Belongingness (16.2%) and Identity (14.8%), both dimensions of psychological ownership, also served as vital predictors. Demographic variables, specifically organizational tenure (4.2%) and age (2.8%), provided minimal predictive utility in the context of the machine learning model, indicating that intrinsic psychological states far outweigh demographic characteristics in driving innovation processes.

Table 3

Relative Feature Importance Rankings from the Gradient Boosting Model

Rank	Predictor Feature	Relative Importance (%)
1	Psychological Ownership: Self-Efficacy	28.4
2	Harmonious Work Passion	24.1
3	Psychological Ownership: Belongingness	16.2
4	Psychological Ownership: Identity	14.8
5	Obsessive Work Passion	9.5
6	Organizational Tenure	4.2
7	Age	2.8

4 Discussion

The primary objective of this study was to apply advanced supervised machine learning algorithms to evaluate the non-linear predictive power of psychological ownership and work passion on employee engagement in innovation processes. By shifting away from traditional linear statistical models, this research sought to capture the complex, multifaceted dynamics that govern how internal psychological states drive the inherently risky and uncertain journey of organizational innovation. The results yielded several critical insights into the hierarchy of these psychological drivers, demonstrating that machine learning, particularly the Gradient Boosting regressor, provides a highly accurate and nuanced predictive framework. The optimal Gradient Boosting model explained a substantial 74%of the variance in the innovation process on unseen data ($R^2 = 0.74$), with a minimal error rate ($RMSE = 0.41$). This robust predictive capability confirms that intrinsic psychological states far outweigh demographic characteristics—such as age and organizational tenure, which collectively contributed less than 7%to the model's predictive power—in determining an employee's capacity to innovate.

The feature importance analysis extracted from the Gradient Boosting model revealed that self-efficacy, a core

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dimension of psychological ownership, was the single most critical determinant of innovation process engagement, accounting for 28.4%of the model's predictive variance. Self-efficacy in this context reflects an employee's fundamental belief in their own capability to successfully execute the tasks required to generate and implement new ideas. This finding strongly aligns with recent literature emphasizing the role of specific self-efficacy domains in driving proactive workplace behaviors. For example, specialized forms of self-efficacy have been identified as vital interplay mechanisms that foster complex behaviors like workplace green behavior and environmental passion (Mughal et al., 2024). In the context of innovation, high self-efficacy reduces the perceived risk associated with proposing novel concepts, allowing employees to navigate the structural complexities of open innovation and knowledge management more effectively (Bloem & Salimi, 2022). When employees believe they possess the necessary skills to contribute meaningfully to the organization's strategic goals, they are more likely to exhibit the innovative behaviors that constitute a sustainable competitive advantage (Shaalan et al., 2022).

Following self-efficacy, harmonious work passion emerged as the second most influential predictor, contributing 24.1%to the overall variance. Harmonious passion reflects a state where individuals freely choose to engage in their work because they derive deep personal satisfaction and joy from it, without the work consuming their entire identity. This intrinsic, balanced drive is essential for sustaining the long-term effort required in iterative innovation processes. Previous studies corroborate this, demonstrating that harmonious work passion is a critical mechanism that channels positive organizational inputs—such as ethical leadership and trust—into enhanced employee work engagement (Islam et al., 2024). Furthermore, cultivating this type of passion is recognized as a vital intervention strategy to promote workplace resilience, particularly in high-stress and demanding professional settings (Unjai et al., 2024). In contrast to harmonious passion, the machine learning analysis revealed a fascinating non-linear threshold effect for obsessive work passion, which accounted for 9.5%of the model's importance. The partial dependence plots indicated that while moderate levels of obsessive passion can positively drive innovation focus, excessive obsessive passion plateaus and eventually degrades innovative output. This non-linear dynamic is difficult to capture with traditional regression but is highly consistent with broader psychological theories regarding burnout and cognitive rigidity. When work passion becomes an uncontrollable, obsessive urge, it generates stress and psychological symptoms that deplete the cognitive resources required for creative thinking (Huang et al., 2023). This aligns with the understanding that without the moderating effects of self-compassion and resilience networks, intense work pressures can lead to burnout and conflict, ultimately hindering performance (Liang, 2025; Pank et al., 2025).

