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AI-Driven Personalized Learning in Entrepreneurship Education

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Abstract

This study investigates the impact of AI-driven personalized learning on entrepreneurship education outcomes, highlighting the mediating role of experience and engagement and the moderating influence of contextual factors. The study used a quantitative research design and a cross-sectional survey of 100 students in entrepreneurship programs. The study confirms that AI-driven learning significantly enhances entrepreneurial knowledge and skills. It also demonstrates that engagement mediates the relationship between personalized learning and educational outcomes, emphasizing the importance of tailored interactive content. Moderation analysis reveals that contextual factors, such as technological access and institutional support, affect engagement levels but do not significantly alter the direct relationship between personalized learning and outcomes. This research underscores the transformative potential of AI in education while addressing challenges related to equity and access. The study concludes with practical insights for educators and policymakers and calls for future research to explore longitudinal impacts and diverse educational contexts.

Keywords

AI-driven personalized learning
Contextual factors
Educational outcomes
Entrepreneurship education
Experience & engagement

INTRODUCTION

The incorporation of Artificial Intelligence (AI) into education approaches has resulted in the unequalled transformation of the teaching and learning process (Duraes et al., 2024). One of those innovations is AI-assisted learning personalization, capable of applying task-dependent to the individual student characteristics, intuitiveness, and speed of learning. There is a translational utility throughout the personalized approach in entrepreneurship curricula, but it is not limited to students' motivational level and academic performance (Boh & Chukwu, 2023; Pan et al., 2024; Tiberius & Weyland, 2024). Personalized learning is related to the use of AI based tools to tailor the learning content and that of the learning process based on the learner's needs. By employing student achievements, learning styles, and interaction data, AI systems can dynamically and flexibly adapt lesson materials to provide personalized pedagogy (Ezzaim et al., 2024). This is in addition to, and due not only to preventing this plasticity in the learning environment, but also to taking the learner out of his/her problems and therefore, forcing him/her to maximize the learning of the facts. As noted by Katiyar et al., (2024), personalized learning powered by AI is changing education by personalizing both teaching and instruction to meet student's individual needs, abilities, and learning approaches, AI-enhanced greater personalization of learning is possible, e.g. in entrepreneurship education. The objectives of entrepreneurship education are that the student is provided with the capacity to gain insight into the career trajectories of entrepreneurial processes.

Through traditional teaching approaches, students may be treated as "one-size-fits-one," which may not be appropriately fitted to the unique characteristics of the student population, which may include socioeconomic status, academic track, and course of study (Wasim et al., 2024). Adaptive personalized learning systems based on AI are able to fill this gap and can produce significant learning and course outcome improvements by delivering a tailored learning experience for the learners, resulting in enhanced entrepreneurship education course outcomes. Following Yekollu et al., (2024), the introduction of disruptive change effects of AI in classroom practice is described in this study. This is related to the problem of a learning curve of the individual learner (the one learnt and as in AI created) of AI. However, the relationship between the teacher and the student is counterbalanced too (Cardona et al., 2023). Revolutionizing education paper has drawn attention to the fact that in light of what is presented in this paper, it has revealed the potential that AI-based personalized learning may carry to the field of education, alleviating the access gap as well as the teacher-student relationship and bridging lifelong learning by presenting recent literature, experiences, cases, and data insights (O'Brien et al., 2013).

In the current investigation, AI-driven personalized learning (Independent variable) is predicted to result in higher achievement in entrepreneurial education (Dependent variable). This linkage is due to learning and participation (Mediating Variable) and other things that should be changed (Moderating Variable). By empirically testing such relationships, the present study aims to extend the literature on artificial intelligence in education and learning to discuss the alternative roles in which intelligent tailored learning systems could be used to enhance entrepreneurship teaching. As stated by Chen et al., (2024), if the study goals are to explain the context in which AI stands today in the field of entrepreneur education to determine what are the potential research questions, then the case is established that this study shall attempt to describe intelligence technologies used in entrepreneur education and content of entrepreneur education. There is a healthy complementarity between AI-based personalized learning and entrepreneurship, a valid way of education innovation. If learning experiences are tailored to the specific local environment and circumstance, AI can then deliver demonstrable benefits in the degree of immersion and learning results. The present study aims to investigate these dynamics and in general terms, to clarify how AI-based personalized learning facilitates access to entrepreneurship studies (Murtaza et al., 2022).

