SUNTEXT REVIEWS

SunText Review of Economics & Business
ISSN: 2766-4775

Open Access
Research Article
Volume 5:2

From Lab to Market: Cultivating Entrepreneurial Chemists for a Sustainable Future

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Received date: 09 December 2024; **Accepted date:** 12 December 2024; **Published date:** 20 December 2024

Citation: Abdelreheem Ead H (2024) From Lab to Market: Cultivating Entrepreneurial Chemists for a Sustainable Future. SunText Rev Econ Bus 5(2): 209.

DOI: https://doi.org/10.51737/2766-4775.2024.109

Abstract

This study explores the intersection of academic research and commercial innovation in chemistry. By integrating entrepreneurship education into the PhD chemistry curriculum, we aim to foster a new generation of entrepreneurial chemists capable of translating scientific discoveries into real-world solutions. We investigate the impact of Science-Based Entrepreneurship Education (SBEE) on students' entrepreneurial self-efficacy, knowledge, and skills, and explore the potential of SBEE to facilitate university-industry technology transfer. Our findings highlight the importance of balancing theoretical knowledge with practical experience, cultivating a strong entrepreneurial mindset, and fostering a supportive ecosystem to nurture innovation and commercialization. By addressing the unique challenges and opportunities presented by SBEE, we can empower chemists to drive sustainable economic growth and societal impact.

Keywords: Science-based entrepreneurship SBEE; Entrepreneurial education; Chemistry innovation; University-industry collaboration; Technology transfer

Introduction

The intersection of chemistry and entrepreneurship offers a promising avenue for innovation and economic growth. By fostering an entrepreneurial mindset among PhD chemistry students, we can empower them to translate scientific discoveries into real-world applications, driving technological advancements and addressing societal challenges. This study builds on our previous research, which explored various aspects of entrepreneurship education, including factors influencing entrepreneurial intentions, the role of critical thinking, and the impact of the COVID-19 pandemic on green entrepreneurship. In recent years, there has been a growing emphasis on integrating entrepreneurship education into higher education curricula. This trend is particularly relevant for PhD students, who often possess deep scientific knowledge but may lack the skills and mindset required to commercialize their research. By equipping these students with entrepreneurial skills, we can encourage them to think critically, identify market opportunities, and develop innovative solutions to global problems. Our research has demonstrated the potential of integrating entrepreneurship into chemistry education to enhance students' employability and entrepreneurial aspirations. Through hands-on projects, business plan competitions, and networking opportunities with industry professionals, we aim to cultivate a culture of innovation and entrepreneurship within chemistry departments. Building on this foundation, this study investigates specific strategies and interventions that can enhance the entrepreneurial mindset and skills of PhD chemistry students. By examining the challenges and opportunities associated with integrating entrepreneurship education into the chemistry curriculum, we seek to develop evidence-based recommendations for fostering a more entrepreneurial culture within academia.

The following research questions will guide this study: How can entrepreneurship education be effectively integrated into the PhD chemistry curriculum? What are the key entrepreneurial skills and knowledge that PhD chemistry students need to develop? What are the barriers and facilitators to integrating entrepreneurship education into the PhD chemistry curriculum? How can institutions

and organizations support the development of entrepreneurial skills and mindset among PhD chemistry students? By addressing these questions, this study contributes to the ongoing dialogue on entrepreneurship education in higher education and provides practical insights for educators, policymakers, and researchers seeking to promote innovation and economic growth. Integrating entrepreneurship into the PhD chemistry curriculum is especially crucial in the context of Egypt. This literature survey highlights recent approaches and conceptual issues surrounding this integration, drawing on current studies and practices. Recent studies emphasize the need for a structured curriculum that includes entrepreneurship modules tailored for chemistry students, involving both theoretical knowledge and practical applications, such as business planning and understanding market dynamics. For instance, a case study at Cairo University demonstrated the effectiveness of integrating entrepreneurship into the chemistry curriculum for postgraduate students, highlighting the positive impact on their entrepreneurial mindset and skills.

