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RESEARCH

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Women as Industry 4.0. entrepreneurs: unlocking the potential of entrepreneurship in Higher Education in STEM-related fields

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Abstract

Industry 4.0 is the realization of digital transformation including enhanced productivity and flexibility due to real-time decision-making, which is possible due to the high-speed internet, the internet of things, and smart machines capable of autonomously exchanging information, triggering actions, and controlling each other independently. A high level of education and skills is increasingly more important in the job market over the next years necessitating finding a balance among behavioural, technological, analytical, and entrepreneurial skills. EU and governments worldwide should invest in closing the gender gap in science, technology, engineering, and mathematics (STEM) education as this will directly impact the economic growth. Even though there is some progress in the hiring percentage of women in large technological companies, a clear glass ceiling in leadership roles is still remains. Here, we have undertaken a pilot study at University Complutense of Madrid (UCM, Spain) aimed at empowering women in academia to transition from the "publish or perish" paradigm towards creating and protecting their intellectual property to close the gender gap in STEM fields and leadership roles as well as training to fuel the development of innovative start-ups addressing societal challenges. A total of 20 participants inclusive of UCM staff and postgraduate and postdoctoral researchers were enrolled after successfully obtaining at least a score of 5 out of 10 in custom-made Entrepreneurial competency test provided by Business and Professional Women Association (BPW, Spain) and theGrowBox Innovation Ltd. The study, approved by the UCM ethical committee, was conducted after participants engaged and completed a training programme on "Enterpreneurship in STEM-related fields in Higher Education" aimed to introduce the participants to the entrepreneurial world. This involved a structured training programme covering the (i) business canvas design; (ii) development of minimum viable product (MVP); (iii) market evaluation; (iv) finance analysis using the Growbox platform; (v) introduction to venture capital; and (vi) human resources management followed by individual mentoring sessions prior completion of their business plans that were pitched to a panel of mentors and BPW representatives. Finally, all participants completed an anonymous survey of 12 open questions to evaluate the impact of the training in awakening the entrepreneurial spirit in academic researchers in Higher Education in STEM-related fields. Three-quarters of participants were novices in terms of Entrepreneurship, but all participants after the programme presented a complete business plan. The three points that women identified as prohibitive factors were lack of self-confidence, ambition, and knowledge in the fields of patent filing, finance and marketing. Participants were likely to initiate their own start-up in the next five years, but had mixed fillings regarding the complexity of the process. Nine months after the course ended, four out of 20 participants have been successful in attracting initial funding to support the initiation of a start-up involving protected intellectual property and managed to secure an award to provide them with office space to build their company. The long-term impact of this training programme will need to be followed up. Entrepreneurial training is crucial to be embedded in curricula for post-graduate and if possible undergraduate students to pursue a major transformation targeting the STEM-related fields in Higher Education to enable women in becoming key participants and leaders in the Industry 4.0 era.

Keywords: Industry 4.0, Science, technology, engineering, and mathematics (STEM) education, Women entrepreneurship, Higher Education

Industrial revolution transformation towards Industry 4.0

Industrial revolutions take place over a period of time where the manufacturing processes and mankind are completely changed. Since the XVIII century, industrial manufacturing systems have evolved from manual labour towards automatization. After three industrial revolutions, we are experiencing the fourth (Fig. 1).

The **1st industrial revolution or Industry 1.0** also known as the Steam Revolution Era occurred from the eighteenth century to the beginning of the nineteenth century. This period was marked by the rise of mechanization of work and the replacement of the agriculture business due to the mass extraction of coal and the innovation of steam engines along with the improvement of railways. These led to faster monetary, human, and material trade having a significant impact on the quality of life mostly, such as the textile industry.

The **2nd industrial revolution or Industry 2.0** started at the end of the nineteenth century thanks to the discovery of a new source of energy, gas, and oil, along with several technological advancements related to the combustion engine set to