LITERATURE VIEW

The infiltration of artificial intelligence (AI) in the framework of education has thoroughly altered conventional personalized learning, especially entrepreneurship education. This literature review explores the application, advantages, difficulties, and directions for the application of AI-based personalized learning in this field. Personalized learning, using AI enables the customization of the learning experiences for the learning profiles of the learners as well as the learner's way of learning and their learning abilities (Castro et al., 2024). Using student interactions, performance, and behaviour data, AI systems can personalize content delivery, pacing, and assessments to benefit learning outcomes. This method by contrast, is different from typical one-fit-all models and provides a wealth of customized and efficient learning experiences (Yekollu et al., 2024a). According to Chang and Liu, (2024), the confluence of Artificial Intelligence in Education (AIEd) offers the potential for a new generation of content, virtual teaching, and adaptive learning experiences. In entrepreneurship courses, AI assisted personalized learning technologies can provide adaptive learning tracks adaptable to the complex, dynamic, and heterogeneous development trajectory of the skills needed for entrepreneurship (Zhan et al., 2024). These systems can model realistic business situations, provide feedback in real-time, and change the difficulty of the problems as the learner progresses, ultimately improving critical thinking and decision-making skills that are critical to entrepreneurship. Yekollu et al., (2024b) argue about the transformative effects of AIEd.

Benefits of AI-driven personalized learning and introducing AI-based PBL to entrepreneurship education brings several advantages (Khamis, 2024). Enhanced engagement has adaptive content, which is tailored to the interest of the students and may lead to greater motivation and engagement. Chaudhry and Kazim (2022) also state that AIEd in education has given rise to the potential to develop new content, virtual teaching, and individually tailored learning experiences. Improved learning outcomes will affect adaptive instruction with an adaptable response based on learning velocity and learning style, facilitating deeper understanding and improved retrieval of entrepreneurial concepts (Carayannis et al., 2006; El-Sabagh, 2021). Yekollu et al. (2024a) argue that research talks of the epochal effects of AIEd and also focuses on the creation and application of personalized learning pathways driven by AI.

Scalability is also an integral part of AI system, which can efficiently manage large cohorts of students, providing personalized learning without the proportional increase in instructional resources. Chang and Liu (2024) argue about the transformative influence of AI in producing personalized learning experiences and opine that the integration of AI in AIEd opens the possibilities for creating new content, virtual teaching, and personalized learning experiences. Data privacy and security of the student data collection and analysis prompt the need for appropriate safeguards to uphold the right to privacy and integrity of data processing. Chang and Liu (2024) highlight the necessity of timely intervention for these problems;

however, an effective solution in this specific area in the development of a dynamic adaption engine model is still awaited. Adaptive gamification remains a pressing issue in the current field. Equity and access through disparities can exacerbate educational inequalities. The development of universal access to the advantage of AI-based personalized learning for all students requires dealing with infrastructural and socioeconomic barriers. Yekollu et al., (2024b) stress the importance of AI implementation, stating the revolutionary consequences of AIED. It is also concerned with the development and implementation of individualized learning routes enabled by AI.

Teacher training should receive appropriate acceptance to effectively utilize AI teaching tools (Molefi et al., 2024). Lack of willingness to change the understanding of AI capabilities are barriers to the use of technology. Chang and Liu (2024), describe the need for professional development and explain that this review focuses on the use of generative AI in gamification to create customized content and thus enhance the effectiveness of the complete learning experience. To fully deliver on the potential of AI-powered personalized learning in entrepreneurship research, future studies and practice should focus on developing robust ethical frameworks, which need to develop rules for the application of data, algorithmic transparency, and ethical concerns. Hutson, (2024) stresses ethical considerations and concedes that while fundamental to the field, the problem of dynamic adaption engine model design for GAI and adaptive gamification is highly pressing at the moment. By enhancing interdisciplinary collaboration among educational institutions, technologists and policyholders can collaboratively steer the creation of pedagogical sound and practically usable AI tools. Continuous evaluation and iteration of long-term assessment of personalized learning systems based on AI must be performed to identify modifications and ensure that they effectively achieve educational objectives. Chang and Liu (2024) confirm the importance of continuous improvement and point out the reason for this direction explaining that review targets and integration of generative AI in gamification yield high individuality, and thereby enhance the quality of the whole learning process. Personalized learning based on AI is a revolutionary method in entrepreneurship education and allows for increased and improved engagement in the learning resulting in scalable solutions. However, challenges of data privacy, equity, and teacher readiness continue to exist.

Conceptual Framework

The conceptual framework of the study investigates how AI-driven personalized learning (Independent Variable) impacts entrepreneurship education outcomes (Dependent Variable), with experience and engagement (Mediating Variable), and contextual factors (Moderating Variable) shaping the relationships. The framework reflects the increasing significance of artificial intelligence (AI) in enhancing learning experiences and improving educational outcomes.