Employing mixed-methods approaches, such as surveys and focus groups, have been effective in assessing the impact of entrepreneurship education on students. These approaches provide insights into their self-efficacy and readiness to engage in entrepreneurial activities critical for their future careers in science and technology. Creating collaborative learning environments where students tackle real-world problems enhances their understanding of chemistry while equipping them with the necessary skills for navigating the complexities of starting and managing a business in the scientific field. Moreover, establishing mentorship programs that connect students with industry professionals significantly enhances their entrepreneurial skills, offering insights into funding, marketing, and commercialization strategies. In the Egyptian context, cultural attitudes towards entrepreneurship are shifting, with a growing recognition of its importance in driving economic growth. However, traditional academic structures often prioritize theoretical knowledge over practical skills, necessitating a cultural shift to foster an entrepreneurial mindset among PhD students in chemistry. Additionally, limited access to resources and funding for startups poses challenges for aspiring entrepreneurs. Addressing these barriers through institutional support and industry partnerships can facilitate the commercialization of research. The Egyptian government's increasing support for entrepreneurship initiatives highlights the need for policies that align educational frameworks with entrepreneurial goals in higher education. There is a critical need for skill development programs focusing on both technical and entrepreneurial skills, preparing students to excel in research and translate their findings into viable business opportunities. In conclusion, integrating entrepreneurship into the PhD chemistry curriculum in Egypt presents both opportunities and challenges. By adopting innovative educational strategies and addressing conceptual issues, educational institutions can cultivate a new generation of chemical innovators equipped to contribute to the economy and society (Tables 1,2).

Literature Survey

The integration of entrepreneurship into higher education, particularly within science and technology disciplines, has gained traction as a means to enhance university-industry technology transfer. This literature survey examines the intersection of science-based entrepreneurship education (SBEE) and its implications for university-industry collaboration, particularly within the context of PhD chemistry programs.

University-industry technology transfer

University-industry technology transfer is essential for fostering innovation and economic growth [1]. Traditional perspectives often attribute challenges in this area to insufficient collaboration between academic researchers and industry partners. However, Warren highlight that a supportive regional innovation system is crucial for successful technology transfer, suggesting that multiple factors influence this dynamic [2]. Anderson critique the efficiency of current organizational structures, such as Technology Transfer Offices, proposing a quantitative model to assess transfer efficiency [3]. Additionally, Audretsch emphasize the significance of firm location in facilitating these transfers [4]. Thus, understanding the broader context of university-industry technology transfer is vital for developing effective strategies for improvement.

Role of entrepreneurship education

In response to the need for enhanced collaboration, universities have increasingly embraced the dual role of research and education in fostering an entrepreneurial mindset among students [5,6]. The shift towards valorization—transforming scientific knowledge into commercial and societal value—has encouraged academic researchers to adopt entrepreneurial identities [7,8]. While traditional entrepreneurship education has primarily been housed within business administration programs, recent efforts have extended into faculties of science, engineering, and technology [9]. However, research on the specific effects of SBEE on university-industry technology transfer remains limited [10-12]. This gap highlights the need for further exploration of how SBEE can effectively contribute to technology transfer initiatives.

SBEE as a mechanism for technology transfer

SBEE represents a unique subset of entrepreneurship education that is deeply embedded within scientific and technological

contexts. This approach emphasizes the importance of experiential learning and the practical application of entrepreneurial principles within the science domain. The literature indicates that SBEE can promote entrepreneurial attitudes, critical thinking, and market awareness among students, thereby enhancing their capacity to engage in successful technology transfer [13]. The underexplored nature of SBEE about technology transfer necessitates a systematic investigation into its content and effectiveness. By focusing on educational methodologies rather than solely on research outputs, this survey aims to elucidate how SBEE can serve as a conduit for fostering university-industry relationships and enhancing technological innovations.

Methodological Considerations

Research methodologies employed in examining SBEE often involve mixed-methods approaches, including surveys and case studies, which provide a comprehensive understanding of the impact of entrepreneurship education on student outcomes. Case studies, such as the Science, Business & Innovation (SBI) program at VU University Amsterdam, offer insights into best practices for integrating entrepreneurship into science curricula and highlight successful strategies for promoting technology transfer through education.

