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Strategic Talent Development: Development of Training Model for Enhancing Competencies for Technology Transfer Professionals

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ABSTRACT

Science, technology, and innovation (STI) often struggle to achieve successful commercial exploitation, resulting in failures during technology commercialization, which highlights the critical gap between research and market implementation. Bridging this gap through effective technology commercialization involves disseminating scientific discoveries to industries capable of commercialization, which is crucial. Technology Transfer Professionals (TTP) serve as crucial intermediaries in the process of technology transfer and commercialization. Despite their importance, there is still a significant gap in understanding the specific skill sets and competencies required to enhance their effectiveness. This study seeks to bridge that gap by identifying the key elements necessary to design a specialized training model uniquely tailored to the needs of TTP, moving beyond traditional, generic employee training approaches. Utilizing the Fuzzy Delphi Method (FDM), the study presents a training model that functions as a strategic talent management tool for both organizations and government agencies. It equips TTP with a focused development program to enhance its credibility, effectiveness, and impact in engaging with diverse stakeholders throughout the innovative ecosystem. By incorporating these findings into professional development initiatives and organizational strategies, the model, which encompasses technical, interpersonal, knowledge-based, and entrepreneurial competencies, aims to enhance technology transfer and commercialization outcomes. Ultimately, this approach strengthens individual TTP capabilities while reinforcing the broader innovation ecosystem at both national and global levels, serving as a catalyst for a more connected, resilient, and innovation-driven global economy.

Keywords: Commercialization, Technology transfer (TT), Technology Transfer Professional (TTP), training model

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INTRODUCTION

Innovation is the precursor to driving economic development nationwide. Perhaps, all countries, including Malaysia, are confronted with the issues of how to position the innovation reservoir for economic growth and its sustainability (Wang et al., 2024). Research institutes, the entities that actively conduct research and development (R&D) activities, which are led by R&D professionals, including universities, research institutions and private R&D companies, are vigorous agents of producing R&D in STI. Therefore, allocating a substantial budget to R&D expenditure represents an optimistic approach to R&D investment. Research consistently suggests that increased upstream R&D investment correlates with enhanced downstream innovation performance (Jiang et al., 2024), which can significantly contribute to technology commercialization and pave the way for successful research pathways. The R&D landscape in Malaysia has expanded significantly over the past decade, with output in categories such as publications, articles, and reviews increasing by 7.2%. In comparison, other countries have reported lower growth rates: Australia at 4.6%, China at 4.2%, and Singapore at 3.6% (Kasim et. al., 2021). According to the Global Innovation Index (GII), Malaysia ranks 33rd among the 133 world economies in 2024, based on its innovation capabilities, which are measured by 80 indicators of innovation inputs and outputs (Figure 1). While Malaysia performs relatively well in terms of innovation inputs, ranking 28th, it lags in innovation outputs, ranking 41st (World Intellectual Property Organization [WIPO], 2024). This discrepancy suggests that while the country excels at developing R&D, it struggles to effectively translate these innovations into commercial outcomes, highlighting a potential bottleneck in technology transfer and commercialization. This gap in exploiting innovation for downstream applications may be contributing to slower and less efficient technology transfer processes.

Innovation can be defined as a process that integrates science, technology, economics, and management to achieve novelty. It spans from the initial emergence of an idea to its eventual commercialization through production, exchange, and consumption. Other scholars describe innovation as the generation of new ideas and their implementation in the form of new products, processes, or services, contributing to dynamic economic growth, increased employment, and the generation of profit for innovative enterprises (Kogabayev & Maziliauskas, 2017).

Dissemination of innovation from the research institutions to potential and capable industries is defined as technology transfer. The advantages of turning the scientific discoveries into commercial potential which referred as innovation, includes (i) leveraging R&D outcome and intellectual assets, (ii) enhance the accessibility of R&D outcome to broad range of industries through technology adoption, (iii) align with government initiative on technology commercialization of local innovation, (iv) accelerate the productivity outcome via utilization of innovation including digital transformation, (v) intensify