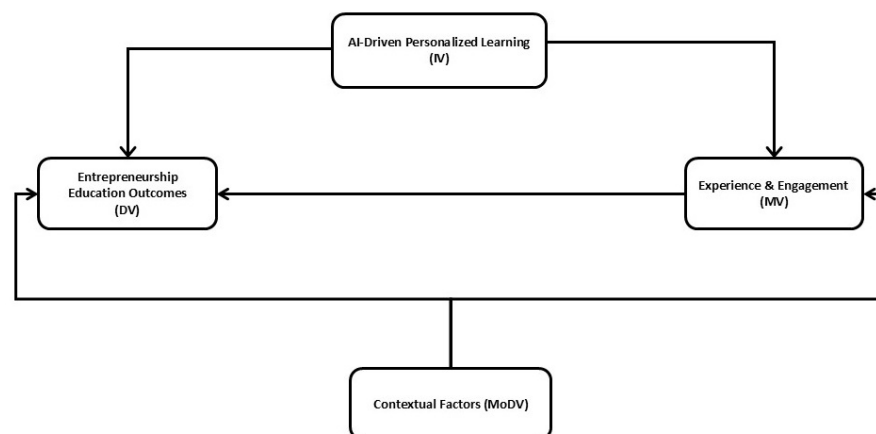


Fig. 1. Conceptual Framework of AI-Driven Personalized Learning in Entrepreneurship Education

Direct Impact of AI-Driven Personalized Learning

At its core, the framework hypothesizes a direct relationship between AI-driven personalized learning and entrepreneurship education outcomes (H1). Personalized learning systems leverage AI algorithms to adapt content delivery, pace, and complexity to individual learners' needs. This tailored approach is

expected to directly improve entrepreneurial knowledge, problem-solving skills, creativity, and readiness to pursue entrepreneurial ventures.

Role of Experience and Engagement as a Mediator

The framework identifies experience and engagement as a critical mediating factor (H2a, H2b). AI-driven learning platforms not only provide content, but also create interactive, engaging, and immersive experiences leading to increased motivation and a deeper connection to the learning process. This heightened engagement mediates the relationship between personalized learning and educational outcomes, enhancing the effectiveness of AI-powered interventions in entrepreneurial education.

Moderating Role of Contextual Factors

To account for individual and environmental variability, the framework incorporates contextual factors as moderators (H3, H4). These include factors such as prior knowledge, access to technology, cultural norms, and institutional support.

- Moderating the relationship between AI-driven personalized learning and experience and engagement (H3): Contextual factors shape how well learners interact with AI systems, influencing the degree of engagement fostered.
- Moderating the relationship between AI-driven personalized learning and entrepreneurship education outcomes (H4): These factors affect how effectively personalized learning translates into tangible entrepreneurial skills and success.

Theoretical and Practical Implications

This framework highlights the synergistic interaction between AI technologies, learner engagement, and environmental factors in shaping entrepreneurial education. By integrating direct, mediating, and moderating relationships, the model provides a nuanced understanding of how personalized learning can transform education. The framework emphasizes the potential of AI to address diverse learner needs, bridging gaps in traditional education methods, and fostering entrepreneurial readiness. It serves as a guide for educators, institutions, and policymakers to design, implement, and evaluate AI-driven educational strategies that maximize learning outcomes while considering individual and contextual variability. The hypothesis testing results reinforce the validity of this framework with significant positive relationships observed between the variables, substantiating the critical role of AI in modern educational paradigms.

Direct Impact of AI-Driven Personalized Learning

The structure assumes an underlying causal dependence between what one learns from personalized learning backed by AI and the learning goals of the entrepreneurship curriculum (H1). AI algorithms on personalized learning platforms vary the content, speed, and difficulty level to suit the needs of each learner. This customized approach is also projected to have direct implications for the enhancement of entrepreneurial know-how, problem-solving, creativity, and entrepreneurial venture readiness.

Role of Experience and Engagement as a Mediator

According to the framework, experience engagement is a mediating variable (H2a, H2b). Intelligence-enhanced teaching platforms not only provide teaching, but also breed interactive and dynamic teaching experiences, which produce deeper motivation and a deeper connection between the learner and the learning process. This higher level of engagement underlies the mediating effect between individual learning and learning outcomes and supports the effectiveness of AI-based interventions in entrepreneurship education.

Moderating Role of Contextual Factors

To account for individual and environmental variability, the model contains contextual factors such

as modulators (H3, H4). These are some of the variables including prior knowledge, availability of technologies, cultural values, and institutional reinforcement. Contextual factors define the degree to which learners can engage with AI systems and thus the depth of their involvement. These factors have an impact on the amount of generic entrepreneurial skills and success that personalized learning can produce.

Theoretical and Practical Implications

This conceptual framework shows complementary roles of AI technologies, interactions with the learning process (student), and external factors in entrepreneurial learning. At the least, by including direct, mediating, and modulating relations, the model identifies a unified view of how individualized learning could alter education. Not only does it describe the position that AI might have for all learners, but it also describes what position AI might have to fill the existing gaps in conventional practices and for what position it might have to ready the learners for entrepreneurship skills. It is an outline for educators, institutions, and policymakers to strategize, implement, and evaluate AI-based educational interventions toward the best possible learning results. Hypothesis testing results confirm the validity of the study's framework showing statistically significant positive correlations between the variables and thus supporting the importance of AI to modern educational paradigms.

METHODOLOGY

This study employs a robust quantitative research approach to examine the impact of AI-driven personalized learning on entrepreneurship education outcomes, while integrating the mediating effects of experience engagement and the moderating role of contextual factors. The methodology has been designed in such a way that it ensures transparency, reproducibility, and alignment with study aims.