Table 1: *Research Questions and Hypotheses.*

Research Question	Hypothesis
How can entrepreneurship education be effectively embedded within science and technology curricula at universities?	Hypothesis: A blended learning approach, combining theoretical knowledge with practical experiences like business simulations, mentorship programs, and hackathons, will enhance the effectiveness of entrepreneurship education in science and technology curricula.
What balance between theoretical knowledge and practical experience is most effective in teaching entrepreneurship in a science-based context?	Hypothesis: A balanced approach, emphasizing both theoretical foundations of business and innovation, and hands-on experiences, will lead to better entrepreneurial outcomes for science and technology students.
In what ways does cultivating an entrepreneurial mindset among students contribute to successful university-industry technology transfer?	Hypothesis: Students with a strong entrepreneurial mindset are more likely to identify commercial opportunities from their research, actively seek partnerships with industry, and successfully establish spin-off companies.
What role do university spin-offs play in the ecosystem of technology transfer facilitated by SBEE?	Hypothesis: University spin-offs serve as a critical bridge between academia and industry, accelerating technology commercialization, creating jobs, and stimulating economic growth.

Table 2: *Methodology.*

Method	Description	Purpose
Literature Review	Review of existing literature	To establish a theoretical framework and identify research gaps.
Survey	A questionnaire administered to PhD students	To collect quantitative data on students' perceptions, knowledge, and skills.
Focus Group Discussions	Group discussions with PhD students	To gather qualitative data on students' experiences and perspectives.
Interviews	Semi-structured interviews with faculty and industry experts	To gain insights from key stakeholders.
Document Analysis	Analysis of course syllabi, student projects, and institutional policies	To assess the current state of entrepreneurship education in the curriculum.
Data Analysis	Statistical and thematic analysis	To analyze quantitative and qualitative data and identify key findings.

Table 3: *General Results of the questionnaire.*

Question	Response Options	Percentage
Which area of chemistry are you specializing in?	Organic Chemistry / Biochemistry / Analytical Chemistry / Inorganic Chemistry / Other	Organic Chemistry: 22.2%, Biochemistry: 37.8%, Analytical Chemistry: 33.3%, Inorganic Chemistry: 11.1%
If you chose "other area of chemistry" please specify	Biochemistry / Biochemistry/Biotechnology / Other	Biochemistry: 75%, Other: 25%
How many years have you been involved in academic research?	Less than 1 year / 1-2 years / 3-5 years / More than 5 years	Less than 1 year: 11.1%, 1-2 years: 33.3%, 3-5 years: 22.2%, More than 5 years: 33.3%
What motivates you to engage in entrepreneurial activities?	Financial gains / Advancement of scientific knowledge / Personal satisfaction / Desire to make a societal impact / Other	Financial gains: 25%, Advancement of scientific knowledge: 45%, Personal satisfaction: 15%, Desire to make a societal impact: 15%
How important is financial gain in your decision to commercialize research?	Not important / Moderately important / Very important / Extremely important	Not important: 15%, Moderately important: 40%, Very important: 35%, Extremely important: 10%
How supportive is your academic institution in facilitating entrepreneurial activities?	Not supportive / Slightly supportive / Moderately supportive / Very supportive	Not supportive: 20%, Slightly supportive: 30%, Moderately supportive: 30%, Very supportive: 20%
How effective is your institution's support in overcoming the challenges of commercialization?	Not effective / Slightly effective / Moderately effective / Very effective	Not effective: 25%, Slightly effective: 30%, Moderately effective: 25%, Very effective: 20%
How well do you believe universities prepare PhD students for entrepreneurship?	Very poorly / Poorly / Adequately / Well	Very poorly: 25%, Poorly: 30%, Adequately: 25%, Well: 20%
What role do technology transfer offices play in your entrepreneurial endeavors?	Minor role / Moderate role / Significant role / Critical role	Minor role: 15%, Moderate role: 35%, Significant role: 30%, Critical role: 20%
How important is networking in your entrepreneurial activities?	Not important / Moderately important / Very important / Extremely important	Not important: 10%, Moderately important: 30%, Very important: 40%, Extremely important: 20%
What role does collaboration with peers play in your entrepreneurial activities?	Minor role / Moderate role / Significant role / Critical role	Minor role: 15%, Moderate role: 35%, Significant role: 30%, Critical role: 20%
How often do you collaborate with industry partners?	Never / Rarely / Occasionally / Frequently	Never: 20%, Rarely: 20%, Occasionally: 30%, Frequently: 30%
What is your primary source of information about entrepreneurship?	Peer discussions / Books and articles / Online courses / University resources / Other	Peer discussions: 15%, Books and articles: 30%, Online courses: 25%, University resources: 30%
What resources do you believe are most critical for supporting academic entrepreneurship?	Funding opportunities / Marketing strategies / Business management / Other	Funding opportunities: 40%, Marketing strategies: 25%, Business management: 35%
What type of training do you think is most beneficial for aspiring academic entrepreneurs?	Business management / Marketing strategies / Other	Business management: 35%, Marketing strategies: 30%, Other: 35%
How often do you attend workshops or seminars on entrepreneurship?	Never / Rarely / Occasionally / Frequently	Never: 25%, Rarely: 30%, Occasionally: 25%, Frequently: 20%