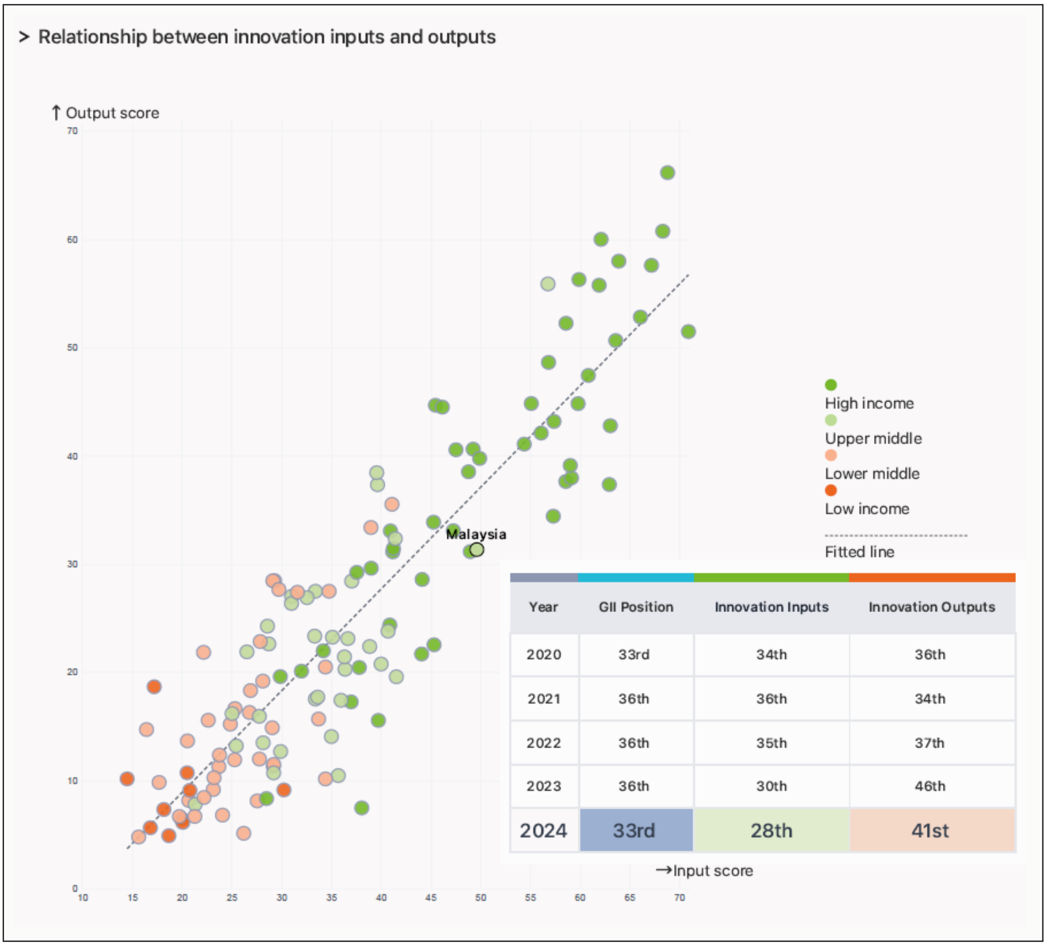

Figure 1. Global Innovation Index 2024 (*Source:* WIPO, 2024)

industrial competition among local and international, and (vi) accelerate economic growth and social development of the communities.

For research institutions to play an active role in creating innovation, TTP is required to effectively perform its role as a professional mediator between research institutions and industries. TTP, also known as a technology transfer officer, is an employee who works in the field of technology transfer and commercialization to transform the research output into commercial value to enhance the innovation-driven and economic growth of the country. Despite numerous studies exploring the issues and challenges associated with technology transfer, the question of which skillsets and competencies are necessary for TTP remains unanswered (Boguszewicz-Kreft et al., 2021; Mom et al., 2012; Soares & Torkomian, 2021; Takata et al., 2022). This issue has been recognized as part of broader challenges since the early 2000s, where concerns over the competency of staff include insufficient training and capability (Jensen & Thursby, 2001; Manap et al., 2017; Mom et. al., 2012; Swamidass & Vulasa, 2009). TTP is required to employ a diverse skill set and competencies to achieve goals set in technology transfer and commercialization. This includes setting goals amidst high uncertainty, translating scientific discoveries into business-viable, and initiating stakeholder engagement. Cunningham and O'Reilly (2018) have emphasized the diverse and varied nature of TTP capabilities, highlighting the importance of identifying the specific skill sets and competencies that contribute to effective technology transfer.

Our study aims to address this gap by investigating the essential components required to be integrated into the training model, which can enhance the impact and efficiency of TTP. Through expert views and consensus, the critical components of competencies were identified for training. Our goal is to improve the effectiveness of TTP by developing a comprehensive training model that includes a series of important components. This strategic approach aims to ensure the delivery of purposeful, successful, and impactful training programs for TTP through a systematic methodology.

THEORETICAL FRAMEWORK

This study focuses on talent management and human resource development to form a pathway to the key variables examined, namely, the Talent DNA Model and McLagan's Model of Human Resource Development (HRD). In the Talent DNA model, Shravanthi and Sumanth (2008) proposed a talent management framework designed to create a strategic roadmap for achieving organizational objectives. The model is built around the concept of DNA, which comprises three key components: identifying critical roles, defining the competencies required for those roles, and recognizing the necessary talent. This cycle is supported by the development of a comprehensive competency database, which provides a structured mechanism for making informed and accurate talent-related decisions (Omotunde & Alegbeleye, 2021). The relevance of the Talent DNA model to this study lies in its emphasis on identifying and integrating role-specific skills and capabilities, thereby guiding the design and development of competencies required for the TTP. These components are critical for shaping an effective training model. To ensure a comprehensive approach, the study also incorporates McLagan's HRD Model, which categorizes competencies into four essential domains: technical, business, intellectual, and interpersonal. These competency areas form a well-rounded foundation for HRD professionals and support both individual and organizational growth. The integration of McLagan's model provides a structured lens for categorizing and defining the competencies needed within the proposed framework. Accordingly, this study recognizes the Talent DNA model and McLagan's HRD model as the key theoretical underpinnings of the study, with both models serving as foundational theories while the Sequential Iterative Model (SIM) serves as supporting model. The theoretical framework developed based on these models is presented in Figure 2.

