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Designing an Academic Artificial Intelligence Entrepreneurship Ecosystem: A Mixed-Method Fuzzy Delphi Approach

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ABSTRACT

The rapid pace of technological change highlights the role of universities as innovation and entrepreneurship ecosystems. Recent advances in artificial intelligence (AI) and the unique linkage of this technology domain with universities have intensified the need to design university entrepreneurship ecosystems with a specialized focus on AI. This study aims to develop an AI-driven entrepreneurship ecosystem model for Persian Gulf University, Bushehr. A mixed-methods, semi-quantitative approach was employed: first, a systematic literature review identified 31 proposed subcomponents; then, the opinions of 17 experts in AI, entrepreneurship, and policymaking were collected and analyzed using the fuzzy Delphi method. A five-point scale and triangular fuzzy numbers were applied, and defuzzification was performed using the centroid method, with an acceptance threshold of 0.60. The results indicate that the AI entrepreneurship ecosystem comprises eight main dimensions: 1 Governance and Policymaking2 Strategic Human Capital Management 3 Research, Technology and Innovation 4 Technology Infrastructure, Data and Security 5 International Industry Networking and Development 6 Experimentation and Market Entry Opportunities 7 Financing and Support System 8 Commercialization and Market Development encompassing a total of 31 key components. The study provides actionable strategic recommendations for the university and regional stakeholders, emphasizing the need to strengthen data governance, establish local computing infrastructures, and enhance knowledge-based entrepreneurial capacities.

Keywords: *Artificial Intelligence, Entrepreneurship Ecosystem, Persian Gulf University, Technological Innovation, Sustainable Development*

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1 Introduction

Over the past decade, the acceleration of digital transformation and the expansion of artificial intelligence (AI) have fundamentally reshaped the logic of science, industry, and higher education development. Universities, which were once primarily institutions for producing theoretical knowledge, are now recognized as "innovation and entrepreneurship ecosystems"—dynamic structures that integrate human resources, technological infrastructure, collaborative networks, policy frameworks, and market mechanisms in continuous interaction to generate both scientific and economic value.

Within this context, AI has assumed a particularly prominent role, as it not only functions as a driving technology but also acts as a "general-purpose technology" influencing industrial, service, and social domains, while affecting governance systems, employment, skill development, and even the future of universities. Despite the growing importance of this field, a review of previous studies indicates that most research has focused on the technical development of algorithms, predictive models, or the commercialization of AI startups, with limited attention to how universities should design, manage, and govern an AI-specific entrepreneurship ecosystem. Most existing entrepreneurship ecosystem models are general in nature and do not address AI-specific characteristics, including strong data dependency, computational infrastructure requirements, data governance challenges, ethical risks, and the necessity of international collaboration. This theoretical gap underscores the scientific and policy-related necessity of developing a localized, university-centered model for an AI entrepreneurship ecosystem.

In addition to this theoretical gap, practical imperatives further highlight the significance of the topic. Many universities, particularly those in peripheral or less-developed regions, lack an integrated model for developing AI capabilities. Persian Gulf University (PGU) in Bushehr, as the leading academic institution in the province and the only comprehensive public university in southern Iran, faces multiple challenges: insufficient computational infrastructure, dispersed stakeholders, lack of data governance, a gap between the energy industry and academia, and limited targeted programs for fostering AI-based knowledge enterprises. These conditions create a pressing need for a precise, operational, and reliable model to design and manage a university-centered AI entrepreneurship ecosystem.

2 Literature Review and Research Background

Entrepreneurship ecosystems are complex networks of interdependent actors and factors that facilitate the success of startups through interactions among universities, industry, policymakers, and individuals. Key elements include market access, government support, entrepreneurial education systems, and a favorable business environment [1, 2]. University-based ecosystems serve as vital platforms for fostering entrepreneurship and innovation, contributing to economic and social development. Studies across six leading global educational institutions indicate that while these ecosystems follow diverse development pathways, seven common success factors ensure high-impact and sustainable outcomes [3, 4].

Artificial intelligence (AI)-driven entrepreneurship ecosystems represent an emerging field, examining how AI shapes startup communities and innovation environments. Research indicates that entrepreneurs increasingly rely on AI algorithms to establish and scale investments, with impacts extending beyond individual organizations to influence the overall ecosystem dynamics [5]. In recent years, scholarly attention has increasingly focused on linking entrepreneurship ecosystems with emerging technologies, particularly AI. Zhu et al. (2019) emphasize the importance of AI adoption and integration within innovation ecosystems [6]. Similarly, Gravatsi et al. (2024) investigate strategies, processes, and management approaches for entrepreneurship ecosystems. [3, 7].

The university-centered AI entrepreneurship ecosystem exhibits a multidimensional structure encompassing education and culture, multi-skilled human capital, digitalized learning, and motivational psychology to empower individuals and teams [8, 9]. From a technological perspective, research and development, infrastructure and data centers, data governance and security, local platforms, and the university's scientific quality provide a foundation for the development and commercialization of AI innovations [10-12]. Institutionally, university leadership and governance, financial systems, intellectual property rights, institutional resilience, and supportive policies play a decisive role in ecosystem sustainability and cohesion [3, 13-15].

Furthermore, networking, accelerators, university-industry-government collaboration, and international partnerships facilitate knowledge transfer and market entry for innovations [5, 16, 17]. Attention to ethics and social responsibility, gender diversity, sustainable development, AI localization, and continuous ecosystem performance monitoring ensures alignment of university innovations with regional and societal [18-20]. Empirical studies highlight that financial resources, supportive policies, education, culture, and social networks are among the most critical factors influencing startup success and ecosystem dynamics [3, 21].

Despite extensive research on entrepreneurship ecosystems and the role of universities, a comprehensive, localized, and university-centered model for AI entrepreneurship ecosystems has not yet been proposed. This study aims to address this gap by designing such a model for Persian Gulf University, filling both theoretical and practical voids in the existing literature.

3 Research Methodology

Following a systematic review of the literature, 31 preliminary sub-components of an AI entrepreneurial ecosystem were identified. To validate and prioritize these components, the study employed a fuzzy Delphi method, which is particularly suited for integrating expert judgments under conditions of uncertainty and for enhancing the reliability of consensus-based indicators in complex, multi-dimensional systems.