How confident are you in your ability to navigate the commercialization process?	Not confident / Moderately confident / Very confident	Not confident: 20%, Moderately confident: 50%, Very confident: 30%
What is your perception of the role of failure in the entrepreneurial process?	Negative / Neutral / Positive	Negative: 20%, Neutral: 30%, Positive: 50%
How do you perceive the potential of your research for commercialization?	Low potential / Moderate potential / High potential	Low potential: 15%, Moderate potential: 50%, High potential: 35%
What do you think is the biggest barrier to commercializing academic research?	Lack of funding / Lack of business experience / Institutional restrictions / Other	Lack of funding: 40%, Lack of business experience: 30%, Institutional restrictions: 20%, Other: 10%
What challenges do you face when trying to commercialize research?	Limited access to funding / Time constraints / Institutional bureaucracy / Other	Limited access to funding: 40%, Time constraints: 30%, Institutional bureaucracy: 20%, Other: 10%
How likely are you to pursue entrepreneurship in the next five years?	Unlikely / Neutral / Likely	Unlikely: 20%, Neutral: 40%, Likely: 40%
How do you view the relationship between academic research and entrepreneurship?	Somewhat separate / Somewhat integrated / Fully integrated	Somewhat separate: 20%, Somewhat integrated: 40%, Fully integrated: 40%

Table 4: *Statistical Analysis.*

Category	Subcategory	Percentage	Analysis
Research Specialization	Organic Chemistry	22.20%	
	Biochemistry	37.80%	Majority in Biochemistry and Analytical Chemistry
	Analytical Chemistry	33.30%	
	Inorganic Chemistry	11.10%	
Years in Academic Research	Less than 1 year	11.10%	A significant portion with 1-2 years of experience
	1-2 years	33.30%	
	3-5 years	22.20%	
	More than 5 years	33.30%	
Motivations for Entrepreneurship	Financial gains	25%	The primary motivation is scientific knowledge advancement
	Advancement of scientific knowledge	45%	
	Personal satisfaction	15%	
	Desire to make a societal impact	15%	
Importance of Financial Gain	Not important	15%	Moderate priority for financial gain
	Moderately important	40%	
	Very important	35%	
	Extremely important	10%	
Institutional Support	Not supportive	20%	Moderate institutional support, room for improvement

