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**INTEGRATING ENTREPRENEURSHIP INTO CHEMISTRY EDUCATION - CAIRO UNIVERSITY
POST-GRADUATE STUDENTS' CASE STUDY***

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Abstract. Chemistry entrepreneurship is the technique of spreading knowledge about discoveries and chemical ideas to a larger audience outside of the classroom and evaluation. Graduates' ability to become job innovators with the potential to reduce unemployment and strengthen the economy is demonstrated by innovative ideas that are implemented with a social value. As a result, while attending college, chemistry students have the chance to apply what they learn in the classroom to a sustainable way of life. In this study, we have covered the breadth of classroom innovations, the "From Theory to Practice" gap, and different aspects that affect students' decisions to start and develop chemistry entrepreneurial ventures. A survey was conducted to find out more about post-graduate students' exposure to and opinions on using entrepreneurship to apply chemistry to the real world. After compiling data from an online survey consisting of 20 statements from 176 post-graduate chemistry students (Ph. D., M. Sc., and diploma) with their replies recorded on a Likert scale describing their experiences with assignments, it was possible to pinpoint areas where chemistry classes could be improved. In order to better understand how students view the use of entrepreneurship to apply chemistry to the real world, a study was conducted to look at the breadth of creativity, the gap between thinking and doing, and the factors encouraging students to select and build a chemical pilot project.

Keywords: Entrepreneurship-Chemistry education; Faculty of Science; Chemistry Curriculum; Post-graduate students

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1. Introduction

Science should be a purposeful and practical experience that helps them solve challenges, particularly economic ones. The goal of integrating concept of entrepreneurship into science education to foster the development of the entrepreneurial character through the merging of science study and entrepreneurship (Muhammad, 2018). Over the last few decades, researchers have become increasingly interested in the topic of entrepreneurship in education. This occurred as part of a larger revision of education's role and principles to reconsider the ultimate role of teaching. This revision included the introduction of new perceptions, such as the need for schools and education to promote students' acquisition of skills and competencies rather than limiting the curriculum to content knowledge (Blankesteyn et al., 2020). Introducing entrepreneurship as a subject in educational structures is a complex reform, innovation, and approach that affects many levels and aspects of schoolwork (Breslin and Jones, 2014). This is the main reason why it is challenging to define this concept in a widely accepted form (Fullan, 2007).

Since chemistry permeates everything and is present everywhere, it provides more diverse commercial options than any other discipline for the growth of small and medium-sized firms. Professional chemists, including chemistry students, could start commercialising their discoveries to reap enormous financial benefits, create jobs, and positively impact the development of the nation's economy, particularly through small and medium enterprises. However, they would need little training in entrepreneurial skills. An area of academic entrepreneurship known as "chemistry entrepreneurship" deals with the process of turning advances in the field of chemistry into commercially viable products. By patenting and commercialising their work for financial advantage, it allows chemists to push their work beyond articles in scholarly journals.

The literature focuses mostly on importance of education of different types of entrepreneurships for graduations and students (Ead and Nassar, 2021; Ead et al., 2022; Ead, Hamed and Sahar, 2021; Ead, Hamed, et al, 2022) and not so much in integration on entrepreneurship in science education (Pittaway and Cope, 2007). As a result, in terms of its theoretical points, it must include ideas about entrepreneurship in education (Jones et al., 2014; OECD, 2015). In addition to its practical implementation strategies (EU, 2011) It should also include the relationship between entrepreneurship and science education (OECD, 2015; Blankesteyn et al., 2020).

The act of commercialising new chemical discoveries for a market or a client is referred to as chemistry entrepreneurship (Al-Shammari and Waleed, 2018). Due to the role that chemistry plays in everyday life, there are several opportunities for chemical entrepreneurs. To increase the potential for chemistry entrepreneurship, it was contending that only chemistry innovation can handle important concerns such as human health, food development, energy production and storage, safe and abundant water, climate change, and others, however, doing so requires bridging the already-existing gap between academia and entrepreneurship. (Confalone, 2014).