The dimensions of psychological ownership related to belongingness (16.2%) and identity (14.8%) also served as vital predictors of the innovation process. Belongingness refers to the extent to which employees feel they are an integral part of the organizational community, while identity reflects the alignment between the employee's self-concept and the organization's mission. These factors are foundational to establishing a secure psychological base from which employees feel safe to experiment and share knowledge. Research indicates that robust working affiliation models are crucial for employee attachment and subsequent proactive behavior (Torabian et al., 2023). When employees feel a deep sense of organizational loyalty and attachment, mediated by their work personality, they are significantly more motivated to invest discretionary effort into the organization's success (Abdollahi & Bejani, 2024). This sense of belonging is particularly critical for fostering the grassroots knowledge-sharing processes that build broader social innovation capabilities within the firm (Fait et al., 2022).

The successful integration of these individual psychological drivers into the broader organizational innovation framework is what ultimately determines competitive success. Innovation is increasingly conceptualized as a collaborative, ecosystem-level phenomenon. Whether organizations are navigating the digital innovation management tools within entrepreneurial ecosystems (Endres et al., 2022), participating in the complex relational networks of digital innovation hubs (Serrano-Ruiz et al., 2024), or seeking to improve new product performance within technology parks (Haghparast et al., 2023), the human element remains the central catalyst. The psychological ownership and harmonious passion of the individual employee drive the competitive intelligence activities and knowledge management processes that fuel broader organizational innovation performance (Zuochun, 2023). This is true across diverse sectors, from the open innovation strategies of the home appliance industry (Saeedi motlagh & Karimishad, 2022) and non-profit organizations

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(Oliveira et al., 2021), to educational entrepreneurship (Paños-Castro & Arruti, 2021) and customer relationship-driven e-business (Khodaei, 2022). Furthermore, team processes and customer engagement strategies, while structurally important, rely entirely on the motivated participation of psychologically invested employees to generate creative service ideas and sustain learning organizations (Shin & Perdue, 2022; Witherspoon, 2021).

To sustain this high level of psychological investment and prevent the detrimental effects of obsessive passion, organizations must actively cultivate environments of compassion and support. Organizational compassion mitigates negative workplace perceptions and rumors, creating a safer space for the vulnerability required in innovation (Mirzai & Zarei, 2024). Brief workplace compassion training has been shown to effectively improve the well-being of stressed employees (Healy et al., 2024). Moreover, fostering self-compassion among employees enhances their moral resilience, allowing them to remain engaged and passionate even when facing the inevitable setbacks that characterize the innovation journey (Liu et al., 2025). In extreme cases, compassion interventions are foundational for processing trauma and restoring the psychological baseline necessary for productive engagement (Willis et al., 2023). Therefore, the digital and structural advancement of innovation processes must be inextricably linked with the human resources strategies that support and protect the psychological well-being of the workforce (Gundorova et al., 2022).