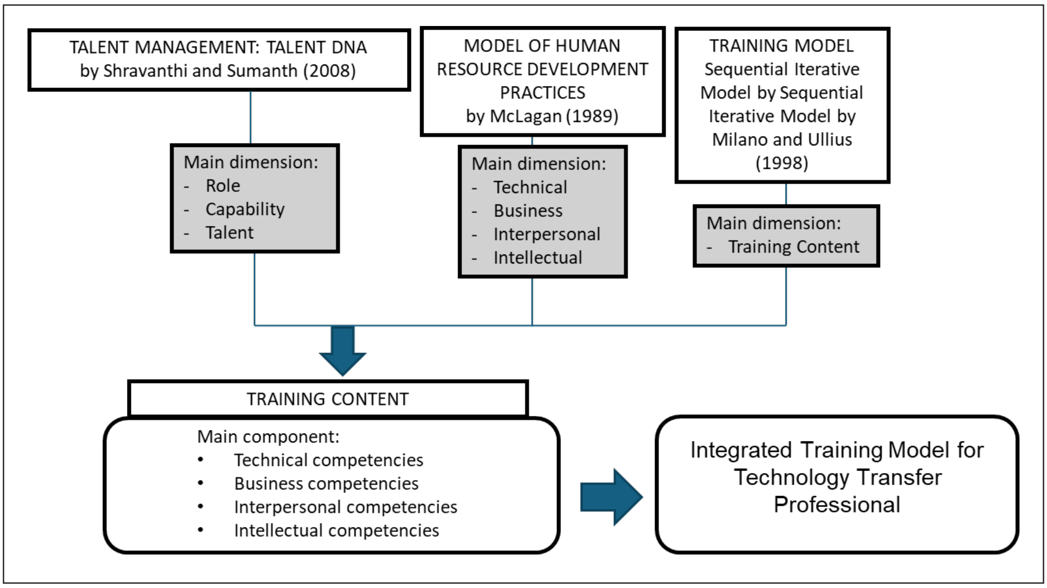

Figure 2. Theoretical framework

METHODOLOGY

This study utilized a quantitative method, specifically FDM, to obtain consensus from experts on the components necessary for a training model for TTP. The FDM was chosen for its ability to systematically gather expert opinions and achieve consensus. Experts were selected through purposive sampling to ensure appropriateness and adherence to criteria recommended by scholars for maximizing result accuracy (Jamil & Noh, 2020; Mohd @ Ariffin & Md Rami, 2023; Siraj et al., 2021). Criteria included a minimum of a bachelor's degree, at least five years of experience in technology transfer and commercialization, and successful commercialization of at least five technologies to companies. According to Berliner (2004), individuals with more than five years of experience are considered skilled in their field, while Gambatese (2008) emphasized the importance of high academic qualifications for experts. The FDM typically requires a minimum of 10 experts to ensure high uniformity in opinions (Adler & Ziglio, 1996; Jones & Twiss, 1978). Therefore, this study involved 14 experts obtaining a consensus on the important components to integrate into the TTP training model.

FDM incorporates principles from fuzzy set theory, representing an evolution from the traditional Delphi method and offering efficiencies in time, cost, and procedural handling through survey questionnaires (Yusoff et al., 2021). It comprises two main components: the triangular fuzzy number and the defuzzification process. To represent expert opinions, a triangular fuzzy number represented as m_1, m_2, m_3 was employed. This format creates a fuzzy scale similar to the Likert scale, enabling the conversion of linguistic variables into fuzzy numerical values. The scale uses odd-numbered levels to indicate degrees of agreement, where higher fuzzy values reflect greater precision and accuracy in the data (Jamil et al., 2024). Figure 3 illustrates the summary of methodology for this study.

The 7-point Likert scale strengthens methodological accuracy as higher Likert scales are reported to enhance precision and reliability of the data (Mohd et al., 2018). Table 1 illustrates the 7-point Likert scale used in this study to represent the fuzzy values.

The questionnaire development in this study draws upon insights from a literature review and a series of interviews with experts conducted in earlier phases (Jamil et al., 2014; Mohd @ Ariffi & Md Rami, 2023). According to Skulmoski et al. (2007), the development of research instruments such as questionnaires should integrate findings from literature reviews, pilot studies, and expert input, tailored specifically to the research area (Okoli & Pawlowski, 2004; Yusof et al., 2021). The questionnaire then underwent validation procedures, including assessments of language and content validity, with input from field experts. This study encompasses four competencies and their respective items (Table 2), identified as essential for TTP to effectively facilitate technology transfer and commercialization.

Table 1
The 7-point Likert scale

Scale	Linguistic variable	Fuzzy scale
1	Extremely disagree	(0.9,1.0,1.0)
2	Strongly disagree	(0.7,0.9,1.0)
3	Disagree	(0.5,0.7,0.9)
4	Partially agree	(0.3,0.5,0.7)
5	Agree	(0.1,0.3,0.5)
6	Strongly agree	(0.0,0.1,0.3)
7	Extremely agree	(0.0,0.0,0.1)

Source: Jamil and Nooh (2020)

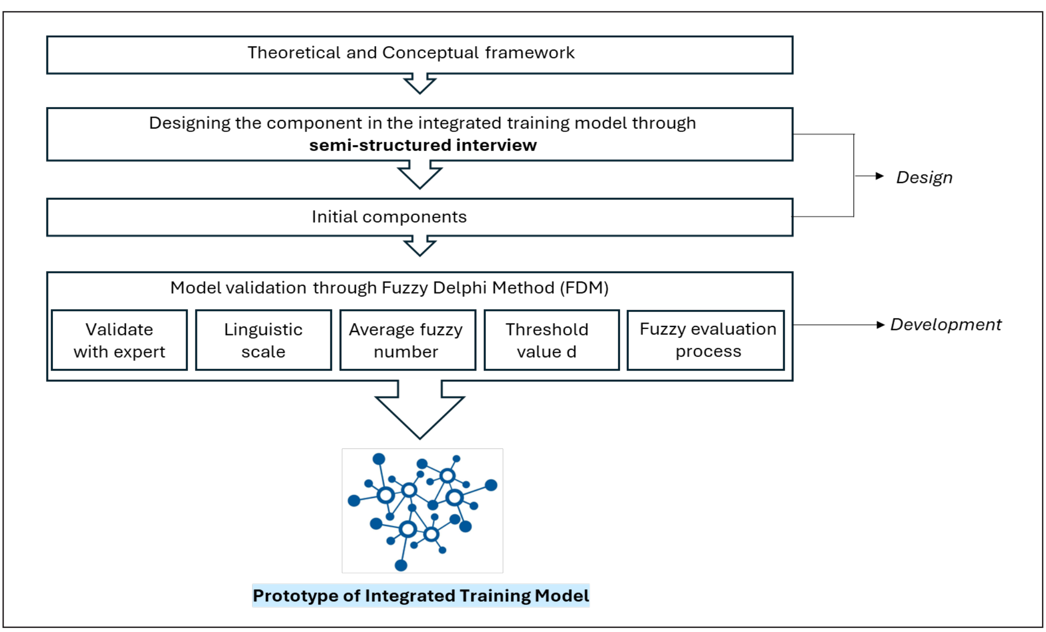

Figure 3. Summary of methodology

Table 2
Components in the training model for Technology Transfer Professionals

No.	Component/ Element	Items	Literature review
1	Technical competency	A1. Science, technology, and innovation (STI) A2. Technology assessment and profiling A3. Technology valuation A4. Intellectual property (IP) management and IP strategy A5. Regulatory requirements A6. Conduct, analyze, present, and evaluate market research whenever necessary A7. Due diligence and company profiling	Fasi (2022); Khademi et. al. (2014); Mom et. al. (2012); Sachani (2020); Soares and Torkomian (2021); Takata et. al. (2022)
2	Interpersonal competency	C1. Communication skills C2. Negotiation skills C3. Networking and sustaining relationships C4. Project management skills C5. Problem-solving skills C6. Teamwork skills C7. Generic interpersonal skills	
3	Knowledge competency	D1. Commercialization knowledge D2. Legal literacy knowledge D3. Marketing strategy knowledge D4. Finance knowledge D5. Investment knowledge which covers investment-worthy to prove the technology can be incorporated into a product or service, investment outcomes, and investment risk D6. Industry knowledge includes: i. Identify and exploit new opportunities ii. Knowledge of industrial competition iii. Compliance with regulation iv. Knowledge of commercial security	
4	Entrepreneurship competency	E1. Respond and manage several uncertain situations E2. Development of a market-viable proof of concept, identify and convince promising stakeholders, and effectively execute the transfer to industries. E3. Envision the commercial value of innovations and technologies and convince potential stakeholders.	