An academic research project is considered to have undergone marketing when it strives to be successful in the commercial market. University research and invention can benefit financially from a variety of tactics, such as copyrighting, licensing, and start-up inventions. (Pimentel, 2010; Zegeye, 2013; Garcia-Martinez, 2014; Oyeku et al., 2015; Sachse and Martinez, 2016; Al-Shammari and Waleed, 2018). Given the high demand for novel materials that are utility-based and serve a variety of purposes in modern civilization, the scope and significance of chemistry entrepreneurship are obvious. Few ground-breaking scientific and research ideas are motivated to be commercialised to generate revenue. (Gokhale, 2016) i.e chemistry graduate Frank Jaksch built his successful company Chroma Dex around the chemistry of natural goods (Siegel et al., 2007). Few institutions train students to select entrepreneurship or discover potential employers for this career path, while the majority of universities focus on increasing students' employability because finding a job after graduation is becoming a big worry Phan and Siegel, 2006; Jaksch, 2016; Chemistry at Illinois, 2022; Donthu and Gustafsson, 2020).

Conceptual clarity and practical comprehension are both crucial components of entrepreneurship education because they help students become competent decision-makers. Finding an idea that is commercially viable is a requirement. In addition, attitude and behaviour are important factors (Bomgardner, 2020). However, students only learn about chemistry in the classroom, where they are unaware of its importance and practical applications (Rajesh Parishwad, 2017). Students who identify problems and offer unique ideas frequently fail to produce something that can be marketed entrepreneurship (Al-Shammari and Waleed, 2018). It is a challenging task to take their labour and convert it into a marketable product. A theoretical understanding of entrepreneurship, market research, entrepreneurial skills, and institutional support is needed. Students can earn money while they are still in school by turning their discoveries, innovations, and breakthroughs into marketable commodities. Incubator cells in academic institutions also, help student-scientists transition from researchers to entrepreneurs in the scientific field (Inspiring women insights - Oxford Brookes University, 2022; Parker et al., 2018). The breadth of classroom innovations that promote entrepreneurship is impacted by many restrictions that restrict its development. It's crucial to remember that students base their career decisions on the exposure and experience they gain while earning their degree.

What are the goals of the "Chemistry/Entrepreneurship" course?

Raise the post-graduate students' awareness of technological entrepreneurship and innovation and support readiness, behaviour, and mentality for starting new technology-based businesses in the fields of chemistry and related scientific and engineering disciplines by providing education and skills using appropriate educational and training methods, tools, and materials following a "Theory-to-Practice.

1. Post graduate students also need to be ready to follow the best career tracks because of how swiftly the industrial world is changing.
2. The program's intrapreneurship component will outline the basic organisational alternatives for structuring industrial research and serve as a means of introducing students to the reality of innovation and R&D in contemporary businesses. An increase in the number of chemists, chemical engineers, and other scientists and engineers with the ability to innovate and commercialise technology, whether as entrepreneurs starting and growing new businesses or as intrapreneurs working within established businesses or research institutes in areas of innovation, research, and New Product Development (NPD).
3. Emphasising how they might increase students' creativity, personal attitudes toward change, entrepreneurial thinking, behavioural changes, decision-making under uncertainty and risk, and employability.
4. Students must understand that entrepreneurship is a way of life rather than merely a business, and it is important to emphasise self-direction.
5. Increase comprehension of the specific business jargon used in the context of entrepreneurship by all parties involved in commercialization-related activities as well as technical innovation, such as those working in market research, intelligence, and marketing, business analysts, investors, bankers, etc.

Factors working against Egyptian Chemistry Entrepreneurship

The same broad obstacles that prevent Egyptian researchers from commercialising their R&D findings also hinder chemistry entrepreneurship. The following list of elements, as listed by (Elemo Gloria et al., 2014) includes some of them:

1. The researcher lacked the financial resources to develop the idea and bring it to market.
2. The inability of the financial sector to transform the results of scientific research in chemistry or innovative ideas developed in partnership with the researcher into marketable goods.
3. Market factor: There is a general lack of interest in Egyptian-made products and technology, and Egyptian have high standards for imported items, especially imported technologies.
4. Egypt's support of research and development is inadequate.

5. The weak connection between academia and business.
6. Inadequate legal foundation for innovation protection and commercialization.