The expert panel comprised 17 specialists with extensive experience in artificial intelligence, entrepreneurship, and science and technology policymaking (detailed profiles are provided in Appendix Table X). The Delphi process was conducted over two iterative rounds. In each round, participants rated the importance of each sub-component using a five-point Likert scale, which was then transformed into triangular fuzzy numbers to capture the inherent uncertainty and subjectivity in expert evaluations. The fuzzy mean of each component was calculated, and defuzzification was performed using the centroid method, ensuring that the resulting scores reflected both central tendency and expert confidence.

To determine the acceptance of each component, a threshold of 0.60 was established. Components with defuzzified scores ≥0.70 were considered key indicators, reflecting strong expert agreement. Convergence between rounds was assessed by examining differences in defuzzified values; when differences exceeded 0.10, a third round was considered, or additional explanations were provided to the panel to achieve clarity. This iterative process ensured that the final set of sub-components was both theoretically grounded and practically validated by experts with domain-specific knowledge.

By employing the fuzzy Delphi method, the study not only systematically prioritized AI ecosystem components but also addressed challenges of subjectivity, uncertainty, and context-specific judgment, thereby producing a robust and operationally relevant framework for designing a university-centered AI entrepreneurial ecosystem.

Table 1: Specifications of Experts

Row	Experience	Education	Job Position
1	Researcher in AI and IoT, experience in research management, technology, and education, experience in launching AI startups and active in the ecosystem	PhD in Communication Systems	Faculty Member at University
2	Researcher in AI, managerial experience in entrepreneurial innovation, experience in launching AI startups	PhD in Artificial Intelligence	Faculty Member at University
3	Manager and expert in AI, active in the ecosystem	Bachelor's in Computer Engineering	Responsible Expert in Entrepreneurship, Mentor, and Entrepreneurship Leader in the Ecosystem
4	Director of the Entrepreneurship and Innovation Center, research experience in entrepreneurship	PhD in Management	Faculty Member and Director of Technology Growth Center
5	Entrepreneur in AI and IoT	Master's in Communication Systems	Entrepreneur in AI and Internet of Things
6	Researcher in innovation ecosystems and entrepreneurship	PhD in Management Systems	Faculty Member at University
7	Researcher and research manager in AI	PhD in Electrical/ Telecommunications	Faculty Member and Research and Technology Manager
8	Entrepreneur in AI	Bachelor's in Computer Engineering	Entrepreneur in AI
9	Researcher in ecosystems with managerial experience in scientific, research, and technology fields, experience in launching AI startups	PhD in Electrical Engineering	Faculty Member at University
10	Manager of research, technology, and innovation in the ecosystem	PhD in Mechanical Engineering	Senior Faculty Member and Manager in Research and Technology, leading technological and entrepreneurial activities
11	Manager of innovation and entrepreneurship ecosystem	PhD in Management	Senior Manager in Technology and leading technological and entrepreneurial activities

12	Researcher in AI and technology manager in the innovation and entrepreneurship ecosystem	PhD in Software Engineering	Faculty Member at University
13	Researcher in AI, statistics, and data science	PhD in Statistics/Data Science	Faculty Member at University
14	Researcher in AI and data science, and education manager in the ecosystem	PhD in Statistics/Data Science	Faculty Member at University
15	Government expert and manager related to the development and application of technology	Bachelor's in Computer Engineering	Government Manager
16	AI expert with experience in innovation ecosystems and entrepreneurship, and experience in launching AI startups	Bachelor's in Computer Engineering	Entrepreneur
17	Researcher, manager, and technology developer in AI	PhD in Electrical/ Telecommunications	Faculty Member at University

4 Fuzzy Delphi Method and Identification of Elements and Dimensions for Designing the AI Entrepreneurial Ecosystem

In the fuzzy Delphi method, achieving consensus among experts is of utmost importance for making precise and valid decisions. For this purpose, data collection was conducted in two separate phases through the distribution of questionnaires. These two phases were designed to enhance the accuracy and credibility of the final decision-making process. The items in the questionnaire were designed using a five-point Likert scale (1: Very Low, 2: Low, 3: Moderate, 4: High, and 5: Very High), and experts were asked to indicate the importance of each indicator by selecting the appropriate option. Table 2 shows the frequency of indicators in the first phase.

Table 2. Frequency of Questionnaire Indicators Rated by Experts in the First Round

Code	Ecosystem Element	Very Low	Low	Medium	High	Very High
A1	Education, Promotion, and Culture	0	0	2	4	6
A2	Support System and Financial Provision	0	0	2	6	4
A3	Networking	0	0	2	3	7
A4	Research and Technology	0	0	2	4	6
A5	University Leadership and Governance	0	0	3	3	6
A6	Human Capital and Multiskilled Teams	0	0	0	4	8
A7	Market and Demand for Innovation	0	0	2	4	6
A8	Infrastructure, Technological Platforms, and Data Centers	0	0	3	5	4
A9	International Interactions and Science–Technology Diplomacy	0	1	2	5	4
A10	Entrepreneurship and Revenue Experience from International Platforms	0	2	3	4	3
A11	AI Ethics and Social Responsibility	2	1	2	5	2
A12	Role of Women and Gender Diversity in the AI Ecosystem	1	3	4	3	1
A13	Data Governance and Management of University Data Resources	0	2	2	5	3
A14	Knowledge-Based Entrepreneurship and Research Commercialization	0	1	2	5	4
A15	Motivational Psychology and Technological Entrepreneurship	0	2	3	7	0
A16	Digitalization of Education and Transformation of Learning in AI	0	1	3	5	3
A17	Institutional Resilience and Crisis Management in Technological Ecosystems	0	1	4	4	3
A18	Digital Security and Cyber Protection in AI Environments	0	1	1	3	7
A19	Intellectual Property Rights in University AI Innovations	0	1	1	2	8
A20	Integration of Sustainable Development Goals and Preservation of Cultural and Indigenous Values in University AI Strategies	1	2	3	4	2
A21	Artificial Intelligence and the Persian Language for Indigenous Applications	0	2	2	6	2
A22	Indigenous Platforms and Digital Sovereignty Infrastructure	2	0	4	4	2
A23	International Legal Challenges and Cross-Border Interactions in AI	1	0	2	3	6
A24	Scientific Quality and University Standing in the Field of AI	0	1	5	2	4
A25	Interdisciplinary Interactions and Integration of Sciences	0	0	2	4	6
A26	University Evaluation and Reward Systems	0	1	3	4	4
A27	Accelerators and Innovation Intermediaries	1	1	3	2	5
A28	University–Industry–Government Interaction	0	0	1	4	7
A29	Policy Learning and Benchmarking from Successful National and International AI Experiences	1	0	2	3	6
A30	Focus on Solving Local Problems and the University's Role in Regional Sustainable Development with an AI Orientation	0	1	2	4	5
A31	Design and Implementation of Quantitative and Qualitative Indicators for Continuous Assessment and Improvement of Ecosystem Performance	0	0	4	4	4