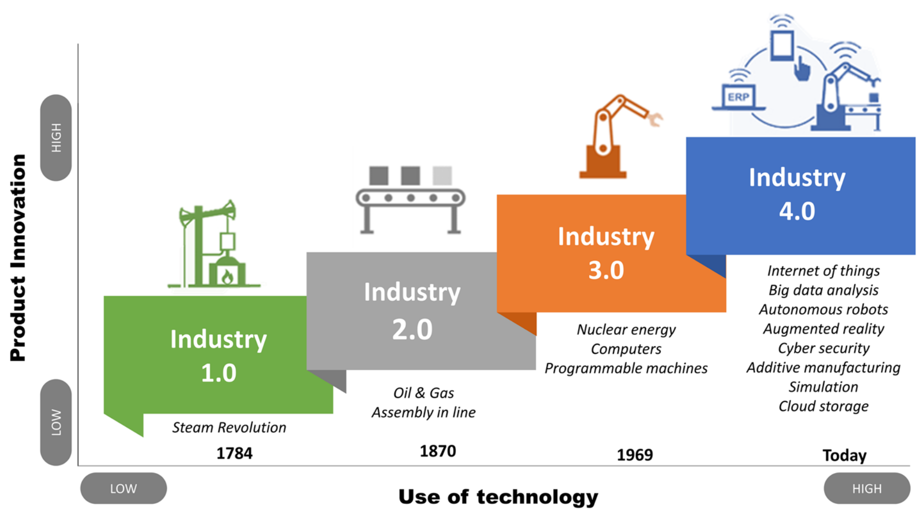

Fig. 1 Schematic summary of industrial revolutions

use gas and oil more effectively to their maximum capacity and the introduction of electricity. This period was marked by several hits, such as the enhancement of the steel industry along with the high steel demand, the chemical industry due to the demand for synthetic fibres, dyes, and fertilizers, the invention of the telegraph, and the telephone as a method of communication. This period also is characterized by the development of automobiles and planes for transportation which resulted in the establishment of large factories and assembly-in-line.

The **3rd industrial revolution or Industry 3.0** started at the end of the twentieth century when nuclear energy immersed as a new source of energy emerged. In the mid-1990s, the era of digitalization started with the introduction of computers, transistors, microelectronics, and automation that revolutionized the world opening biotechnology and space research. The two major inventions were the programmable logic controller and robotics allowing the production of a variety of products on flexible production lines with programmable machines.

The **4th industrial revolution or Industry 4.0** also known as smart manufacturing is the realization of the digital transformation of the field, which includes enhanced productivity and flexibility due to real-time decision-making. This is possible due to the high-speed internet and industrial internet of things. Digitalization allows us to build a new virtual world from which the physical world can be improved known as the era of Cyber Physical Systems (CPS) in which smart machines, storage systems, and production facilities are capable of autonomously exchanging information, triggering actions, and controlling each other independently. The aim of this 4th revolution is focused on interconnecting all production steps and enabling their interaction in real-time feasible through cloud computing, big data analytics, and the internet of things. The implementation of thousands of sensors working on real-time transfer of data to a local server or a cloud server able to carry out instantaneously data analysis by developing predictive models. This revolution focuses also on greener sources of energy coming from the sun, the wind, and geothermal sources (Kumar, 2019).

The 4th Revolution's key tools allow a step change from the 3rd Industrial revolution. Big data analytics supports real-time decision-making which is able to revolutionize large industries. Utilizing advanced hardware, software, and frameworks, data collected from different sensors are accumulated and assessed almost instantaneously. This allows for the development of stronger and more reliable models to simulate machinery settings before the next item in line is manufactured. Advanced robotics, a keystone of the 4th industrial revolution, allow robots and humans to interact and work safely in parallel. A full system integration is required to empower truly automated value chains and fast communication between systems enabled by fast internet and virtual cloud storage able to store all data generated from connections, machines, and humans. The concept of cyber security becomes paramount to ensure safety of the produced virtual data stored in the cloud. Another two new concepts are brought in this 4th Revolution; augmented reality and additive manufacturing (such as 3D printing for the design and production of customized prototypes adapted to the instantaneous needs of humans or equipment) (Serrano, et al., 2023).

Women are a minority in Industry 4.0

The world is experiencing a transcendental transformation in the way we work, live, and think. Women are at risk of missing out jobs of the future, particularly in STEM fields. It is expected that half of the current jobs will have disappeared by 2050, which means that five women will lose their jobs for every one gained, while just three jobs will be lost by men for every one gained and is predicted that 60% of children entering primary school today will end up working in jobs that currently do not exist (ITU, 2017; UNESCO, 2018). It is critical to ensure that the future workforce possesses the necessary skills to face the new working reality taking into account that STEM jobs will rise by about 6.5% compared to just 3% in other sectors. A shortage of skills for jobs in Industry 4.0 in the EU is expected to triple from 8 to 24% between 2015 to 2025 (UNESCO, 2021).

A high level of education and skills will be increasingly important in the job market over the next years. Low-skilled jobs have a higher risk to become automated and hence disappear such as, for example, the implementation of automatic checkouts in shops resulting in one in four cashier jobs disappearing, most of them occupied by women (UNESCO & Equal Skills Coalition, 2019). On the contrary, other jobs such as scientific research and development have a very low probability of automation and hence, the need for a high-skilled workforce.