In the current study, a survey was conducted to learn what Egyptian post-graduate students believed about entrepreneurship in the field of chemistry. We must create a methodology to include chemical entrepreneurship in the curriculum for students based on the survey's findings. This seeks to fill the knowledge gap between developing an innovation that applies chemistry to the actual world and conceptualising chemical entrepreneurship. The ideation-action gap between innovation and entrepreneurship is highlighted in the current study. This paper calls for curriculum re-engineering to fully integrate entrepreneurship into the Chemistry curriculum at the degree level as well as to encourage researchers to make commercialization a part of their research agenda from the stage of project conceptualization.

2. Methodology

The sample was made up of a collection of post-graduate students. These individuals were chosen from the Chemistry Department of the Faculty of Science. A total number of 176 students, responded to questionnaires that were distributed to collect the data. Stages were identified as the strata, and the sample of 176 consisted of 22 Ph. D. students, 25 M. Sc. students and 130 represent diploma students. The number chosen for each stage was almost appropriate to the size of the stratum in relation to the entire students. During the process of data collection, the lecturers were asked for 15 minutes of their lecturing time. The questionnaires were distributed by the researcher, who waited for the respondents to complete the survey and collected them once they were completed, Figure 1.

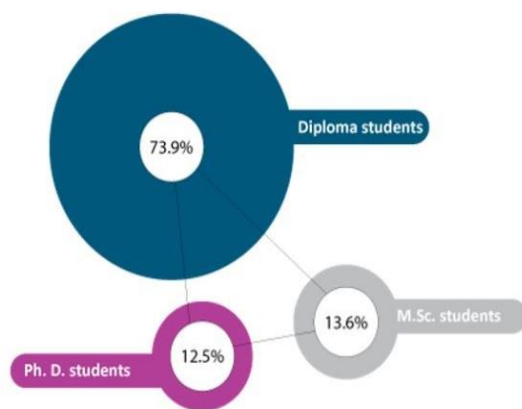


Fig.1. samples of post-graduate students

Source: Authors

A 5-point Likert-scale questionnaire was adopted from the studies of Al-shammari & Waleed (2018) to test the assigned relations. The survey consisted of 20 statements, Table 1.

Table 1. Statements of survey

EC1	I am familiar with chemistry entrepreneurship.
EC2	I think the selection would cover topics like marketing expertise and financial management for leadership in chemistry.
EC3	Chemistry entrepreneurship is driven by motivation and ambition.
EC4	I prefer Chemistry's Academic Study for Entrepreneurship
EC5	In my opinion, fostering entrepreneurship requires interdisciplinary or cross-disciplinary collaboration between students and peers.
EC6	It costs a lot to turn chemical ideas into commercially viable goods

EC7	I'm willing to take a chance on chemistry entrepreneurship.
EC8	I enjoy questioning established theories and practises and seeking for the best ones.
EC9	Seeking out effective strategies and tactics.
EC10	I am open to new ideas that come up in my work and studies.
EC11	I do my chemistry work fondly and persistently.
EC12	I have a strong drive and propensity for business in chemistry.
EC13	I have no hesitance about attempting to study entrepreneurship in chemistry.
EC14	Working in the chemistry industries allows me to face challenges and take risks.
EC15	I typically have faith in my chemistry abilities.
EC16	I am willing to take on any risk in my business.
EC17	When the work is extremely challenging, I try to give it my all.
EC18	I have the ability to give myself new options if I am forced to leave my job.
EC19	I don't hesitate to take part in chemistry projects that my friends propose.
EC20	I believe that the choices I make will help to mould my life.

3. Results and Discussion

Universities have the capacity to create courses that satisfy both student needs and those of rapidly changing industry. They provide a range of credentials, including postgraduate programmes, honours degrees, bachelor's degrees, and higher national certificates (Zegeye, 2013). A total of 176 students pursuing postgraduate courses and postgraduates who have completed their course in chemistry from the Faculty of Science, Cairo University, Egypt, between the age group of 25 and 35, responded to the survey on chemistry entrepreneurship.