Note. The authors' comprehension derived from prior interviews with subject matter experts

DATA ANALYSIS

The data analysis of the FDM is conducted systematically using Microsoft Excel software, as advocated by leading scholars in the field (Jamil et al., 2014; Jamil & Noh, 2020; Ramlie et al., 2014; Yusoff et al., 2021). The analysis adheres to established FDM guidelines, which specify that the threshold value (d) should not exceed 0.2 (Chen, 2000; Cheng & Lin, 2002). Moreover, it ensures that the percentage of expert agreements meets or exceeds 75% (Chu & Hwang, 2008) and that the fuzzy score (A_{max}) equals or exceeds 0.5.

In the ranking process, components are prioritized based on their fuzzy score values, with higher scores indicating greater consensus among experts. A detailed explanation of these conditions is as follows:

(a) Condition 1: Triangular Fuzzy Numbers – Threshold value (d) is ≤ 0.2

Expert consensus is achieved when the resultant value is 0.2 or less. Components and items with values of 0.2 or lower are considered accepted, indicating consensus among experts. This determination is based on the following formula:

$$d(\vec{m},\vec{n}) = \sqrt{\frac{1}{3}[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - m_3)^2]}$$

(b) Condition 2: Expert agreement percentage is ≥ 75%

This criterion follows the principles of the traditional Delphi method, where the percentage value is determined based on the number of items with a threshold value (d) not exceeding 0.2. Each item meeting or falling below this threshold (d ≤ 0.2) is accepted and converted to a percentage value based on the traditional Delphi method (Mohd @ Ariffin & Md Rami, 2023).

(c) Condition 3: Defuzzification value – Fuzzy score (A) value is ≥ 0.5

This condition determines the fuzzy score value based on the α-cut, which is set at 0.5. A fuzzy score (A) value below 0.5 indicates that the item is rejected based on the consensus of the experts. Conversely, a value of 0.5 or above indicates acceptance of the item. Further steps to determine the position or ranking of items involve prioritizing items based on their fuzzy score values, with the highest A value assigned the first position or rank. The determination of the value A score is based on the following formula:

$$A = \frac{1}{3}(m_1 + m_2 + m_3)$$

RESULTS

Demographic Information

Experts' demographic information is shown in Table 3. The majority of the experts possessed a Ph.D., obtained years of experience working in technology transfer and commercialization, and 64% are certified Registered Technology Transfer Professional (RTTP).

Technical Competency

Based on the findings presented in Table 4, items A1, A2, A4, and A7 have garnered consensus among experts. These items were evaluated against the three conditions stipulated in the FDM:

Table 3
Experts' demographic information

Expert	Years of experience in technology transfer and commercialization (Years)	Professional certification	Academic qualification
FDM1	30	-	Doctoral degree
FDM2	16	RTTP	Doctoral degree
FDM3	6	RTTP	Doctoral degree
FDM4	10	RTTP	Doctoral degree
FDM5	45	RTTP	Master's degree
FDM6	7	RTTP	Doctoral degree
FDM7	15	RTTP	Doctoral degree
FDM8	10	-	Doctoral degree
FDM9	17	RTTP	Master's degree
FDM10	7	RTTP	Doctoral degree
FDM11	7	-	Doctoral degree
FDM12	14	-	Doctoral degree
FDM13	21	-	Doctoral degree
FDM14	18	RTTP	Master's degree

Note. FDM = Fuzzy Delphi Method; RTTP = Registered Technology Transfer Professional

Table 4
Findings of the expert consensus on technical

Technical competency	Value d of item	Value d of element	Percentage of expert agreement on the item (%)	Fuzzy score (A_{max})	Position/ Ranking	Expert consensus
A1	0.153	0.138	79	0.860	4	Accept
A2	0.111		86	0.914	1	Accept
A3	0.192		57	0.817	-	Reject
A4	0.111		86	0.914	1	Accept
A5	0.162		64	0.850	-	Reject
A6	0.147		64	0.836	-	Reject
A7	0.089		86	0.871	3	Accept

a threshold value ≤ 0.2, expert agreement exceeding 75%, and a defuzzification value (α-cut) of 0.5 or higher. Conversely, other items were rejected due to their failure to meet the required threshold of expert agreement exceeding 75%. The accepted items were subsequently ranked in order of priority, as depicted in Table 5, highlighting their significance for integration into the training model for TTP.

Table 5
Ranking of items for technical

Ranking	Items	Item code
1	Technology assessment and profiling	A2
2	IP management and IP strategy	A4
3	Due diligence and company profiling	A7
4	STI	A1

Note. IP = Intellectual property; STI = Science, technology, and innovation

Interpersonal Competency

Based on the findings presented in Table 6, all items have garnered consensus among experts. These items were evaluated against the three conditions stipulated in the FDM: a threshold value ≤ 0.2, expert agreement exceeding 75%, and a defuzzification value (α-cut) of 0.5 or higher. The items were subsequently ranked in order of priority, as depicted in Table 7, highlighting their significance for integration into the training model for TTP.