EU should invest in closing the gender gap in STEM education as this will impact directly economic growth increasing the gross domestic product (GDP) per capita by 0.7–0.9% in 2030 and by 2.2–3% by 2050. This results in a reduction in the gender pay gap by 2050 considering that between 6.3 and 10.5 million jobs should have added to EU economy and about 70% of these will be occupied by women (EIGE, 2017).

Currently, women are a minority in Industry 4.0 sectors considering that women are underrepresented in fields most relevant to Industry 4.0 such as IT, physics, math, and engineering (UNESCO, 2023). For example, more than 50% of men finishing a degree in information technology (IT) end up working in digital jobs compared to just one-quarter of women (UNESCO & Equal Skills Coalition, 2019). A similar trend is observed in the technical and leadership roles in the top multinational technology companies. There is some progress in the hiring percentage of women, but a clear glass ceiling in the top roles still exists (Fig. 2). For example, Google has increased the total percentage of women hired, but below a quarter of these jobs were technical. A similar pattern is followed by Apple, where only 23% and 29% of women employees are in technical and leadership roles, respectively (UNESCO, 2021). Similar trends are encountered in Amazon, Facebook, or Microsoft companies. More scenarios occur in Asian companies such as Samsung and Huawei where only 6–7% of the management and executive team were women (UNESCO, 2021).

An increasing number of women are enrolling in universities in almost every nation. Women have equal representation among graduates at both the bachelor's (53%) and master's (55%) levels globally. Women currently make up 44% of Ph.D. graduates, up from 43% in 2013, although many drop out once they reach the level necessary for a research career (Fraguas-Sanchez et al., 2023; Huyer, 2030). Generally, the majority of countries still have a higher proportion of women graduates than men in the humanities and arts, media and information, social sciences, and health and welfare.

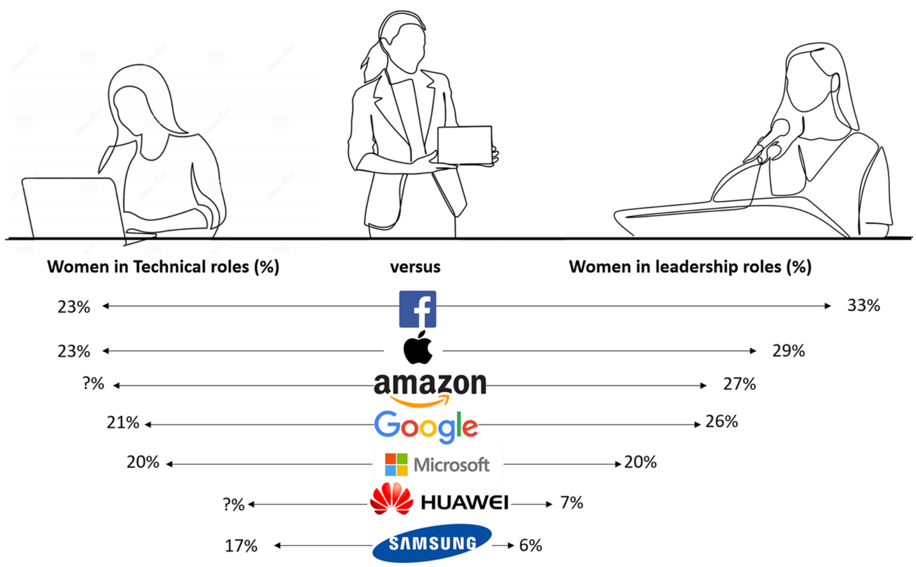

Fig. 2 Comparison of the percentage of women employed in technical and leadership roles in top technological companies between 2018–2019. Modified from: (UNESCO, 2021)

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) Institute for Statistics, data from 107 countries between 2015–2018 indicate that women make up 33.3% of researchers globally. Although this is substantially greater than it was five years ago (28.4%), there are still significant data gaps (UNESCO, 2021). However, women are still a minority among researchers in the industry. In four out of ten countries that have reported data, the proportion of female researchers in the academic and governmental sectors are equal to men, but this is not the scenario in industry. With a few notable exceptions, such as Iceland, Latvia, Lithuania, and Spain, where women make up between 30 and 40% of industrial researchers, the proportion of women in the business sector is relatively low among Organisation for Economic Co-operation and Development (OECD) nations (UNESCO, 2021). Other countries, like Germany (15%), Japan (10%), and Saudi Arabia (2%), have even lower percentages (UNESCO, 2021).