Fuzzy evaluation scale assigns fuzzy numerical values to each option. These values are represented as (l,m,u)(l, m, u)(l,m,u), which respectively denote the lower bound, the most probable value, and the upper bound of a triangular fuzzy number. In this study, the scale is defined as follows:

1. Very Low: (0.25, 0, 0)
2. Low: (0.50, 0.25, 0)
3. Medium: (0.75, 0.50, 0.25)
4. High: (1.00, 0.50, 0.50)
5. Very High: (1.00, 1.00, 0.75)

Based on the results of the first phase, in this stage of the fuzzy Delphi method, the fuzzy mean of experts' opinions is calculated for each indicator. The obtained fuzzy values are then defuzzified. Any indicator that obtains a defuzzified score of less than 0.6 indicates insufficient consensus among the experts and will be eliminated from the subsequent stages of the process.

Table 3. Results of Experts' Opinions in the First Round of the Fuzzy Delphi Method

Code	Ecosystem Element	Triangular Fuzzy Mean (l, m, u)	Defuzzified Value	Decision
A1	Education, Promotion, and Culture	(0.96, 0.83, 0.58)	0.792	Accepted
A2	Support System and Financial Provision	(0.96, 0.79, 0.54)	0.764	Accepted
A3	Networking	(0.96, 0.85, 0.60)	0.806	Accepted
A4	Research and Technology	(0.96, 0.83, 0.58)	0.792	Accepted
A5	University Leadership and Governance	(0.88, 0.75, 0.50)	0.708	Accepted
A6	Human Capital and Multiskilled Teams	(1.00, 0.92, 0.67)	0.861	Eliminated
A7	Market and Demand for Innovation	(0.96, 0.83, 0.58)	0.792	Accepted
A8	Infrastructure, Technological Platforms, and Data Centers	(0.94, 0.77, 0.52)	0.743	Accepted
A9	International Interactions and Science–Technology Diplomacy	(0.92, 0.75, 0.50)	0.722	Accepted
A10	Entrepreneurship and Revenue Experience from International Platforms	(0.85, 0.67, 0.42)	0.646	Accepted
A11	AI Ethics and Social Responsibility	(0.79, 0.58, 0.38)	0.583	Eliminated
A12	Role of Women and Gender Diversity in the AI Ecosystem	(0.73, 0.50, 0.27)	0.500	Eliminated
A13	Data Governance and Management of University Data Resources	(0.88, 0.69, 0.44)	0.667	Eliminated
A14	Knowledge-Based Entrepreneurship and Research Commercialization	(0.92, 0.75, 0.50)	0.722	Accepted
A15	Motivational Psychology and Technological Entrepreneurship	(0.85, 0.60, 0.35)	0.604	Eliminated
A16	Digitalization of Education and Transformation of Learning in AI	(0.90, 0.71, 0.46)	0.688	Eliminated
A17	Institutional Resilience and Crisis Management in Technological Ecosystems	(0.88, 0.69, 0.44)	0.667	Eliminated
A18	Digital Security and Cyber Protection in AI Environments	(0.94, 0.83, 0.58)	0.785	Accepted
A19	Intellectual Property Rights in University AI Innovations	(0.94, 0.85, 0.60)	0.799	Eliminated
A20	Integration of Sustainable Development Goals and Preservation of Cultural and Indigenous Values in University AI Strategies	(0.79, 0.58, 0.35)	0.576	Eliminated
A21	Artificial Intelligence and the Persian Language for Indigenous Applications	(0.88, 0.67, 0.42)	0.653	Accepted
A22	Indigenous Platforms and Digital Sovereignty Infrastructure	(0.79, 0.58, 0.38)	0.583	Eliminated
A23	International Legal Challenges and Cross-Border Interactions in AI	(0.90, 0.77, 0.54)	0.736	Eliminated
A24	Scientific Quality and University Standing in the Field of AI	(0.85, 0.69, 0.44)	0.660	Accepted
A25	Interdisciplinary Interactions and Integration of Sciences	(0.96, 0.83, 0.58)	0.792	Accepted
A26	University Evaluation and Reward Systems	(0.90, 0.73, 0.48)	0.701	Accepted
A27	Accelerators and Innovation Intermediaries	(0.83, 0.69, 0.46)	0.660	Accepted
A28	University–Industry–Government Interaction	(0.98, 0.88, 0.63)	0.826	Accepted
A29	Policy Learning and Benchmarking from Successful National and International AI Experiences	(0.90, 0.77, 0.54)	0.736	Accepted
A30	Focus on Solving Local Problems and the University's Role in Regional Sustainable Development with an AI Orientation	(0.92, 0.77, 0.52)	0.736	Accepted
A31	Design and Application of Quantitative and Qualitative Indicators for Continuous Assessment and Improvement of Ecosystem Performance	(0.92, 0.75, 0.50)	0.722	Accepted

In the first round of the fuzzy Delphi study, the survey results indicated that several indicators, as shown in Table 3, were eliminated from the evaluation process due to insufficient consensus among experts (based on the criterion of a defuzzified value below 0.6). In addition, new elements were proposed and incorporated into the second-round questionnaire, including **"**coherent legal support for domestic and international AI projects," "internship, traineeship, and income-generating experiential opportunities during students' academic period," "the establishment of small, medium, and large AI-related firms within the university ecosystem," "attraction, retention, and development of high-quality and skilled human resources," "AI ethics," "data security," "project-based learning," "research and technology groups," and "team-based laboratories**."** These elements were respectively coded as A32, A33, A34, A35, A36, A37, A38, A39, and A40.