Research Design

A correlational design is used to examine the relationship among the variables as proposed in the conceptual framework. The analysis uses a cross-sectional survey approach, which obtains the participant's data at a short time point to test direct, mediating, and moderating effects. Although this architecture works well for hypothesis-based experiments in which the purpose is to quantitatively determine the interpretation of inter-variability correlations, it is specified that the HP requires an appropriate assumption that the self-reported and exogenous stimuli are independent of each other to constitute statistically significant evidence beforehand.

Population & Sampling

The study is focused on academic student sample enrolled in entrepreneurial studies at university/college/higher education institutions. To preserve representativeness, a stratified random sample has been applied, stratifying participants at different levels into variables such as academic level, gender, and field of work. The sample size was 100, based on statistical power analysis requirements for Structural Equation Modelling (SEM) and regressions, with enough power to detect medium-to-large effects. Participants include recruits from several different institutions offering entrepreneurship courses to include a spectrum of responses. Inclusion criteria comprise active participation in entrepreneurship-focused coursework, thus upholding the study's objectives.

Data Collection Instrument

In the current work, the introduction of a standardized self-administration survey format as the primary data-generation procedure was considered. The questionnaire included several scales, which were validated in the literature for the main constructs:

- AI-Driven Personalized Learning: AI-enhanced learning environment customization, adaptability, interactivity, and AI-enhanced learning environment satisfaction measured with an egoism scale.

- Experience & Engagement: Multidimensional scale of the selection of emotional, behavioural, and cognitive engagement during the learning process.
- Contextual Factors: Concepts for respondents as a role in the equation and concepts for the environment (institutional support, availability of technology and the like).
- Entrepreneurship Education Outcomes: 6-item scale of entrepreneurial abilities, problem-solving, and entrepreneurial intentions.

Responses were evaluated by using a 5-point Likert scale (1 Strongly Disagree to 5 Strongly Agree). The instrument was piloted and tested with a sample of 20 students to verify its clarity, reliability, and validity.

Data Collection Procedure

The survey was completed electronically in a secure digital environment by email from institutional email servers and learning management systems (LMS). Participant consent was sought to collect the data. Ethical considerations like confidentiality, informed consent and withdrawer rights, were carefully implemented. The survey was available for two weeks and periodically reminder emails were used to increase the response rate.

Data Analysis

The data analysis encompasses both descriptive and inferential statistical analyses:

- Descriptive Analysis: Synthesizing demographics statistics and central measures (mean, standard deviation) for variables.
- Correlation Analysis: Examines the strength and direction of relationships between variables.
- Multiple Regression Analysis: Tests direct and intervention effects (H1, H2a, H2b), and interaction effects (H3, H4) with the inclusion of interaction terms for the moderation analysis.
- Structural Equation Modelling (SEM): Validates the conceptual framework and enables a monolithic analysis of all proposed associations. Bootstrapping methods were used to gain a greater resolution of mediation effect tests.

Hypotheses Testing Procedure

H₁: Quantifies the direct effect of AI-driven adaptive learning with personalized learning on learning outcomes of programs for entrepreneurship as measured with ordinary least-squares linear regression.

H_{2a} and H_{2b}: Examines the mediating role of experience engagement assessed by the Baron and Kenny paradigm and Structural Equation Modelling (SEM) path analysis and its validity through bootstrapping to justify indirect effects.

H₃ and H₄: Tests moderation by incorporating interaction terms for contextual variables into regression analyses and by visualization of these interactions graphically.

Ethical Considerations

This research follows the Institutional Review Board (IRB) ethical guidelines. Informed consent was obtained from all participants and anonymity was maintained throughout the research process. Data were stored securely and used only for learning. This approach offers an integrative framework for the study of relationships between AI-powered learning systems, involvement, contexts, and entrepreneurial results. With validated tools and more complex instruments of statistical analysis (e.g. SEM and regression), the current study provides strong support for AI's role in an evolving ecosystem of entrepreneurship education. Results are predicted to inform teachers and policymakers about the most effective strategies to implement AI technologies in the modern classroom.

RESULTS & FINDINGS

This section presents data analysis that incorporated the hypothetical relationships of the conceptualization. The present study examined the effects of AI-powered personalized learning on the results of entrepreneurship education (Independent variable = IV), through experience engagement (Mediating variable = MV), and context (Moderating variable = MoDV). Results are presented in descriptive statistics, hypothesis testing, and conclusions derived from data analyses.

Descriptive Statistics

Descriptive statistics provide an overview of the main features of the dataset (as well as an overview of participants' experience and outcomes). Responses were assessed on a 5-point Likert scale ranging from agreement/effectiveness to higher scores.