The weighted average is calculated and then described in the following table in order to have a better interpretation of the results of the analysis of the questionnaire responses and to best describe the five-level Likert item is 1. Strongly Disagree, 2. Disagree, 3. Neither Agree nor Disagree (neutral), 4. Agree, and 5. Strongly agree. The following table demonstrates that the respondents agreed with the majority of the questionnaire's statements.

Table 2. The respondents agreed with the majority of the questionnaire's statements

Likert Scale	Interval	Difference	Description
1	1.00-1.79	0.79	Strongly Disagree
2	1.80-2.59	0.79	Disagree
3	2.60-3.39	0.79	Neutral
4	3.40-4.19	0.79	Agree
5	4.20-5.00	0.80	Strongly Agree

The online survey consisted of 20 statements with students' responses recorded on a Likert scale, excluding the respondent's current course of study. The results of the survey are provided in figure 2 and in the Supporting Information. The 176 postgraduate respondents (current students of post-graduation courses and postgraduates (since 2019) with the same syllabus) have been introduced to 20 statements about chemistry entrepreneurship, as a stand-alone course.

The main objectives of this course focus on skills, basic knowledge of digital and technical requirements, and publication ethics in academic research along with a unit on chemistry entrepreneurship.

The first subunit on chemistry entrepreneurship introduces students to the steps involved in establishing a chemical factory based on innovation and its build-up. The second subunit covers the processes involved in carrying out a market survey for chemicals and chemical-based products. The third subunit explains the principles of designing a bench-scale generation and scaling up for chemical production. The unit further continues on digital modes and methods of analyses used in general that is, for academic research and market survey.

This survey has enabled to discuss the outlook of students with and without a prior introduction to chemistry entrepreneurship. The statements in the survey were based on our hypothesis on factors that influence the students' perspective on chemistry entrepreneurship. The results helped us validate these factors and to provide a suggestion for a holistic approach to learning chemistry entrepreneurship. The

results of this survey are presented in Table 2. The average response was calculated as $[\Sigma(\text{number of respondents} \times \text{rating})]/\text{total number of respondents}$. The value was corrected to one decimal place and given in terms of percentage in the last column.