Table 6
Findings of expert consensus on interpersonal

Interpersonal competency	Value d of item	Value d of element	Percentage of expert agreement on the item (%)	Fuzzy score (A_{max})	Position/ Ranking	Expert consensus
C1	0.078	0.101	93	0.933	1	Accept
C2	0.087		93	0.926	4	Accept
C3	0.087		93	0.926	3	Accept
C4	0.138		86	0.879	7	Accept
C5	0.078		93	0.933	1	Accept
C6	0.120		93	0.905	5	Accept
C7	0.120		93	0.905	5	Accept

Knowledge Competency

Based on the findings presented in Table 8, items D1, D3, D4, and D6 have garnered consensus among experts. These items were evaluated against the three conditions stipulated in the FDM: a threshold value ≤ 0.2, expert agreement exceeding 75%, and a defuzzification value (α-cut) of 0.5 or higher. Conversely, other items were rejected due to their failure to meet the required threshold of expert agreement exceeding 75%. The accepted items were subsequently ranked in order of priority, as depicted in Table 9, highlighting their significance for integration into the training model for TTP.

Table 7
Ranking of items for interpersonal

Ranking	Items	Item code
1	Communication skills	C1
2	Problem-solving skills	C5
3	Networking and sustaining the relationship	C3
4	Negotiation skills	C4
5	Teamworking skills	C6
6	Generic interpersonal skills	C7
7	Project management skills	C4

Entrepreneurship Competency

Based on the findings presented in Table 10, all items have garnered consensus among experts. These items were evaluated against the three conditions stipulated in the FDM:

a threshold value ≤ 0.2, expert agreement exceeding 75%, and a defuzzification value (α-cut) of 0.5 or higher. The items were subsequently ranked in order of priority, as depicted in Table 11, highlighting their significance for integration into the training model for TTP.

Table 8
Findings of expert consensus on knowledge

Knowledge competency	Value d of item	Value d of element	Percentage of expert agreement on the item (%)	Fuzzy score (A_{max})	Position/ Ranking	Expert consensus
D1	0.062	0.134	100	0.938	1	Accept
D2	0.147		64	0.836		Reject
D3	0.113		86	0.893	3	Accept
D4	0.166		79	0.795	4	Accept
D5	0.199		64	0.788		Reject
D6	0.115		86	0.900	2	Accept

Table 9
Ranking of items for knowledge

Ranking	Items	Item code
1	Commercialization knowledge	D1
2	Industry knowledge	D6
3	Marketing strategy knowledge	D3
4	Finance knowledge	D4

Table 10
Findings of expert consensus on entrepreneurship

Entrepreneurship competency	Value d of item	Value d of element	Percentage of expert agreement on the item (%)	Fuzzy score (A_{max})	Position/ Ranking	Expert consensus
E1	0.153	0.143	79	0.860	3	Accept
E2	0.138		86	0.879	1	Accept
E3	0.138		86	0.879	1	Accept

Table 11
Ranking of items for entrepreneurship

Ranking	Items	Item code
1	Development of a market-viable proof of concept, identify and convince promising stakeholders, and effectively execute the transfer to industries.	E2
2	Envision the commercial value of innovations and technologies and convince potential stakeholders.	E3
3	Respond and manage several uncertain situations in bridging commercialization gaps.	E1

DISCUSSION

Through the analysis of FDM, the researcher has identified several elements and items that should be integrated into the training model for TTP. This study represents a novel contribution by offering a comprehensive model specifically focused on TTP as a human capital system designed to optimize the utilization of individual talents for achieving maximum returns for their organization (Kibui et al., 2014). Furthermore, through a holistic perspective, enhancing technology transfer and commercialization within organizations contributes to governmental goals, thereby fostering economic growth and advancing a globally competitive, innovation-driven economy. The research output, namely the training model for TTP, serves as a pivotal component of a talent management tool designed to systematically attract, identify requisite competencies, develop, engage through appropriate training programs, retain, and strategically deploy TTP that transmit substantial value to the organization. This value may manifest in their high potential for future roles or in their critical contributions to business operations (Brantnell & Baraldi, 2022; Chau et al., 2017).

The training model developed in this study differs significantly from the professional certification known as the RTTP, which is organized by the Alliance of Technology Transfer Professionals (ATTP). According to ATTP (2025), RTTP is an internationally recognized standard that certifies the professional competence and experience of technology transfer practitioners working in universities, industry, and government laboratories, based on a proven track record of real-world achievements. It requires individuals to demonstrate mastery of domain-specific knowledge and a specific achievement in technology transfer and commercialization. The RTTP framework leverages a specialized model that has been integrated with existing national systems across several countries. It emphasizes core competencies essential for RTTP designation, including entrepreneurial leadership, governance, and project management, as well as strategic and business acumen.

In contrast, the training model proposed in this study is designed specifically for end users such as novice or early-career TTP. It emphasizes applied learning, proactive role development, and is aligned with the latest advancements and best practices in the field of technology commercialization. Unlike RTTP, which necessitates prior experience and accomplishments, this model addresses the foundational capacity-building needs of beginner TTPs, who are not yet eligible for RTTP certification. By providing structured, competency-based training early in their careers, this model plays a crucial role in bridging the gap between entry-level practice and professional recognition. It serves as an essential stepping stone, equipping novice TTPs with the knowledge, skills, and confidence needed to advance toward future RTTP certification and excel in the field of technology transfer and commercialization.

Based on the findings, the components encompassing technical, interpersonal, knowledge, and entrepreneurial competencies are identified as critical prerequisites for effectively equipping TTP to perform tasks in technology transfer and commercialization activities in the Malaysian framework. Each component includes specific items acknowledged by experts as crucial for training TTP. Therefore, these components have been integrated into the training model as a research output of the overall study to guide the development of future training programs. Competency refers to the capability of TTP to effectively address complex demands within a specific context by mobilizing knowledge, skills, attitudes, and values. It comprises behavioral patterns necessary for TTP to perform tasks and functions effectively. Within the competencies, it pertains to the functional knowledge, skills, and attributes required for technology transfer and commercialization activities (Brantnell & Baraldi, 2022).