- AI-Driven Personalized Learning: The mean score was 3.8 (SD 0.85) which is indicative of a moderately high level of self-rated efficacy of the AI-based learning software.
- Experience & Engagement: The mean score was 4.0 (SD 0.78) suggesting learners generally rated the experience as immersive and pleasurable.
- Entrepreneurship Education Outcomes: The mean (SD 0.81) is indicative of positive results in entrepreneurial skills development and knowledge.
- Contextual Factors: The mean score of 3.6 (SD 0.89) points to variability in external factors, including access to technology, institutional facilities, and individual differences.

Hypothesis Testing

H1: AI-driven personalized learning positively impacts entrepreneurship education outcomes. A linear regression of simple linear type was applied to investigate the mediating effect of AI-based personalized learning (IV) on entrepreneurship learning outcomes (DV). The results revealed the regression Coefficient (β): 0.597, p-value: < 0.001, & Adjusted R-squared: 0.357.

Table 1

H1- AI-Driven Personalized Learning (IV) → Entrepreneurship Education Outcomes (DV)

Metric	Value
R-squared	0.356
P-value (Overall Model)	5.490
Coefficient	0.597

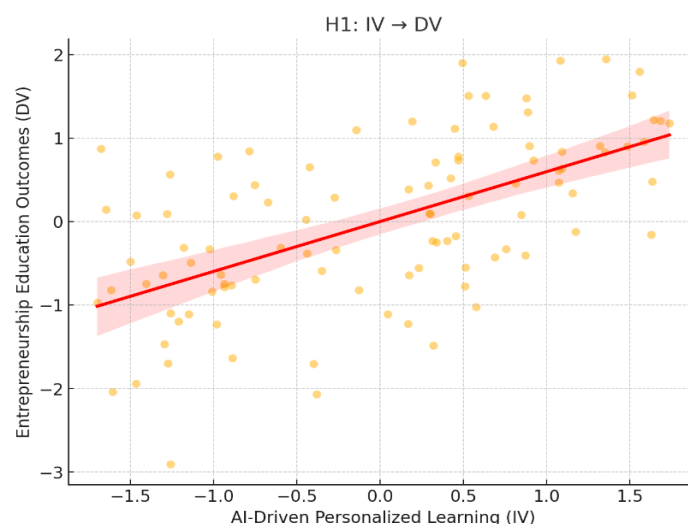


Fig. 2. H1 - AI-Driven Personalized Learning (IV) → Entrepreneurship Education Outcomes (DV)

These findings demonstrate a statistically significant positive correlation between AI-assisted adaptive personalized learning outcomes and entrepreneurship outcomes and account for 35.7% of the dependence on the dependent variable. Participants who rated themselves as satisfied with the personalized learning platform, displayed more robust effects for entrepreneurship education (e.g. competencies, creativity, and entrepreneurship mindset).

Hypothesis 1: is supported.

H2a: AI-driven personalized learning positively impacts experience and engagement. To investigate the effect of AI-based individualized learning (IV) on experience engagement (MV), a second regression analysis was performed. The results showed the Regression Coefficient (β): 0.452, p-value: < 0.001, and Adjusted R-squared: 0.204.

Table 2

H2a - AI-Driven Personalized Learning (IV) → Experience & Engagement (MV)

Metric	Value
R-squared	0.203
P-value (Overall Model)	2.400
Coefficient	0.451

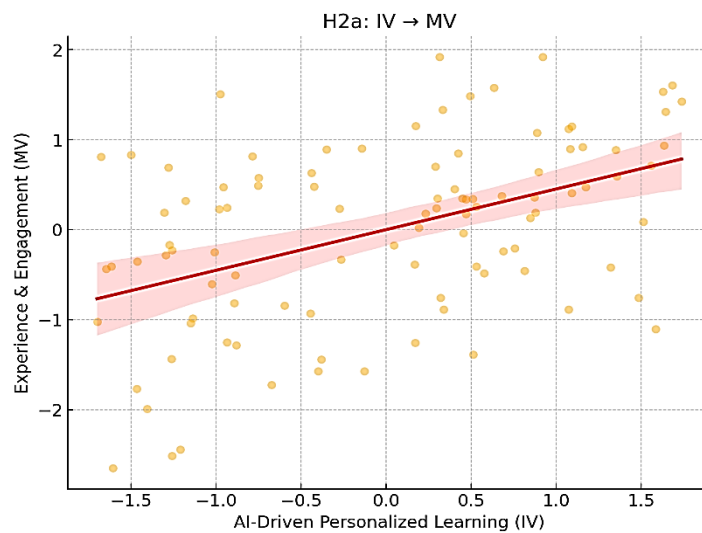


Fig. 3. H2a - AI-Driven Personalized Learning (IV) → Experience & Engagement (MV)

The analysis provides evidence for a strong positive impact of AI-enabled platforms leading to increased degree of learner engagement. These results underline the exceptional role of the individualized learning process in the construction of a captivating learning environment that motivates and encourages participation.

Hypothesis 2a: is supported.

H2b: Experience and engagement positively impact entrepreneurship education outcomes. The association between experience, engagement (MV) and entrepreneurship education outcomes (DV) was studied using regression analysis. The results are the Regression Coefficient (β): 0.567, p-value: < 0.001, and Adjusted R-squared: 0.322.