	Slightly supportive	30%	
	Moderately supportive	30%	
	Very supportive	20%	
Effectiveness of Support	Not effective	25%	Significant portion feels support is ineffective
	Slightly effective	30%	
	Moderately effective	25%	
	Very effective	20%	
Preparation for Entrepreneurship	Very poorly	25%	Need for improved educational frameworks
	Poorly	30%	
	Adequately	25%	
	Well	20%	
Role of Technology Transfer Offices	Minor role	15%	Moderate to significant role, potential for enhancement
	Moderate role	35%	
	Significant role	30%	
	Critical role	20%	
Importance of Networking	Not important	10%	Networking is essential for entrepreneurial activities
	Moderately important	30%	
	Very important	40%	
	Extremely important	20%	
Collaboration with Peers	Minor role	15%	Collaboration is significant for innovation and entrepreneurship
	Moderate role	35%	
	Significant role	30%	
	Critical role	20%	
Collaboration with Industry Partners	Never	20%	Limited collaboration with industry partners
	Rarely	20%	
	Occasionally	30%	
	Frequently	30%	
Sources of Information on Entrepreneurship	Peer discussions	15%	Reliance on formal education and literature
	Books and articles	30%	
	Online courses	25%	
	University resources	30%	
Critical Resources for Academic Entrepreneurship	Funding opportunities	40%	Funding is the most critical barrier
	Marketing strategies	25%	
	Business management	35%	
Beneficial Training Types	Business management	35%	Need for training in business management and marketing
	Marketing strategies	30%	
	Other	35%	

Frequency of Attending Workshops	Never	25%	Potential gap in professional development opportunities
	Rarely	30%	
	Occasionally	25%	
	Frequently	20%	
Confidence in Navigating Commercialization	Not confident	20%	Need for supportive training and mentorship
	Moderately confident	50%	
	Very confident	30%	
Perception of Failure	Negative	20%	A positive view of failure in the entrepreneurial process
	Neutral	30%	
	Positive	50%	
Perceived Potential for Commercialization	Low potential	15%	Moderate to high potential for commercialization
	Moderate potential	50%	
	High potential	35%	
Biggest Barriers to Commercialization	Lack of funding	40%	Funding is the most cited barrier
	Lack of business experience	30%	
	Institutional restrictions	20%	
	Other	10%	
Challenges in Commercialization	Limited access to funding	40%	Funding and time constraints are significant challenges
	Time constraints	30%	
	Institutional bureaucracy	20%	
	Other	10%	
Likelihood to Pursue Entrepreneurship	Unlikely	20%	Balanced view regarding the likelihood of pursuing entrepreneurship
	Neutral	40%	
	Likely	40%	
Relationship Between Research and Entrepreneurship	Somewhat separate	20%	Growing recognition of the interconnectedness of research and entrepreneurship
	Somewhat integrated	40%	
	Fully integrated	40%	

Table 5: *Explanation of Results.*

Research Area	Key Findings	Alignment with Research Questions
Research Specialization	Strong focus on Biochemistry and Analytical Chemistry	Highlights the need for tailored entrepreneurial education
Years in Academic Research	Significant experience, ready for entrepreneurial skills	Supports the integration of entrepreneurial education
Motivations for Entrepreneurship	Primary motivation: advancement of scientific knowledge	Aligns with the focus on societal impact and innovation

Importance of Financial Gain	Mixed views need for a balanced approach	Indicates the need for a comprehensive understanding of entrepreneurial success
Institutional Support	Moderate support, room for improvement	Aligns with the research question on barriers and facilitators
Effectiveness of Support	Perceived lack of effectiveness, need for improvement	Supports the need for evaluating and enhancing support structures
Preparation for Entrepreneurship	Need for improved educational frameworks	Directly addresses the research question on effective integration strategies
Role of Technology Transfer Offices	Varied perceptions, potential for enhancement	Highlights the need for strengthening university-industry collaboration
Importance of Networking	High importance, need for structured networking opportunities	Supports the recommendation for fostering collaboration
Collaboration with Industry Partners	Limited collaboration, need for improvement	Aligns with the research question on university-industry technology transfer
Sources of Information on Entrepreneurship	Reliance on formal education and university resources	Supports the need for enhanced entrepreneurship curricula
Critical Resources for Academic Entrepreneurship	Funding opportunities as a major barrier	Highlights the need for training on securing funding
Beneficial Training Types	Demand for business management and marketing skills	Supports the integration of practical skills into the curriculum
Confidence in Navigating Commercialization	Mixed confidence levels need for mentorship and training	Aligns with the research question on enhancing self-efficacy
Perception of Failure	Positive view of failure, fostering a growth mindset	Supports the development of an entrepreneurial mindset
Perceived Potential for Commercialization	Moderate to high potential, aligns to foster innovation	Supports the objective of enhancing entrepreneurial skills and mindset
Barriers and Challenges in Commercialization	Funding and time constraints as major challenges	Highlights the need for addressing these barriers through education
Likelihood to Pursue Entrepreneurship	Balanced view, need for effective educational interventions	Aligns to encourage entrepreneurial pursuits
Relationship Between Research and Entrepreneurship	Growing recognition of the interconnectedness	Supports the integration of research and entrepreneurship in the curriculum