According to the findings, technical competency requires TTP to be competent in (i) STI, (ii) technology assessment and profiling to ensure its commercial potential, (iii) IP management and IP strategy, and (iv) due diligence and company profiling. These items are crucial to be part of the training model as TTP often encounters a diversity of technological developments created by researchers, and it may lead to distinct patterns of IP protection and managing the overall commercialization pathway (Soares & Torkomian, 2021). In today's rapidly advancing technological landscape, technological revolution boosts numerous advancements observed in health, agriculture, energy, and global development. Hence, TTP must adeptly navigate these challenges. According to Comacchio et al. (2012), TTPs' technical expertise allows them to effectively translate scientific language and transform intellectual knowledge into practical applications. This capability not only increases the potential for commercial exploitation and reduces information asymmetry during negotiations with firms, but also has significant international relevance. By bridging the gap between research and industry across different innovation systems, this function of TTP can facilitate cross-border technology commercialization, support international R&D collaborations, and contribute to the global diffusion of innovation, thereby accelerating technological adoption globally. This activity involves several pathways besides the linear process, including invention disclosure, technology assessment, patenting, and licensing to potential and capable firms or industry (Hayter et al., 2020).

In interpersonal competency, the finding reveals that all items are important to integrate in the training model for TTP, this includes (i) communication skill, (ii) problem-solving skill, (iii) networking and sustaining the relationship, (iv) negotiation skill, (v) team working skill, (vi) generic interpersonal skill, and (vii) project management skill. This study defines interpersonal skills as TTP's special skills and abilities for effective interaction. These skill sets are crucial for TTP to acquire and master, as they serve as professional mediators between institutions and industry (Mom et al., 2012; Sachani, 2020; Takata et al., 2022). TTP needs to translate scientific language into business language effectively. As technology advances, every stakeholder within the ecosystem, whether technology provider, technology recipient, investor, policymaker, or consumer, has their distinct mission and vision. Therefore, the roles and responsibilities of TTP today are increasingly complex due to the diverse interests within the ecosystem, particularly in concluding commercialization agreements. Interpersonal competency is critically important for TTPs operating in a global context, as it enables them to navigate cross-cultural environments effectively and build strong, collaborative relationships across international boundaries.

For knowledge competency, several items are important to be integrated in the training model, and they include (i) commercialization knowledge, (ii) industry knowledge, (iii) marketing strategy knowledge, and (iv) finance knowledge. In this study, knowledge is defined as the intellectual aspects of TTP, which relate to knowledge and skills for thinking and processing information related to technology transfer and commercialization. This component is crucial for TTP to navigate the entirety of the technology transfer and commercialization process—from its inception to its conclusion. By effectively managing stages such as technology and market positioning, identifying suitable licensees or partners for technology transfer and commercialization, and delineating potential commercialization pathways, TTP can significantly enhance the likelihood of achieving successful outcomes. This minimizes the risk of misjudgment at any stage of the process and ensures more effective technology transfer and commercialization, not only at the national level but also within the global innovation landscape. The knowledge and awareness related to these activities are deemed crucial for the business environment of technology transfer and commercialization strategic decisions (Mom et al., 2012). With this knowledge, it would be straightforward for TTP to identify opportunities at various stages, given the evolving nature of technology-related knowledge. TTP may encounter risks associated with a lack of knowledge and awareness in technology transfer and commercialization, as noted by scholars. Research has shown that this deficiency has led universities in the United Kingdom to misjudge their approach to spin-offs in technology transfer engagements (Lambert, 2003; Mom et al., 2012).

Entrepreneurship competency has been remarked as the evolving component that TTP should have today. It comprises the elements of (i) developing a market-viable proof of concept, identifying and convincing promising stakeholders, and effectively executing the transfer to industries, (ii) envisioning the commercial value of innovations and technologies, and convincing potential stakeholders, and (iii) responding to and managing several uncertain situations. In this study, entrepreneurship is defined as the behavioral patterns of TTP that progressively look at the opportunities in technology transfer and commercialization. Recent studies have shown that entrepreneurial behavior is influenced by the emerging roles of TTP and the function of research institutions, including universities (Fasi, 2022; Takata et. al., 2022). In the Malaysian framework, the government emphasizes that scientific inventions should benefit the community, thereby contributing to economic growth. With the commercialization gap widening, TTPs play a crucial role in facilitating researchers in technological development. This includes persuading businesses of the commercial viability of innovations and ensuring that inventions can penetrate the market and meet manufacturability standards. This process often involves consultations and collaboration with research engineers to scale up the technology effectively. The aspect of commercialization strategies is important for TTP as it observes technology risk management, how to transform inventions into marketable products, and how to identify the best commercialization pathway for specific technologies or innovations. At the global level, entrepreneurial-minded TTPs play a pivotal role in accelerating international technology transfer, enabling cross-border innovation, and driving the development of competitive, innovation-led economies worldwide. This study defines entrepreneurship competency as one of the components for sustainable business practices that lead to shaping the future of technology innovation. Today, the role of TTP has evolved to encompass not only facilitating technological development but also validating innovations for practicality and commercial viability (Sachani, 2020; Takata et al., 2022) to ensure the technology succeeds in penetrating the market. This dual responsibility aims to mitigate the risk of business sustainability failures for firms.

In response to the evolving role of TTP today, research underscores the importance of developing a training model focused on professional work in technology transfer and commercialization. This initiative aligns with the increasingly complex and diverse responsibilities of TTP today. As professional mediators, the organization and government must support TTP through offering tailored training programs that enhance their credibility and reputation in professional engagements with stakeholders, while bolstering their skills, competencies, and intelligence. Given the importance of the training program's content and modules, there is a distinct need to create a specialized training model tailored for TTP, as identified by Giday and Elantheraiyan (2023). This model should cater not only to novice TTP but also to experienced professionals who seek to enhance their competencies in technology transfer and commercialization.

CONCLUSION

This study contributes a novel perspective to the research on training model development for TTP by presenting a structured model as a key research output. It identifies and integrates four essential competency components into the model: (i) technical competency, (ii) interpersonal competency, (iii) knowledge competency, and (iv) entrepreneurship competency. Each component includes specific items that will serve as essential elements—or module content of training programs—requiring training for TTP to enhance their competency and skill set in executing their roles effectively. Its focused approach ensures the training is highly relevant, addresses specific needs, and bridges practical gaps, thereby enhancing the training's effectiveness and meeting the unique requirements of TTP.

From a theoretical perspective, this model represents a significant advancement in talent development, HRD, and the broader field of technology transfer and commercialization. It is purposefully designed to address the evolving roles and responsibilities of TTP, integrating core competencies that are essential in today's innovation landscape.