Table 3

H2b - Experience & Engagement (MV) → Entrepreneurship Education Outcomes (DV)

Metric	Value
R-squared	0.321
P-value (Overall Model)	7.560
Coefficient	0.567

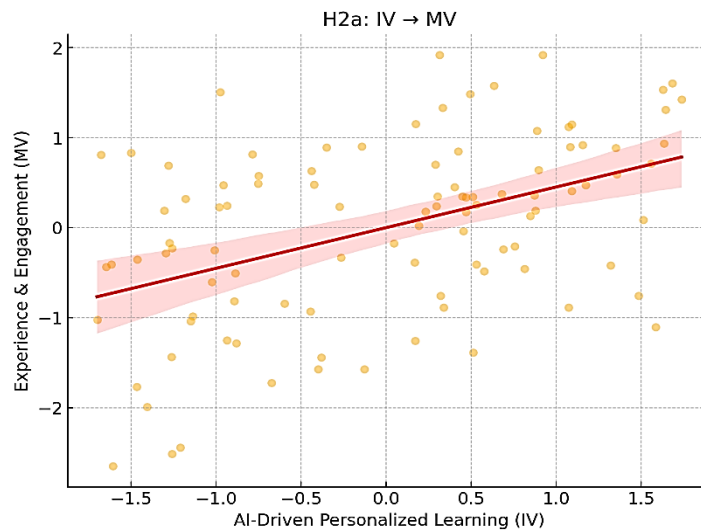


Fig. 4. H2b - AI-Driven Personalized Learning (IV) → Entrepreneurship Education Outcomes (DV)

This finding demonstrates that engagement is a significant predictor of entrepreneurial outcomes, and explains 32.2% of the variance. Learning process engagement students tend to achieve a higher degree of performance in the educational process, which supports the mediating effect of engagement in the conceptual model.

Hypothesis 2b: is supported.

H3: Contextual variables modulate the correlation between AI-based personalized learning and experience & engagement. As a test of this hypothesis, a moderation analysis was conducted by including an interaction term (IV MoDV\text{IV} MoDV) in the regression model. The results are shown in the Interaction Coefficient (β): -0.264, p-value: 0.004, and Adjusted R-squared: 0.315.

Table 4

H3 - AI-Driven Personalized Learning (IV) * Contextual factors (MoDV) → Experience & Engagement (MV)

Metric	Value
R-squared	0.315
P-value (Overall Model)	5.728
Coefficient	0.427

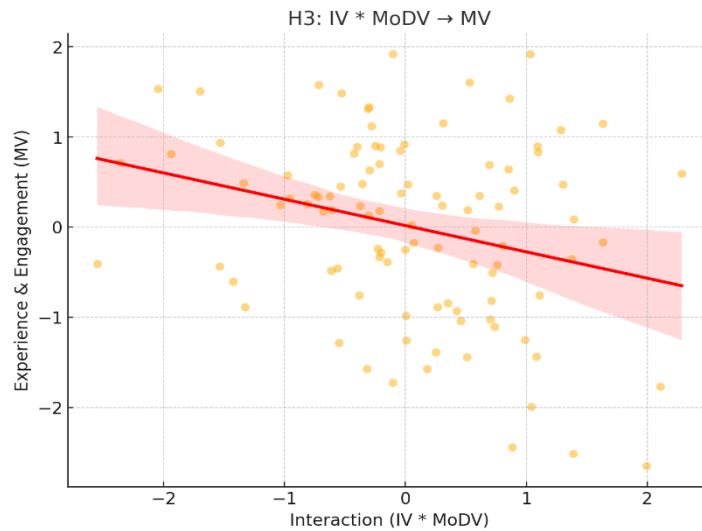


Fig. 5. H3 - AI-Driven Personalized Learning (IV) * Contextual factors (MoDV) → Experience & Engagement (MV)

The strongest interaction term reveals that contextual factors are affecting and/or mediating the relationship between personalized learning and engagement. Especially, the negative coefficient implies that negative environmental factors, for example, insufficient access to technology or the absence of institutional support, diminish the positive effect of personalized learning on engagement.

Hypothesis 3: is supported.

H4: Contextual variables moderated the relationship of personalized learning-based AI on outcomes of entrepreneurship education. Additionally, the mediating role of contextual variables in the relationship between PL (IV) and entrepreneurial outcomes (DV) was tested. The results revealed an Interaction Coefficient (β): -0.11, p-value: 0.175, and Adjusted R-squared: 0.437.