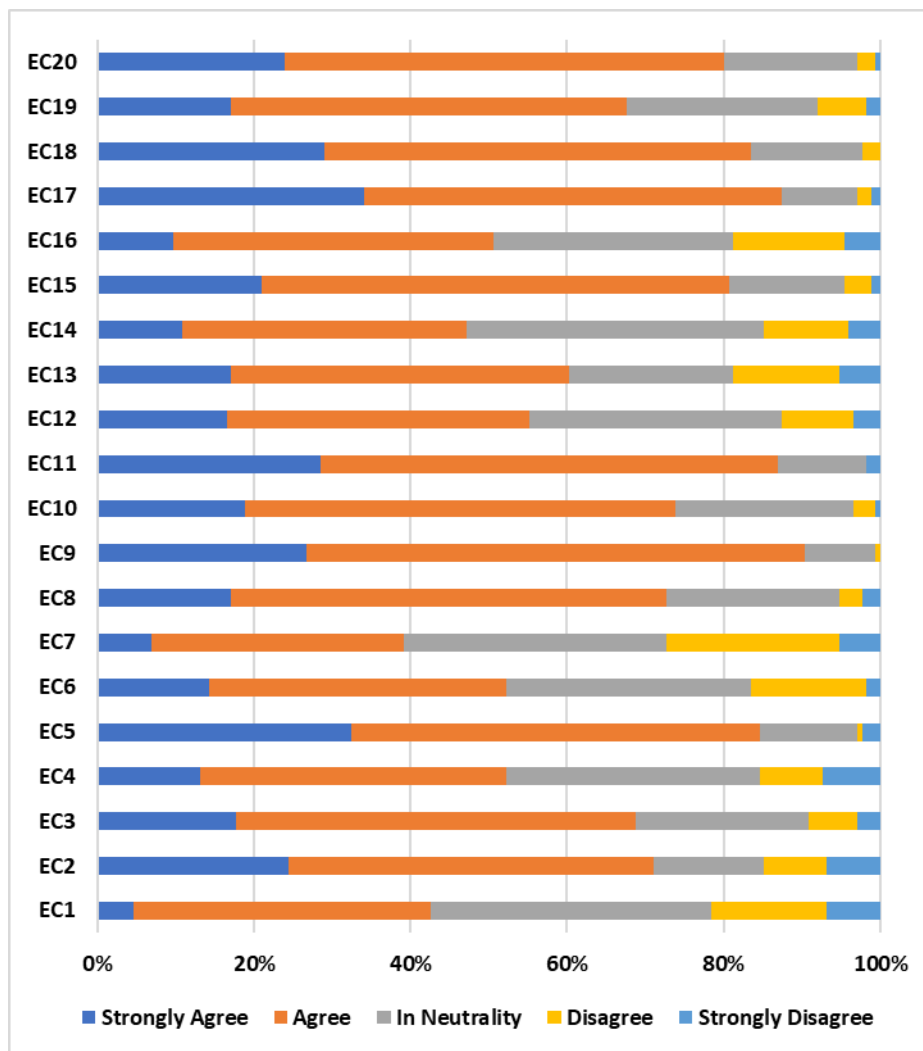


Fig. 2. Chart for all responses results

Source: Authors

Table 3. Weighted average 5-points Likert scale

	Sentence	Mean	St. d.	Decision
EC1	I am familiar with chemistry entrepreneurship.	3.19	1.09	Neutral
EC2	I think the selection would cover topics like marketing expertise and financial management for leadership in chemistry.	3.74	1.25	Agree
EC3	Chemistry entrepreneurship is driven by motivation and ambition.	3.74	1.02	Agree
EC4	I prefer Chemistry's Academic Study for Entrepreneurship	3.43	1.18	Agree
EC5	In my opinion, fostering entrepreneurship requires interdisciplinary or cross-disciplinary collaboration between students and peers.	4.12	0.91	Agree
EC6	It costs a lot to turn chemical ideas into commercially viable goods	3.48	1.08	Agree

EC7	I'm willing to take a chance on chemistry entrepreneurship.	3.14	1.12	Neutral
EC8	I enjoy questioning established theories and practices and seeking for the best ones.	3.82	0.92	Agree
EC9	Seeking out effective strategies and tactics.	4.16	0.66	Agree
EC10	I am open to new ideas that come up in my work and studies.	3.89	0.84	Agree
EC11	I do my chemistry work fondly and persistently.	4.12	0.82	Agree
EC12	I have a strong drive and propensity for business in chemistry.	3.56	1.10	Agree
EC13	I have no hesitation about attempting to study entrepreneurship in chemistry.	3.53	1.21	Agree
EC14	Working in the chemistry industries allows me to face challenges and take risks.	3.39	1.07	Neutral
EC15	I typically have faith in my chemistry abilities.	3.96	0.86	Agree
EC16	I am willing to take on any risk in my business.	3.37	1.11	Neutral
EC17	When the work is extremely challenging, I try to give it my all.	4.18	0.85	Agree
EC18	I have the ability to give myself new options if I am forced to leave my job.	4.10	0.80	Agree
EC19	I don't hesitate to take part in chemistry projects that my friends propose.	3.75	0.97	Agree
EC20	I believe that the choices I make will help to mould my life.	4.01	0.83	Agree

For the first statement, the post-concept responses showed 76% of respondents to be aware of/exposed to chemistry entrepreneurship. It was found that, the responses did not reach to 100% responses due to the reduced impact and uncertainty of the topic among students who completed their post-graduation course. While the pre-concept response to statement 1 is 46%, which can be due to the awareness of entrepreneurship that students of undergraduate courses have gained through the newly instituted ideation club in the college (in 2020). This shows that recent developments in the institution have promoted interest in and awareness of entrepreneurship. Additionally, knowledge about various social events and schemes that nurture entrepreneurial ventures can also contribute to increased awareness among the younger generation.

A total of 96% of (post concept) respondents prefer to learn revenue management and marketing skills involved in the monetization process. This is 30% higher than the pre-concept responses. It can be inferred that students are curious to learn more than the existing curriculum, about the financial skills required in building an enterprise. Both groups of respondents perceive chemistry entrepreneurship to be a skill/career developed through self-interest and motivation.