This training model contributes to talent management in both HRD and technology transfer and commercialization, practically and theoretically. It serves as a reference tool for strategizing key components essential for effective succession management through guiding the organization in forecasting the TTP needs. Moreover, this study identifies critical components to integrate into the training model, aimed at equipping TTP with essential modules to engage in technology transfer and commercialization activities proficiently. It is a recognized model among Malaysian organizations with Technology Transfer Offices (TTOs), demonstrating its applicability across universities, research institutions, agencies, and ministries. As institutions globally confront similar challenges in bridging the gap between research and market, this model provides a scalable and adaptable framework for enhancing the talent management of TTP ecosystems, which could extend its impact beyond Malaysia.

RECOMMENDATIONS

For future research, it is recommended to develop a dedicated training module grounded in the training model proposed in this study. This approach will support the creation of high-quality content, ensure consistency across the training program, and effectively achieve intended outcomes aligned with best practices. The training program also has the potential to empirically measure performance outcomes for TTP, including the number of technology licensing activities, commercialization success rates, startup creation, and enhanced industry-academic collaborations. The model is further strengthened by a comprehensive evaluation framework that incorporates pre- and post-training assessments, participant feedback, and longitudinal tracking of key performance indicators. These metrics not only reflect the development of individual competencies but also validate the model's broader contribution to fostering a more dynamic, resilient, and innovation-driven economy.

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REFERENCES

Adler, M., & Ziglio, E. (Eds.) (1996). *Gazing into the Oracle: The Delphi method and its application to social policy and public health*. Jessica Kingsley Publisher.

Alliance of Technology Transfer Professionals. (2025). *ATTP – Global standards in knowledge and technology transfer*. https://attp.global/

Berliner, D. C. (2004). Describing the behavior and documenting the accomplishments of expert teachers. *Bulletin of Science, Technology and Society*, *24*(3), 200-212. https://doi.org/10.1177/0270467604265535

Boguszewicz-Kreft, M., Arvanitis, A., Karatzas, K., Antonelli, G., & Simonetti, B. (2021). Technology transfer steps towards the commercialization of research results for universities. *WSB Journal of Business and Finance*, *55*(1), 26-39. https://doi.org/10.2478/wsbjbf-2021-0003

Brantnell, A., & Baraldi, E. (2022). Understanding the roles and involvement of technology transfer offices in the commercialization of university research. *Technovation*, *115*, 102525. https://doi.org/10.1016/j.technovation.2022.102525

Chau, V. S., Gilman, M., & Serbanica, C. (2017). Aligning university–industry interactions: The role of boundary spanning in intellectual capital transfer. *Technological Forecasting and Social Change*, *123*, 199–209. https://doi.org/10.1016/j.techfore.2016.03.013

Chen, C.-T. (2000). Extensions of the TOPSIS for group decision-making under fuzzy environment. *Fuzzy Sets and Systems*, *114*(1), 1–9. https://doi.org/10.1016/S0165-0114(97)00377-1

Cheng, C.-H., & Lin, Y. (2002). Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation. *European Journal of Operational Research*, *142*(1), 174-186. https://doi.org/10.1016/S0377-2217(01)00280-6

Chu, H.-C., & Hwang, G.-J. (2008). A Delphi-based approach to developing expert systems with the cooperation of multiple experts. *Expert Systems with Applications*, *34*(4), 2826–2840. https://doi.org/10.1016/j.eswa.2007.05.034

Comacchio, A., Bonesso, S., & Pizzi, C. (2012). Boundary spanning between industry and university: The role of technology transfer centres. *The Journal of Technology Transfer*, *37*, 943-966. https://doi.org/10.1007/s10961-011-9227-6

Cunningham, J. A., & O'Reilly, P. (2018). Macro, meso and micro perspectives of technology transfer. *The Journal of Technology Transfer*, *43*, 545-557. https://doi.org/10.1007/s10961-018-9658-4

Fasi, M. A. (2022). An overview on patenting trends and technology commercialization practices in the university Technology Transfer Offices in USA and China. *World Patent Information*, *68*, 102097. https://doi.org/10.1016/j.wpi.2022.102097

Giday, D. G., & Elantheraiyan, P. (2023). A study on the effect of training on employee performance in the case of Mekelle City, Tigray, Ethiopia. *Social Sciences and Humanities Open*, *8*(1), 100567. https://doi.org/10.1016/j.ssaho.2023.100567

Hayter, C. S., Rasmussen, E., & Rooksby, J. H. (2020). Beyond formal university technology transfer: Innovative pathways for knowledge exchange. *The Journal of Technology Transfer*, *45*, 1-8. https://doi.org/10.1007/s10961-018-9677-1

Jamil, M. R. M., Idris, N., Aris, N. M., Razalli, A. R., Zalli, M. M. M., Othman, M. S., Hosshan, H., & Noh, N. M. (2024). Crafting a blueprint for enhancing emotional well-being in special education post-pandemic: A fuzzy Delphi approach. *International Journal of Advanced and Applied Sciences*, *11*(11), 99-111. https://doi.org/10.21833/ijaas.2024.11.011

Jamil, M. R. M., & Noh, N. R. M. (2020). *Kepelbagaian metodologi dalam penyelidikan reka bentuk dan pembangunan* [Diversity of methodologies in design and development research]. Qaisar Prestige Resources.

Jamil, M. R. M., Siraj, S., Hussin, Z., Noh, N. M., & Sapar, A. A. (2014). *Pengenalan asas kaedah Fuzzy Delphi dalam penyelidikan rekabentuk dan pembangunan* [Basic introduction to the Fuzzy Delphi method in design and development research]. Minda Intelek.

Jensen, R., & Thursby, M. (2001). Proofs and prototypes for sale: The licensing of university inventions. *American Economic Revi*ew, *91*(1), 240–259. https://doi.org/10.1257/aer.91.1.240

Jiang, C., Li, S., & Shen, Q. (2024). Science and technology evaluation reform and universities' innovation performance. *Technology in Society*, *78*, 102614. https://doi.org/10.1016/j.techsoc.2024.102614

Jones, H., & Twiss, B. C. (1978). *Forecasting technology for planning decisions*. Macmillan Press.