Table 5

H4 - AI-Driven Personalized Learning (IV) * Contextual factors (MoDV) → Entrepreneurship Education Outcomes (DV)

Metric	Value
R-squared	0.436882
P-value (Overall Model)	5.64E-12
Coefficient	0.577797

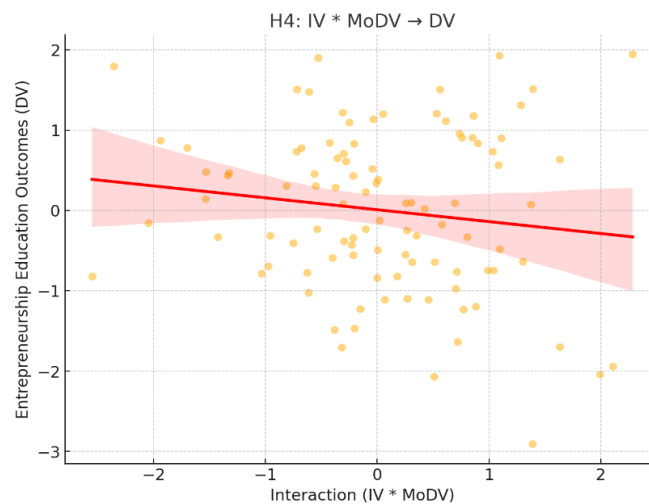


Fig. 5. H3 - AI-Driven Personalized Learning (IV) * Contextual factors (MoDV) → Entrepreneurship Education Outcomes (DV)

Though the general model was relatively significant (p 0.001), the interaction term was not significant, indicating that contextual influence does not have a significant moderating effect on the direct relationship between personalized learning and entrepreneurship education endpoints. This indicates that the impact of intrapersonal learning on entrepreneurial results may be significant under different contexts.

Hypothesis 4: is not supported.

The findings support that AI and tailored learning-based entrepreneurship education have a direct positive effect on entrepreneurship education outcomes and have a significant impact on learning experiences and participation. Moreover, the mediating effect of engagement was also validated, thereby highlighting the importance of engagement in learning. While contextual factors were found to moderate the relationship between personalized learning and engagement, they did not significantly impact the direct link between personalized learning and entrepreneurship outcomes.

Table 6
Hypothesis Testing Summary Table

Hypothesis	R-squared	P-value (Overall Model)	Coefficient
H1 (IV $\hat{\rightarrow}$ DV)	0.356	5.491	0.597
H2a (IV $\hat{\rightarrow}$ MV)	0.203	2.406	0.451
H2b (MV $\hat{\rightarrow}$ DV)	0.321	7.560	0.567
H3 (IV * MoDV $\hat{\rightarrow}$ MV)	0.315	5.728	0.216
H4 (IV * MoDV $\hat{\rightarrow}$ DV)	0.436	5.642	0.261