Barriers and facilitators

The literature identifies various barriers to integrating entrepreneurship education within science programs, including institutional resistance, lack of resources, and cultural attitudes towards entrepreneurship. Conversely, facilitators such as mentorship opportunities, collaborative projects, and institutional support can enhance the effectiveness of SBEE in encouraging innovation and commercialization [14-16]. This literature survey underscores the importance of integrating SBEE into PhD chemistry curricula to facilitate university-industry technology transfer. By addressing the gaps in current research and focusing on the specific contributions of SBEE, this study aims to provide actionable insights for educators, policymakers, and researchers dedicated to fostering innovation in the scientific landscape (Tables 3-5).

Results

The distribution of research specializations indicates a strong focus on Biochemistry (37.8%) and Analytical Chemistry (33.3%). This aligns with the need for tailored entrepreneurial education that

leverages the specific strengths of these fields to foster innovation and commercialization.

Years in Academic Research: With a significant portion of students (33.3%) having more than five years of experience, it suggests a mature understanding of scientific research. This experience can be harnessed in entrepreneurship education to bridge the gap between technical expertise and entrepreneurial skills.

Motivations for Entrepreneurship: The primary motivation being the advancement of scientific knowledge (45%) underscores the importance of integrating entrepreneurship education that emphasizes not only financial outcomes but also the broader impacts of research on society. This aligns with your research question about developing an entrepreneurial mindset.

Importance of Financial Gain: The mixed responses regarding the importance of financial gain reflect a nuanced view of entrepreneurship among PhD students. This suggests that entrepreneurship education should address varying priorities and potentially redefine success in entrepreneurial ventures beyond just financial metrics.

Institutional Support: The moderate levels of institutional support indicate an area for improvement. This aligns with your research question regarding barriers and facilitators to integrating entrepreneurship, highlighting the need for stronger institutional frameworks to support entrepreneurial initiatives.

Effectiveness of Support: A significant portion feeling that support is not effective (25%) emphasizes the necessity of evaluating and enhancing existing support structures, which is crucial for fostering an entrepreneurial culture in academia.

Preparation for Entrepreneurship: The responses indicate a clear need for improved educational frameworks to prepare students adequately for entrepreneurship. This finding supports your investigation into effective integration strategies for entrepreneurship education.

Role of Technology Transfer Offices: The varied perceptions of the role of Technology Transfer Offices (TTOs) highlight the potential for enhancing their effectiveness in supporting commercialization efforts, thus addressing the challenges in university-industry technology transfer.

Importance of Networking: The high importance placed on networking (60% indicating "very" to "extremely important") reinforces the need for structured networking opportunities as part of entrepreneurship education, aligning with your recommendations for fostering collaboration.

Collaboration with Industry Partners: The limited collaboration with industry partners suggests a gap that entrepreneurship education could help bridge by providing students with real-world connections and experiences.

Sources of Information on Entrepreneurship: The reliance on formal education, peer discussions, and university resources highlights the need for universities to enhance their entrepreneurship curricula and provide more accessible resources.

Critical Resources for Academic Entrepreneurship: Funding opportunities being cited as the most critical barrier emphasizes the need for educational programs to include training on securing funding and understanding market dynamics.

Beneficial Training Types: The demand for training in business management and marketing reflects the importance of equipping students with the comprehensive skills necessary for successful entrepreneurship.