Kasim, A. M., Chang, L. W., Norpi, N. M., Kasim, N. H. A., & Hashim, A. (2021). Enhancing research mechanisms and institutional processes in Malaysia: A case study of Universiti Malaya (UM). *Journal of Research Management and Governance*, *4*(1), 10-23. https://doi.org/10.22452/jrmg.vol4no1.2

Khademi, T., Parnian, A., Garmsari, M., Ismail, K., & Lee, C. T. (2014). Role of technology transfer office/centre of universities in improving the commercialization of research outputs: A case study in Malaysia. In *Knowledge Management International Conference* (pp. 538–542). Universiti Utara Malaysia Press. https://doi.org/10.13140/2.1.2122.9443

Kibui, A. W., Gachunga, H., & Namusonge, G. S. (2014). Role of talent management on employees retention in Kenya: A survey of state corporations in Kenya: Empirical review. *International Journal of Science and Research*, *3*(2), 414–424.

Kogabayev, T., & Maziliauskas, A. (2017). The definition and classification of innovation. *HOLISTICA - Journal of Business and Public Administration*, *8*(1), 59–72. https://doi.org/10.1515/hjbpa-2017-0005

Lambert, R. (2003). *Lambert Review of business-university collaboration: Final report*. Her Majesty's Treasury.

Manap, A., Ismail, N., & Sidek, S. (2017). The roles of technology transfer offices to facilitate intellectual property commercialisation in the university: Issues and challenges. *The Social Sciences*, *12*(6), 919–924.

McLagan, P. A. (1989). Models for HRD practice. *Training and Development Journal*, *41*(9), 49–59.

Milano, M., & Ullius, D. (1998). *Designing powerful training: The sequential-iterative model* (1st ed.). Pfeiffer.

Mohd @ Ariffin, J. A., & Md Rami, A. A. (2023). Application of the Fuzzy Delphi Method to identify middle leaders' competencies in crisis management. *Management Research Journal*, *12*(1), 26–37. https://doi.org/10.37134/mrj.vol12.1.3.2023

Mohd, R., Siraj, S. & Hussin, Z. (2018). Aplikasi kaedah Fuzzy Delphi dalam pembangunan modul pengajaran pantun Melayu berasaskan maksud al-Quran mengenai keindahan flora, fauna dan langit Tingkatan 2

[Fuzzy Delphi method application in developing model of Malay poem based on the meaning of the Quran about flora, fauna and sky in Form 2]. *Jurnal Pendidikan Bahasa Melayu*, *8*(2), 57-67.

Mom, T. J. M., Oshri, I., & Volberda, H. W. (2012). The skills base of technology transfer professionals. *Technology Analysis and Strategic Management*, *24*(9), 871-891. https://doi.org/10.1080/09537325.2012.718663

Okoli, C., & Pawlowski, S. D. (2004). The Delphi method as a research tool: An example, design considerations and applications. *Information and Management*, *42*(1), 15-29. https://doi.org/10.1016/j.im.2003.11.002

Omotunde, O. I., & Alegbeleye, G. O. (2021). Talent management practices and job performance of librarians in university libraries in Nigeria. *The Journal of Academic Librarianship*, *47*(2), 102319. https://doi.org/10.1016/j.acalib.2021.102319

Ramlie, H. A., Hussin, Z., Jamil, M. R. M., Sapar, A. A., Siraj, S., & Noh, N. R. M. (2014). Aplikasi teknik Fuzzy Delphi terhadap keperluan aspek 'Riadhah Ruhiyyah' untuk profesionalisme perguruan Pendidikan Islam [Application of Fuzzy Delphi technique to the needs of 'Riadhah Ruhiyyah' aspects for the professionalism of Islamic Education teachers]. *The Online Journal of Islamic Education*, *2*(2), 53-72.

Sachani, S. S. (2020). Best of both worlds: A career in technology transfer and business development. *Developmental Biology*, *459*(1), 30-32. https://doi.org/10.1016/j.ydbio.2019.10.025

Shravanthi, S., & Sumanth, G. (2008). Talent DNA model. *Journal of Human Resource Management*, *22*(1), 78-85.

Siraj, S., Abdullah, M. R. T. L. A., & Rozkee, R. M. (2021). *Pendekatan penyelidikan rekabentuk dan pembangunan: Aplikasi kepada penyelidikan pendidikan* [Design and development research approaches: Applications to educational research]. Penerbit Universiti Pendidikan Sultan Idris.

Skulmoski, G. J., Hartman, F. T., & Krahn, J. (2007). The Delphi method for graduate research. *Journal of Information Technology Education*, *6*(1), 1-21.

Soares, T. J., & Torkomian, A. L. V. (2021). TTO's staff and technology transfer: Examining the effect of employees' individual capabilities. *Technovation*, *102*, 102213. https://doi.org/10.1016/j.technovation.2020.102213

Swamidass, P. M., & Vulasa, V. (2009). Why university inventions rarely produce income? Bottlenecks in university technology transfer. *The Journal of Technology Transfer*, *34*, 343-363. https://doi.org/10.1007/s10961-008-9097-8

Takata, M., Nakagawa, K., Yoshida, M., Matsuyuki, T., Matsuhashi, T., Kato, K., & Stevens, A. J. (2022). Nurturing entrepreneurs: How do technology transfer professionals bridge the Valley of Death in Japan? *Technovation*, *109*, 102161. https://doi.org/10.1016/j.technovation.2020.102161

Wang, W., Hu, B., Liu, J., & Yang, Z. (2024). Can antitrust policy promote enterprise innovation? Evidence from Zhongguancun Science and Technology Park. *Heliyon*, *10*(9), e30341. https://doi.org/10.1016/j.heliyon.2024.e30341

World Intellectual Property Organization. (2024). *Global Innovation Index 2024: Unlocking the promise of social entrepreneurship* (17th ed.). WIPO. https://doi.org/10.34667/tind.50062

Yusoff, A. F. M., Hashim, A., Muhamad, N., & Wan Hamat, W. N. (2021). Application of Fuzzy Delphi technique to identify the elements for designing and developing the e-PBM PI-Poli module. *Asian Journal of University Education*, *17*(1), 292-304.