Following the elimination and addition of these new elements, the questionnaire was refined to include 26 indicators and prepared for entry into the second round of the fuzzy Delphi method, in order to further examine the convergence of experts' opinions on the remaining indicators. The frequency distribution of indicators in the second round is presented in Table 4

Table 4. Frequency of Questionnaire Indicators Rated by Experts in the Second Round

Code	Ecosystem Element	Very Low	Low	Medium	High	Very High
A1	AI Promotion, Culture, and Education	0	0	1	6	10
A2	Support System and Financial Provision	0	0	3	7	7
A3	Networking	0	0	2	3	12
A4	Research, Technology, and Innovation in AI	0	0	1	4	12
A5	Smart University Leadership and Governance	0	0	4	4	9
A7	Market Development and Demand for Innovation	0	0	1	3	13
A8	Infrastructure, Technological Platforms, and Data Centers	0	0	1	7	9
A9	International Cooperation and Interactions	0	1	1	1	14
A10	International Entrepreneurship and Revenue Experience from Global Platforms	0	1	3	5	8
A14	Technological Entrepreneurship and Research Commercialization	0	1	3	4	9
A21	Artificial Intelligence and Its Indigenous Applications in the Persian Language with a Localization and Local Development Approach	2	1	4	4	6
A24	Scientific Quality and University Standing in the Field of AI	1	1	1	4	10
A25	Interdisciplinary Interactions and Integration of Sciences	0	0	2	5	10
A26	University Evaluation and Reward Systems	0	0	2	5	10
A27	Accelerators and Innovation Intermediaries	0	0	2	5	10
A28	University–Industry–Government Interaction	0	0	0	4	13
A29	Policy Learning and Benchmarking	0	0	3	10	4
A32	Coherent Legal Support for Domestic and International AI Projects	0	2	6	5	4
A33	Internship, Traineeship, and Income-Generating Opportunities During the Student Period	0	0	4	2	11
A34	Establishment of Small, Medium, and Large Firms within the University Ecosystem	0	1	3	3	10
A35	Attraction, Retention, and Development of High-Quality and Skilled Human Resources	0	0	2	9	6
A36	AI Ethics	0	0	1	9	7
A37	Data Security	0	0	2	10	5
A38	Project-Based Learning	0	0	2	9	6
A39	Research and Technology Groups	0	0	1	6	10
A40	Team-Based Laboratories	0	0	2	7	8

Table 5 presents the results of the second round of the fuzzy Delphi method**.** At this stage, all indicators achieved defuzzified values higher than 0.6, indicating consensus among the experts. Furthermore, Table 5 shows that for several indicators, the difference between defuzzified values obtained in the first and second rounds was below the threshold of 0.1, reflecting convergence and stability of expert opinions.

However, some indicators—namely A8, A10, A12, A13, A15, and A16—exhibited differences greater than 0.1, suggesting the absence of complete agreement regarding their relative importance. Despite these discrepancies, the Delphi process was terminated and did not proceed to a third round.

The primary reason for terminating the process was related to cost, time, and operational constraints of the study. Given the professional commitments of the experts and the extended duration of each round, it was not feasible to continue the process while maintaining active expert participation and adhering to the overall research timeline.

The second reason for termination was that, although the differences for these six indicators exceeded 0.1, all indicators in the second round met the final acceptance threshold (defuzzified value ≥ 0.6). This finding indicates that while experts held differing views regarding the *degree of importance* of these six indicators, they reached a general consensus on their *inclusion* in the proposed model.

Based on the acceptable level of approximate disagreement among experts and considering the time and cost constraints, the Delphi process was concluded, and all indicators confirmed in the second round were retained for subsequent analyses

Table 5. Experts' Opinions in the Second Round of the Fuzzy Delphi Method

Code	Ecosystem Element	Triangular Fuzzy Mean (l, m, u)	Defuzzified Value (Round 2)	Decision	Defuzzified Value (Round 1)	Change from Round 1	Difference Between Rounds	Priority Based on Round 2*
A1	AI Promotion, Culture, and Education	(0.99, 0.88, 0.63)	0.833	Accepted	0.792	Increasing	0.041	High Priority
A2	Support System and Financial Provision	(0.96, 0.81, 0.56)	0.775	Accepted	0.764	Increasing	0.011	Medium Priority
A3	Networking	(0.97, 0.90, 0.65)	0.838	Accepted	0.806	Decreasing	0.032	High Priority
A4	Research, Technology, and Innovation in AI	(0.99, 0.91, 0.66)	0.853	Accepted	0.792	Increasing	0.061	High Priority
A5	Smart University Leadership and Governance	(0.94, 0.82, 0.57)	0.779	Accepted	0.708	Increasing	0.071	Medium Priority
A7	Market Development and Demand for Innovation	(0.99, 0.93, 0.68)	0.863	Accepted	0.792	Increasing	0.071	High Priority
A8	Infrastructure, Technological Platforms, and Data Centers	(0.99, 0.87, 0.62)	0.824	Accepted	0.743	Increasing	0.081	High Priority
A9	International Cooperation and Interactions	(0.96, 0.91, 0.66)	0.843	Accepted	0.722	Increasing	0.121	High Priority
A10	International Entrepreneurship and Revenue Experience from Global Platforms	(0.93, 0.79, 0.54)	0.755	Accepted	0.646	Increasing	0.109	Considerable Priority
A14	Technological Entrepreneurship and Research Commercialization	(0.93, 0.81, 0.56)	0.765	Accepted	0.722	Increasing	0.043	Considerable Priority
A21	AI and Its Indigenous Applications in Persian with a Localization and Local Development Approach	(0.82, 0.66, 0.44)	0.642	Accepted	0.653	Decreasing	0.011	Considerable Priority
A24	Scientific Quality and University Standing in AI	(0.91, 0.81, 0.57)	0.765	Accepted	0.660	Increasing	0.105	Considerable Priority
A25	Interdisciplinary Interactions and Integration of Sciences	(0.97, 0.87, 0.62)	0.819	Accepted	0.792	Increasing	0.027	Medium Priority
A26	University Evaluation and Reward Systems	(0.97, 0.87, 0.62)	0.819	Accepted	0.701	Increasing	0.118	Medium Priority
A27	Accelerators and Innovation Intermediaries	(0.97, 0.87, 0.62)	0.819	Accepted	0.660	Increasing	0.159	Medium Priority
A28	University–Industry–Government Interaction	(1.00, 0.94, 0.69)	0.877	Accepted	0.826	Increasing	0.051	High Priority
A29	Policy Learning and Benchmarking	(0.96, 0.76, 0.51)	0.745	Accepted	0.736	Increasing	0.009	Considerable Priority
A32	Coherent Legal Support for Domestic and International AI Projects	(0.91, 0.82, 0.57)	0.794	Accepted	-	-	-	Medium Priority
A33	Internship, Traineeship, and Income-Generating Opportunities During the Student Period	(0.94, 0.85, 0.60)	0.799	Accepted	-	-	-	Medium Priority
A34	Establishment of Small, Medium, and Large Firms within the University Ecosystem	(0.93, 0.82, 0.57)	0.775	Accepted	-	-	-	Medium Priority
A35	Attraction, Retention, and Development of High-Quality and Skilled Human Resources	(0.97, 0.81, 0.56)	0.779	Accepted	-	-	-	Medium Priority
A36	AI Ethics	(0.99, 0.84, 0.59)	0.804	Accepted	-	-	-	Medium Priority
A37	Data Security	(0.97, 0.79, 0.54)	0.770	Accepted	-	-	-	Medium Priority
A38	Project-Based Learning	(0.97, 0.81, 0.56)	0.779	Accepted	-	-	-	Medium Priority
A39	Research and Technology Groups	(0.99, 0.88, 0.63)	0.833	Accepted	-	-	-	High Priority
A40	Team-Based Laboratories	(0.97, 0.84, 0.59)	0.799	Accepted	-	-	-	Medium Priority