This survey has given us the opportunity to talk about the perspectives of students who have already been not engaged to chemistry entrepreneurship. The claims made in the survey were based on our hypotheses regarding the variables that affect students' perspectives on chemistry entrepreneurship. The findings enabled us to confirm these elements and offer a recommendation for an all-encompassing strategy for learning chemical entrepreneurship. In Table 2, the survey's findings are displayed. Using the formula [(number of respondents rating)/total number of respondents], the average response was determined. The value was updated to one decimal place and displayed in the final column as a percentage.

The first statement, EC1, revealed that 4.55%+35.07% of respondents had heard of, had experience with, or had exposure to chemistry entrepreneurship. This indicates how recent modifications to the institution's entrepreneurship course have increased interest in and awareness of entrepreneurship. The students' awareness might also be boosted by learning about numerous social occasions that support entrepreneurial endeavours. 13.07%+39.50% of those surveyed said they would like to acquire the marketing and revenue management skills that are part of the EC3, EC4, and EC5 commercialization processes. Students' desire to learn more about the financial abilities necessary to start a business than is covered in the current curriculum is evident. The respondents believe that self-interest and motivation are what drive chemistry entrepreneurship as a talent or vocation.

For statements EC6 and EC16, Students believe that developing chemical ideas into commercially viable goods is an expensive process. This fear may arise from the failure of pioneering ideas or a lack of funding to begin prototypes or assist in market entry. The statements from EC7 to EC15 It shows students' eagerness to seize the opportunity of entrepreneurship in the field of chemistry and seek out effective strategies and tactics. The responses also demonstrate the students' conviction that they must continue in the field of chemistry through entrepreneurship and that working in the chemical industries allows them to face challenges and risks. The statements from E17 to E20 showed that, a noticeable shift in students' thinking after studying entrepreneurship, which is reflected in their responses, as the students indicated that they possess some personal characteristics required for entrepreneurship, such as the ability to leave a traditional job, share ideas with friends, and research new options.

Conclusion

University curricula frequently place a strong emphasis on subject-specific knowledge, with employability sometimes being seen as an "add-on feature" typically handled by a central university department. The task presented here gave students a chance to use their imaginations to address a commercial requirement and gave them experience working in a multidisciplinary environment. The students, however, spent too much time being obsessed with actual results and found it difficult to understand the concept of presenting an idea on paper since they were unfamiliar with being given the opportunity for freedom in thinking and exhibiting business acumen. The group students, however, appreciated and welcome the chance to learn new information and use their specialised skills. To emphasise the significance of these subjects, data suggests that these learning opportunities should be offered throughout B. Sc. program.

Chemistry/technology entrepreneurship is needed to take the nation to the next level of industrialization through small and medium enterprises most especially the attainment of Egypt's Vision 20/30 and the national Transformation Agenda. Even though Chemistry entrepreneurship is a personal choice of individual Chemists or researchers, this paper makes a clarion call for chemistry entrepreneurship for the sake of Egypt; the economy is nose-diving at an alarming rate! We probably cannot boast that 20% of graduates of Chemistry from various Universities are gainfully employed! This is the time for the nation just like it was done in the US to turn to its universities and research institutes to bail it out. The onus, therefore, lies on the universities and research institutes to start devising solutions and workable programs that will take them out of the economic doldrums.

Developing countries must begin to take research and development very seriously and imbibe the culture of solving national problems including economic problems using the instrument of science and technology. The education and the economy of the 21st century must be driven by entrepreneurship. The education and the economy of the 21st century must be driven by entrepreneurship.

As Cairo University is taking the lead in promoting entrepreneurship and Critical Thinking education in higher education in Egypt, along at the same time the Government had begun to have specialized universities: research-based, teaching-based, and entrepreneurial universities.

At this critical state of the economy in the whole world, what is needed is more entrepreneurial universities and adequate motivation of scientists (academic staff and students inclusive) to move their innovations from the laboratories to the marketplace through patenting of innovations. So, the students must learn the fundamentals of innovation, potential markets, entrepreneurial skills, investments/investors, and product development. The coursework can be evaluated by periodic tests throughout the semester and a final examination, similar to the major coursework for all students.

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