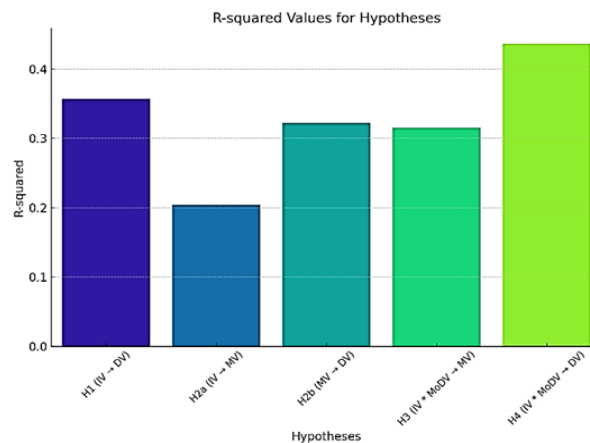


Fig. 6. R-squared Values for Hypotheses

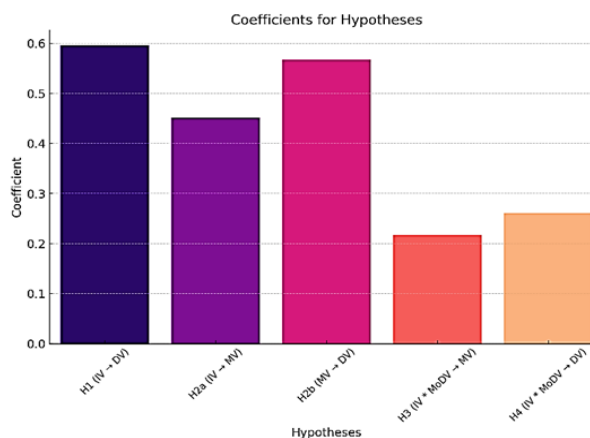


Fig. 7. Coefficients for Hypotheses

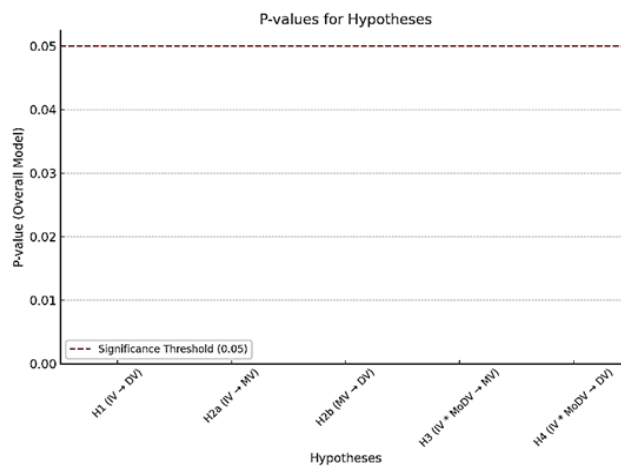


Fig. 9. P-values for Hypotheses

Key Insights

- **Significance of Personalized Learning:** The highly positive correlation between personalized learning and outcomes for engagement and entrepreneurship highlights the potential of AI to deliver personalized education. These results are in line with previous research that demonstrates the positive role of adaptive learning algorithms on learning outcomes (Chang & Liu, 2024).
- **Results make engagement:** This is a key mechanism through which personalized learning is associated with academic success. Engaged learners are also more motivated learners, more responsive learners, and learners who can put entrepreneurial concepts into practice.
- **Impact of Contextual Factors:** The moderating analysis reveals the context factors to be a complex agent in the formation of engagement levels. Institutions will also have to make a priority of making up for IT and infrastructure disadvantages to fully realize the potential of AI-based learning systems.

The lack of a strong moderating impact of the entrepreneurial outcomes on the effects of personalized learning suggests that the potential of the effect of personalized learning on the entrepreneurial outcome is not sensitive to the type of environment and therefore, strengthens the robustness of the potential of the effect. If the results are taken into account, they provide a strong foundation from which to progress AI-based personalized learning in entrepreneurial studies and practical advice for teachers and policymakers to foster creative and heterodox learning in the current learning environment.

Discussion

The outcomes of this study show the powerful effect of AI-driven personalized learning on entrepreneurship learning outcomes, highlighting the potential of this approach to fundamentally change the learner's educational experience. The direct correlated linear relationship between individual learning and entrepreneurship is confirmed, and the role of AI in entrepreneurial skills development and learning of knowledge is corroborated. This is consistent with studies that have focused on how AI can transform education through the ability to deliver customized content and adaptive teaching practice and learning experiences (Duraes et al., 2024; Katiyar et al., 2024; Murtaza et al., 2022). The mediating effect of experience engagement also validates the belief that students who are engaged are more likely to succeed. Beyond providing just the right content, tailored learning systems not only guarantee the implementation of a compelling and motivating personalized learning process consisting of sub-processes and component tasks, but also foster motivation and learning engagement and encourage deeper cognitive engagement that spans from theory to practice in entrepreneurship study. This finding is consistent with the literature that has focused on the role of learning engagement in learning efficacy (El-Sabagh, 2021).

In particular, the study also shows that contextual factors mediate the association between personalized learning and engagement, thereby highlighting the need to include external factors (i.e. access to technology and institutional support). However, contextual effects do not significantly moderate the

strong association between individualized learning and entrepreneurship outcomes, which confirm the generalizability of the AI-supported interventions across contexts. This study provides actionable lessons for teachers and policymakers, showing the importance of integrating AI technologies, but not the same level of contribution to the success realized from education benefits due to the variations in context.

CONCLUSION

This study demonstrates the potential of AI-based personalization in entrepreneurial education and outcomes. Results show positive mediation of educational achievement through personalized learning by experience engagement. The findings illustrate the benefits of AI systems, through which the pedagogical process can be adapted to meet the individual learning contexts of students from which will emerge more sophisticated entrepreneurial problem-solving skills and more innovative knowledge production. Furthermore, if contextual variables mediated the mediating effect of personalized learning on engagement, their contribution to near outcome is weak, suggesting relatively robustness of the mediating effect of personalized learning across educational contexts.

Limitations

Despite its contributions, this study has several limitations:

- **Sample Size:** In comparison to that of the sample of 100 participants, there is a limitation on the generalizability of the data, especially when it comes to heterogeneous educational contexts.
- **Cross-Sectional Design:** Utilization of a cross-sectional survey use provides a picture of associations, but not of changes over time or causal effects.
- **Self-Reported Data:** The application of self-report can lead to the following biases (e.g. social desirability), or as a result to overreporting of enrolment and outcome.
- **Context-Specific Variables:** Contextual determinants including the need and capability of AI-based tools and institutional mandate were self-assessed and may not represent technological or cultural heterogeneity.

Future Work

While there is a need for continued study, the following constraints should be taken into account to generalize the current findings.

- **Longitudinal Studies:** A longitudinal investigation of the impact of individualized learning on an entrepreneurial career.
- **Larger and Diverse Samples:** By using a larger sample size from different education levels and geographic regions to enhance the external validity.
- **Objective Data Collection:** Objective measures of engagement and outcome (e.g. system-level data or performance measure) should be used to provide incentives for the collection of self-reported measures.
- **Advanced Contextual Analysis:** Discuss the importance of personal contextual factors such as SES, school facility quality adequacy, and attitude toward the culture in explaining the impact of AI-based learning apps.

Competing Interest

The authors reported no potential conflict of interest.

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