Priority Classification: High Priority > 0.820, Medium Priority 0.770–0.820, Considerable Priority < 0.770

5 Categorization of Indicators Based on Fuzzy Delphi Dimensions

Using expert opinions, with an emphasis on practical experience and for the purpose of summarization and better organization, the 26 final indicators confirmed through the fuzzy Delphi method were grouped into eight main dimensions. Each of these eight dimensions encompasses related indicators, all of which refer to a specific aspect of the university AI entrepreneurship ecosystem. Table 6 presents the dimensions and their corresponding indicators.

Table 6. Dimensions and Elements of the University AI Entrepreneurship Ecosystem

No.	Dimension	Ecosystem Elements
1	Governance and Policy	Smart University Leadership and Governance (A5), University–Industry–Government Interaction (A28), Policy Learning and Benchmarking (A29), University Evaluation and Reward Systems (A26), Accelerators and Innovation Intermediaries (A27), Research and Technology Groups (A39)
2	Strategic Human Capital Management	AI Promotion, Culture, and Education (A1), AI and Its Indigenous Applications in Persian with a Localization and Local Development Approach (A21), Attraction, Retention, and Development of High-Quality and Skilled Human Resources (A35), AI Ethics (A36), Project-Based Learning (A38)
3	Research, Technology, and Innovation	Research, Technology, and Innovation in AI (A4), Interdisciplinary Interactions and Integration of Sciences (A25), Scientific Quality and University Standing in AI (A24)
4	Technology Infrastructure, Data, and Security	Infrastructure, Technological Platforms, and Data Centers (A8), Data Security (A37), Team-Based Laboratories (A40)
5	Networking and International Collaboration	Networking (A3), International Cooperation and Interactions (A9), Establishment of Small, Medium, and Large Firms within the University Ecosystem (A34)
6	Experiential Learning and Market Entry Opportunities	Internship, Traineeship, and Income-Generating Opportunities During the Student Period (A33), International Entrepreneurship and Revenue Experience from Global Platforms (A10)
7	Financial Support and Backing	Support System and Financial Provision (A2), Coherent Legal Support for Domestic and International AI Projects (A32)
8	Commercialization and Market Development	Market Development and Demand for Innovation (A7), Technological Entrepreneurship and Research Commercialization (A14)

Table 7 presents the results of the analysis of the dimensions and elements of the university AI entrepreneurship ecosystem**,** emphasizing experiential learning, based on the fuzzy Delphi method.

Table 7. Fuzzy Delphi Results for the First and Second Rounds at the Element Level

Code	Dimension	Ecosystem Elements	Defuzzified Value (Round 1)	Defuzzified Value (Round 2)	Difference Between Rounds (Threshold)	Status
B1	Governance and Policy	(A5, A25, A29, A26, A27, A39)	0.726	0.812	0.086	Accepted
B2	Strategic Human Capital Management	(A1, A21, A35, A36, A38)	0.723	0.767	0.044	Accepted
B3	Research, Technology, and Innovation	(A4, A25, A24)	0.748	0.812	0.064	Accepted
B4	Technology Infrastructure, Data, and Security	(A8, A37, A40)	0.743	0.797	0.054	Accepted
B5	Networking and International Collaboration	(A3, A9, A34)	0.722	0.809	0.087	Accepted
B6	Experiential Learning and Market Entry Opportunities	(A33, A10)	0.646	0.777	0.131	Accepted
B7	Financial Support and Backing	(A2, A32)	0.764	0.784	0.020	Accepted
B8	Commercialization and Market Development	(A7, A14)	0.757	0.814	0.057	Accepted