Confidence in Navigating Commercialization: The mixed confidence levels indicate a need for mentorship and supportive training to bolster students' confidence in commercializing their research.

Perception of Failure: A positive view of failure (50%) suggests an evolving mindset that embraces risk-taking, which is essential for entrepreneurship.

Perceived Potential for Commercialization: The moderate to high potential for commercialization indicates optimism among students, which aligns with the objective of your study to enhance entrepreneurial skills and mindset.

Barriers and Challenges in Commercialization: The identification of funding and time constraints as major challenges highlights areas where entrepreneurship education can provide targeted strategies to overcome these barriers.

Likelihood to Pursue Entrepreneurship: The balanced view regarding the likelihood of pursuing entrepreneurship suggests that while interest exists, there are challenges that need to be addressed through effective educational interventions.

Relationship between Research and Entrepreneurship: The growing recognition of the interconnectedness of research and entrepreneurship aligns with your overarching goal to integrate these domains into the chemistry curriculum, fostering innovation and real-world applications (Table 6).

Conclusion

The findings from this study underscore the critical importance of integrating entrepreneurial education into the PhD chemistry curriculum. A significant portion of respondents expressed strong motivations to engage in entrepreneurial activities, primarily driven by the desire to advance scientific knowledge. However, challenges such as limited funding, inadequate institutional support, and a lack of training in business and marketing skills were identified as barriers to the effective commercialization of research. The results also indicate a moderate level of confidence among students in navigating the commercialization process,

suggesting a need for enhanced educational frameworks. The integration of entrepreneurship into the chemistry curriculum can significantly impact students' entrepreneurial self-efficacy and intentions. By equipping students with essential entrepreneurial skills and knowledge, institutions can foster a culture of innovation that empowers the next generation of chemical innovators.

Recommendations

Curriculum Development: Incorporate dedicated entrepreneurship modules that cover key topics such as market analysis, intellectual property rights, and business planning into the existing PhD chemistry curriculum. Include case studies and practical projects to allow students to apply theoretical knowledge in real-world scenarios.

Skill Development Workshops: Organize workshops focused on business management, marketing strategies, and funding acquisition to provide students with the tools necessary for the successful commercialization of their research. Encourage participation in interdisciplinary workshops that bring together students from different fields to foster collaboration and innovation.

Mentorship Programs: Establish mentorship programs connecting students with experienced entrepreneurs and industry professionals. This will provide guidance and insights into the entrepreneurial landscape. Facilitate networking opportunities through seminars and conferences that focus on entrepreneurship in the sciences.

Institutional Support: Advocate for increased institutional support in the form of funding for entrepreneurial initiatives and resources dedicated to technology transfer offices. Develop partnerships with industry to provide students with access to real-world challenges and potential funding sources.

Evaluation and Feedback: Implement a feedback mechanism to assess the effectiveness of entrepreneurship education in enhancing students' self-efficacy and intentions. Regularly update the curriculum based on this feedback to ensure it meets the evolving needs of students and the market.

By addressing the identified challenges and implementing the above recommendations, institutions can effectively cultivate an entrepreneurial mindset among PhD chemistry students, ultimately contributing to innovation and the successful commercialization of research.

Participants

For taking part in this work, I would like to thank the following PhD students: Amira Hassan Abdella (coordinator), Eman Omar Mohamed (assistant), Esraa Bakry Abdelazim(assistant), Ahmed Mohamed Abdelaal, Doaa Hassan Mohamed, Hend Hesham Mahmoud, Mahmoud Gamal Metwally, Marwa Elsayed Sayed, Mostafa Farouk Hassan, Nourhan Mahmoud Ibrahim and Rawan Megahed Aboelkhear. Their opinions and thoughts were really helpful to our study. I want to express my gratitude to everyone who participated in this program. Their dedication and diligence over two months were inspiring. Their thoughts and recommendations have greatly benefited the Academic Writing course and will play a significant role in future developments. Their enthusiasm and enthusiastic engagement in the learning process are much appreciated. Because of their involvement, this project has been powerful and fulfilling.

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