5 Conclusion

In conclusion, this study successfully demonstrates the profound utility of applying advanced supervised machine learning algorithms to unravel the complex, non-linear psychological drivers underpinning employee engagement in organizational innovation processes. By moving beyond the inherent constraints of traditional linear statistical models, the research reveals that an employee's capacity to innovate is not a simplistic function of demographic characteristics or organizational tenure, which collectively accounted for less than 7%of the model's predictive variance. Instead, successful innovation is deeply rooted in specific intrinsic psychological states, with the optimal Gradient Boosting regressor explaining an impressive 74%of the variance in innovative behavior. The findings unequivocally identify self-efficacy and harmonious work passion as the paramount catalysts for the innovation journey, emphasizing that employees must fundamentally believe in their own creative capabilities and derive a balanced, intrinsic joy from their tasks to effectively navigate the inherent risks of ideation and implementation. Furthermore, the algorithmic detection of a non-linear threshold effect for obsessive passion provides a critical, data-driven cautionary insight for modern management; while a moderate degree of intense focus can initially propel novel ideas forward, an unchecked, obsessive drive ultimately depletes cognitive resources, induces burnout, and degrades long-term innovative output. Consequently, the core dimensions of psychological ownership—specifically the cultivation of deep belongingness and a cohesive organizational identity—must be strategically managed to foster a psychologically secure environment where harmonious passion can organically thrive. Ultimately, to sustain a resilient competitive advantage in today's rapidly evolving economic landscape, organizational leaders must pivot toward holistic, human-centric human resource strategies. By actively nurturing employee self-efficacy, enforcing healthy work-life boundaries to prevent obsessive tendencies, and prioritizing overall psychological well-being, organizations can sustainably unlock the discretionary effort required to fuel continuous, high-impact innovation.

Despite the robust predictive capabilities demonstrated by the machine learning models utilized in this study, several important methodological limitations must be acknowledged. First, the cross-sectional nature of the study design inherently limits the ability to establish strict temporal precedence or definitive causal relationships between the psychological constructs and the innovation process. While the predictive models achieved high accuracy, longitudinal data would be required to track how fluctuations in psychological ownership and work passion over time causally impact the trajectory of innovation outputs. Second, the reliance on self-reported questionnaire data introduces the potential for common method bias and social desirability effects, as employees may consciously or subconsciously inflate their perceived levels of harmonious passion or innovation engagement. Third, the sample was drawn exclusively from Moroccan technology and manufacturing firms. While this provides valuable localized insights, it restricts the generalizability of the findings to other cultural contexts or different industrial sectors where the manifestations of psychological ownership and the structural requirements of innovation might differ significantly. Finally, while the algorithms handled non-

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linearities efficiently, machine learning models often operate as "black boxes," and despite the use of feature importance extraction, the deep qualitative nuances of the employees' lived experiences during the innovation process remain uncaptured by purely quantitative metrics.

To build upon the findings and address the limitations of the current study, future research should adopt mixed-methods and longitudinal designs. Tracking cohorts of employees over an extended period, perhaps utilizing experience sampling methods, would provide a more granular understanding of how daily or weekly shifts in self-efficacy and harmonious passion directly influence specific stages of the innovation process, from ideation to implementation. Additionally, future studies should expand the geographical and industrial scope of the sampling frame to conduct cross-cultural comparative analyses. Investigating how different cultural dimensions—such as collectivism versus individualism—interact with psychological ownership to predict innovation could yield highly valuable global management insights. From a computational perspective, future research could explore the integration of natural language processing to analyze qualitative employee feedback, emails, or collaborative platform data to indirectly measure passion and belongingness, thereby reducing reliance on self-report surveys. Finally, experimental research designs that implement specific organizational interventions aimed at boosting self-efficacy or shifting obsessive passion toward harmonious passion, and subsequently measuring the pre- and post-intervention changes in actual innovation output, would provide definitive evidence of causality and practical efficacy.

The findings of this study offer highly actionable suggestions for organizational leaders and human resource practitioners aiming to optimize their innovation ecosystems. Since self-efficacy emerged as the primary driver of the innovation process, management must prioritize practices that actively build employee confidence. This can be achieved through targeted skill-development programs, providing structured autonomy, and implementing recognition systems that celebrate intelligent failures as vital learning steps rather than penalizing them, thereby reducing the perceived risk of innovation. Furthermore, to cultivate the highly predictive harmonious passion while mitigating the diminishing returns of obsessive passion, organizations should enforce healthy work-life boundaries and actively discourage chronic overworking. Leaders should promote a culture of psychological safety and organizational compassion, ensuring that employees feel a strong sense of identity and belongingness without their work entirely consuming their personal lives. By shifting human resource strategies away from merely measuring output and toward holistically managing the complex, non-linear psychological states of their workforce, organizations can sustainably unlock the deep, intrinsic drivers of continuous innovation.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were observed.

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