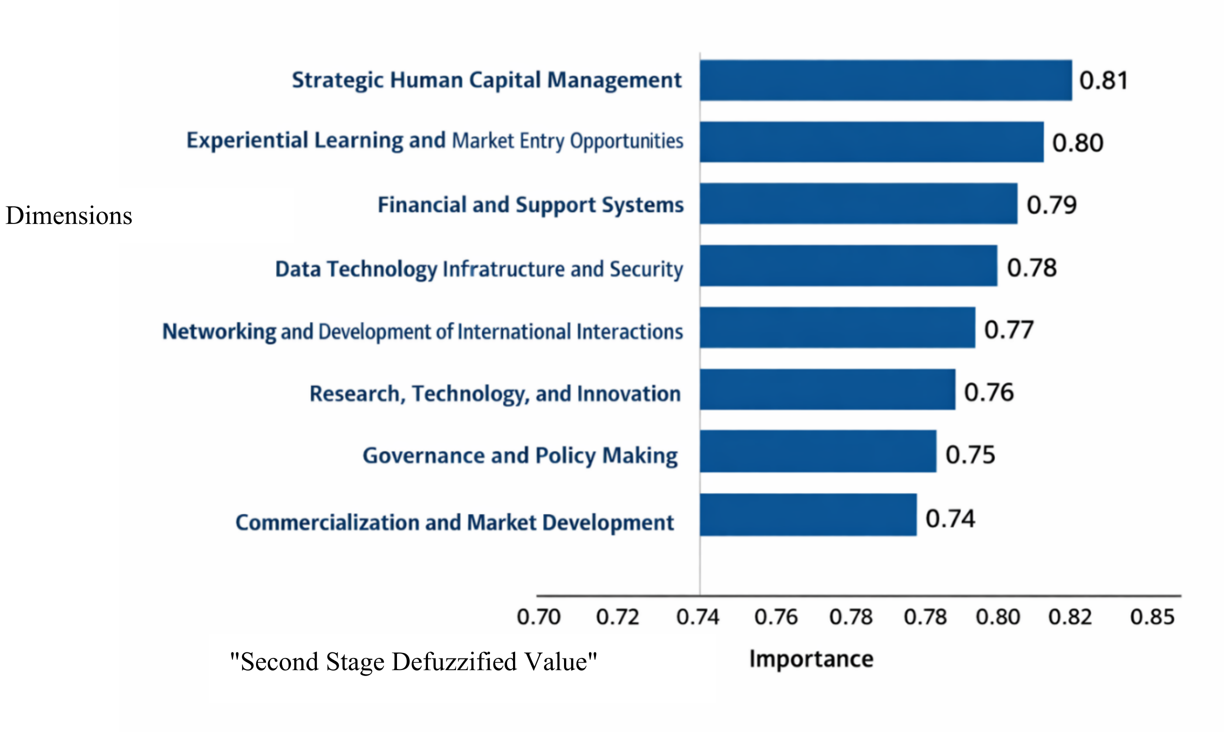

Figure 1: Column chart of the importance of the main dimensions of the ecosystem from the experts' perspective

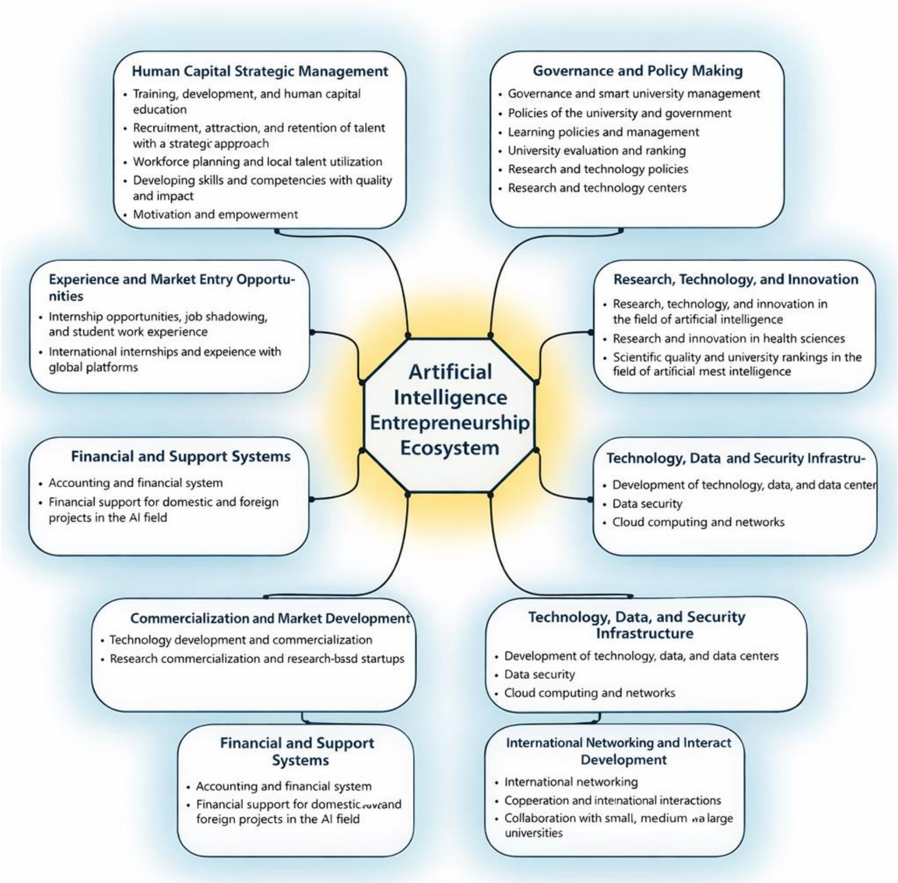

Figure 2: Dimensions and constituent elements of the AI entrepreneurship ecosystem with an entrepreneurial approach, emphasizing experientiality

6 Research Findings

The findings of this study, derived from semi-structured interviews with 17 experts in artificial intelligence, entrepreneurship, and science and technology policy, and validated through a fuzzy Delphi process, indicate that the design of a university-based AI entrepreneurial ecosystem is a multidimensional, interdisciplinary, and dynamic phenomenon. Thematic and inductive analysis revealed 31 key components, which were systematically organized into five primary dimensions: human and cultural, technological and infrastructural, institutional and governance, networked and international, and economic and commercialization.

The human and cultural dimension underscores the centrality of human capital, interdisciplinary expertise, systems thinking, innovation-oriented mindset, and gender diversity. Experts emphasized that skilled, creative, and collaborative personnel constitute the primary source of value creation within AI-driven ecosystems, highlighting the necessity of fostering a culture that embraces experimentation and innovation.

The technological and infrastructural dimension reflects the critical need for robust local computational infrastructures, university data centers, AI-specific platforms (including Persian-language processing tools), cybersecurity measures, and technical support for startups. These infrastructural elements not only enable scalable and sustainable AI innovation but also serve as the foundation for translating research into market-ready solutions.

The institutional and governance dimension encompasses clear legal and regulatory frameworks, intellectual property protection, data ethics, algorithmic transparency, inter-institutional coordination, and strategic university leadership. This dimension forms the backbone of ecosystem stability and sustainability, ensuring that diverse stakeholders can interact effectively and that knowledge can be mobilized safely and efficiently.

The networked and international dimension highlights the importance of systematic networking among universities, industry, government, and financial institutions. Trilateral collaborations, research consortia, knowledge exchange, and cross-border scientific interactions enhance the ecosystem's absorptive capacity, accelerate innovation diffusion, and foster globally competitive ventures.

Finally, the economic and commercialization dimension focuses on mechanisms that convert academic research into economic value, including support for knowledge-based startups and accelerators, venture capital funding, and technology marketplaces. Translating intellectual outputs into market-ready products and services is critical for sustaining ecosystem dynamism and ensuring tangible socio-economic impact.

Collectively, these findings portray the AI entrepreneurial ecosystem as a learning-oriented, adaptive, and networked system, wherein human, technological, institutional, cultural, and economic factors operate synergistically. Its effectiveness depends on mutual trust, integrated policymaking, a culture that embraces innovation, and efficient technological infrastructures. The results underscore the evolving role of universities: transitioning from traditional educational institutions to orchestrators and facilitators of technological innovation and entrepreneurship, capable of generating both social and economic value from academic knowledge.

7 Discussion and Conclusion

This study demonstrates that designing a university-based AI entrepreneurial ecosystem is a complex, multidimensional, and interdisciplinary endeavor, dependent on coordinated interactions among universities, industry, government, financial institutions, and the scientific community. The findings indicate that an effective AI ecosystem integrates five interdependent dimensions—human and cultural, technological and infrastructural, institutional and governance, networked and international, and economic and commercialization—operating synergistically to foster innovation and value creation.

The human and cultural dimension emerges as a critical driver, with entrepreneurial mindset, creativity, risk-taking, and trust among stakeholders underpinning ecosystem dynamics. Without these capabilities, even advanced technological infrastructures may fail to generate meaningful innovation. The technological and infrastructural dimension provides the foundation for ecosystem functionality, encompassing robust local data platforms, high-performance computing resources, cybersecurity, and transparent data governance. Deficiencies in these areas can lead to technological dependence and delayed commercialization.

The institutional and governance dimension is equally decisive, highlighting the necessity of clear legal frameworks for intellectual property, data ethics, algorithmic transparency, and support mechanisms for startups, alongside active engagement by policymaking institutions. The networked and international dimension emphasizes structured collaboration among universities, industry, government, and financial actors, as well as cross-border research consortia and knowledge exchange, which facilitate collective learning and accelerate innovation diffusion. Finally, the economic and commercialization dimension ensures that academic research translates into market-ready products through venture funding, accelerators, and technology marketplaces.

Taken together, the AI entrepreneurial ecosystem represents a dynamic, adaptive, and learning-oriented system**,** where technological, institutional, human, cultural, network, and economic factors co-evolve. Its sustainability depends on mutual trust, integrated policy frameworks, innovation-oriented culture, and operational technological infrastructures. Universities, serving as orchestrators rather than merely educational institutions, can facilitate knowledge valorization, foster regional innovation, and provide actionable models for other academic institutions.

In conclusion, the present study demonstrates that the university-based AI entrepreneurship ecosystem has a multidimensional structure, and the interaction among technological, institutional, human, and cultural components facilitates the development and success of university startups and innovations. The findings align with previous studies emphasizing the importance of combining multi-skilled human resources, technological infrastructure, governance and supportive policies, networking, and university-industry-government collaboration in the success of entrepreneurship ecosystems (Rice et al., 2014; Zou et al., 2019; Rondi, 2022; Gravatsi et al., 2024). Moreover, the results are consistent with research highlighting the role of psychological and motivational dimensions in empowering individuals and teams (Chen et al., 2024; Patrens et al., 2021).

Overall, these findings indicate that to create and maintain a dynamic and successful university-based AI entrepreneurship ecosystem, simultaneous attention to technology, human capital, governance, and organizational culture is essential. Additionally, this study addresses the existing gap in the literature by providing a comprehensive, locally adapted, university-centered model for AI entrepreneurship ecosystems, offering practical guidance for developing university innovation ecosystems.

8 Scientific, Policy, and Practical Recommendations

The findings of this study underscore that the development of a university-based AI entrepreneurial ecosystem requires coordinated and systemic collaboration among universities, government, industry, financial institutions, and the scientific community. Based on the identified five dimensions of the ecosystem, the study proposes actionable recommendations across academic, policy, industrial, financial, and research perspectives:

Academic Perspective:

- Establish AI-focused innovation and acceleration centers that integrate interdisciplinary education, applied research, and commercialization support.
- Implement specialized capacity-building programs to enhance technical, managerial, and entrepreneurial competencies among students and faculty.
- Foster domestic and international collaborations and create robust monitoring and evaluation systems to assess ecosystem performance.

Policy and Institutional Perspective:

- Develop national and regional strategies that emphasize technology localization, digital autonomy, and comprehensive data governance.
- Design policies to address institutional and functional gaps, including clear legal frameworks, intellectual property protection, algorithmic transparency, and support for international scientific collaborations.

Industrial and Economic Perspective:

- Strengthen university–industry collaborations through research contracts, joint projects, and translational initiatives.
- Support knowledge-based entrepreneurship and the establishment of specialized AI startups.
- Promote opportunity-driven, localized AI ecosystems to enhance both national and international competitiveness.

Financial and Supportive Perspective:

- Establish specialized venture capital funds involving government, universities, and the private sector.
- Facilitate access to financial resources and tailored support mechanisms for startup teams and innovation projects.

Research Perspective:

- Extend similar studies to other universities and regions to validate and generalize the model.
- Conduct quantitative and survey-based analyses to evaluate the impact of ecosystem components.

- Examine stakeholder interactions through predictive, simulation, and network modeling to assess ecosystem performance and sustainability.

Triple-Synergy Framework

The recommendations converge on a triple-synergy framework that emphasizes:

1. Human capital and innovation culture**:** Project-based education, internship programs, and entrepreneurial mindset development.
2. Technological infrastructure and data governance: University data centers, local AI platforms, and transparent data policies.
3. Supportive institutions**:** Accelerators, venture funding, legal and ethical support mechanisms.

Illustrative Case: Regional University Implementation

For illustration, a regional university in southern Iran could consider the following phased actions:

- Short-term**:** Establish an AI innovation center focusing on commercialization and continuous industry engagement.
- Medium-term**:** Develop and implement robust data governance policies and secure data-sharing standards.
- Long-term**:** Launch a dedicated AI accelerator/incubator with mechanisms for attracting investment, facilitating international networking, and promoting knowledge-based entrepreneurship.

Each phase can be monitored using key performance indicators (KPIs) such as the annual number of startups, revenue generated from AI platforms, and industry satisfaction indices. Future research may expand the expert panel, conduct additional Delphi rounds, and employ quantitative validation techniques to examine the stability and generalizability of these indicators.

Table 8: Recommended Actions for Persian Gulf University

Proposed Duration	Financial/Resource Requirement	Suggested KPI	Responsible Actor	Action
Medium-term (6–12 months)	High	Number of startups established; number of accepted teams	Vice President for Research / Incubation Center	Establish a specialized AI innovation and acceleration center
Short-term (3–6 months)	Medium	Number of courses; number of participants	Vice President for Education / Faculties	Design AI skills training programs
Long-term (12+ months)	Low to Medium	Number of contracts and joint projects	Industry Liaison Office	Develop university–industry collaboration
Medium-term (6–12 months)	Medium	Data volume; number of active research groups	IT Unit	Establish a university data repository
Long-term	High	Number of recruited faculty; research output	Vice President for Research	Recruit faculty and visiting researchers
Annual	Medium	Number of participants; number of publications	Vice President for Research / Cultural Affairs	Organize annual AI conference or festival
Short-term	Low to Medium	Number of supported theses	Vice President for Research	Financial support for AI theses
Short-term	Low	Number of members; number of events	Scientific Associations / Cultural Affairs	Create a network of students interested in AI
Medium-term	High	Server usage rate	IT Unit	Expand computational infrastructure
Medium-term	Medium	Number of consulting services provided	Incubation Center / Industry Liaison Office	Establish a digital transformation consulting center

9 Future Research Directions

Given the exploratory nature of this study and its focus on designing a university-centered AI entrepreneurial ecosystem, several avenues for future research emerge:

1. Quantitative Validation and Modeling:

- Employ methods such as Structural Equation Modeling (SEM) or Interpretive Structural Modeling (ISM) to quantitatively test the relationships among the 31 identified components and the five dimensions of the ecosystem.
- Conduct comparative studies across universities in Iran or benchmark against leading international AI entrepreneurship ecosystems to identify structural similarities, divergences, and best practices.

2. Longitudinal and Evolutionary Studies:

- Undertake longitudinal research to examine ecosystem dynamics over time, analyzing how maturity, policy interventions, and stakeholder engagement influence sustainability, adaptability, and innovation outcomes.
- Develop and validate performance indicators (KPIs) for efficiency, productivity, resilience, and

knowledge valorization within university AI ecosystems.

3. Stakeholder Network and Governance Analysis:
   - Apply Social Network Analysis (SNA) to map critical relationships, collaboration patterns, and influence nodes among universities, industry, government, and financial institutions.
   - Investigate governance mechanisms, data management practices, and ethical considerations in AI ecosystem development, with particular attention to transparency, accountability, and regulatory compliance.
4. Cultural, Social, and Psychological Dimensions:
   - Examine the influence of cultural, social, and psychological factors on innovation, collaboration, and entrepreneurial engagement within the ecosystem.
   - Explore strategies to foster an innovation-oriented culture, enhance interdisciplinary collaboration, and strengthen entrepreneurial competencies among students, faculty, and researchers.
5. Policy and Strategic Implications:
   - Conduct comparative analyses of national and international AI development policies to derive insights for optimizing university-based ecosystem strategies.
   - Develop a comprehensive national AI ecosystem policy model for Iran to align universities, industry, and government in supporting technology-driven entrepreneurship and sustainable development goals (SDGs).

By pursuing these directions, future research can not only validate and refine the proposed AI entrepreneurial ecosystem model but also provide actionable insights for universities, policymakers, and industry stakeholders seeking to foster sustainable, innovation-driven, and globally competitive ecosystems.

10 Research Limitations

Like any empirical study, this research has several limitations that should be considered when interpreting the findings and assessing their generalizability, while also offering directions for future investigations:

1. Scope and Case Limitation: The study focused on a single illustrative case—Persian Gulf University—and a specific AI entrepreneurial ecosystem. Consequently, the findings may not be fully generalizable to other universities, regions, or educational systems, although the proposed framework provides a conceptual foundation that can guide similar institutions.
2. Data Limitations: Data collection relied primarily on literature review and semi-structured interviews with experts. While these sources provided rich insights, responses may be influenced by individual perspectives, cognitive biases, or limited access to complete information. Triangulation with additional data sources could further strengthen model validity.
3. Qualitative Nature: Thematic analysis enabled identification of conceptual and processual dimensions of the ecosystem, but precise quantification of the relative impact of each component was limited. Complementary quantitative studies (e.g., SEM, ISM) are necessary to validate the structural relationships among elements.
4. Lack of Comparative Analysis: The study did not conduct systematic comparisons with other universities or AI ecosystems at national or international levels. Such comparative analyses could illuminate common patterns, localized adaptations, and best practices, thereby enhancing the model’s applicability.
5. Dynamic Context: Given the rapid evolution of AI technologies, digital infrastructures, and business environments, some findings may become time-sensitive. Periodic updates and iterative revisions of the proposed model are recommended to maintain its relevance and practical utility.
6. Fuzzy Delphi Constraints: Due to operational and time constraints, the Delphi process was limited to two rounds, despite some indicators exhibiting partial disagreement (differences above 0.10). While this may minimally affect the full convergence of opinions, the overall consensus among experts supports the robustness of the final set of validated components.

Overall, these limitations underscore the exploratory and contextual nature of the study while highlighting opportunities for future validation, generalization, and longitudinal investigation. By acknowledging these constraints, the research provides a transparent and methodologically sound foundation for subsequent studies on AI entrepreneurial ecosystems in higher education.

Ethical Considerations

All procedures performed in this study were under the ethical standards.

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Conflict of Interest

The authors report no conflict of interest.

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