Another milestone is the growth in the number of patents with at least one female inventor involved. Even though the proportion of patent applications with at least one female inventor reached a record high in 2019, just 19% of inventors are women. Although progress has been extremely slow, it has at least been consistent; in 2013, just 14% of inventors were women. The World Intellectual Property Organization (WIPO) reported that between 2010 and 2019, the average percentage of international (Patent Cooperation Treaty, PCT) patent applications with at least one female inventor climbed from 28 to 35% globally. Africa was the only continent unaffected by this trend. In 2000, at least one female inventor was listed on 20% of patent applications (WIPO, 2019).

In academia, even though four out of ten academics worldwide are women, they frequently are forced in lower academically ranked position (Fig. 3). Women have now virtually attained gender parity at universities, however, they continue to be

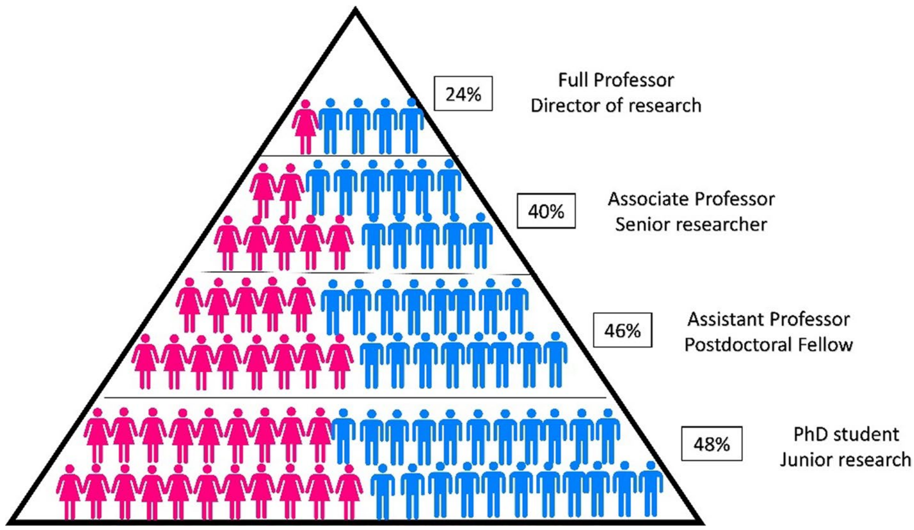

Fig. 3 The career academic pyramid. Data obtained from: UNESCO and Equal Skills Coalition (2019)

underrepresented in fields related to Industry 4.0. The gender pay gap worsens as more women pursue careers in science. As they ascend to the upper tiers of research governance bodies like academies of science or scientific councils, their presence becomes more and more rarefied. As seniority increases, the representation of women declines. A similar trend is observed in practically all nations, as women are a minority in higher leadership or government roles indicative of vertical segregation.

Women also face higher criteria in grant applications, peer reviews, tenure reviews, and employment applications (Brower & James, 2020; Witteman et al., 2019). The quality of research of women researchers is undervalued, even though women researchers grow their careers at faster rates (Brower & James, 2020). Women researchers accrue lower research grants. In 2015, female researchers in Argentina, who were in charge of scientific initiatives, requested and received 25% less funding than their male counterparts (UNESCO, 2018). Women are just as productive as men in terms of research output, but they often have shorter careers and higher rates of departure at each point of their careers (Huang et al., 2020). Women often quit their research careers for various reasons, including the challenge of finding a balance between work and family (Huang et al., 2020). Another possible explanation is the gender pay disparity in academia.

Despite identical publication output per career year, the disparity is due to women's shorter careers (Huang et al., 2020). Although being published in prestigious journals is a crucial component of career growth, female authors have consistently been underrepresented. Women are less likely than men to be the first or last authors, and publications by women are cited less frequently. Publishers may be reluctant to accept papers written by women for publication, because having a low citation rate has a detrimental impact on a journal's impact factor (Kleijn et al., 2020; Shen et al., 2018).

Peer review is another area where gender bias remains. According to a study that examined over 23,000 research manuscripts in ecology and evolution that was submitted to six journals between 2010 and 2015, women generally received lower grades and were more likely to have their submissions rejected by peers (Fox & Paine, 2019). The same tends to occur when selecting academics for giving a keynote or plenary session. Female scientists are invited less frequently than men (Kiser et al., 2019; UNESCO, 2021).

Necessary skills of Industry 4.0 entrepreneurs

To seize the opportunities presented by Industry 4.0, it is critical to clearly define the skills and experience required to fully utilize automation, data exchange, and IoT, cloud computing and cognitive computing. Academia should equip newly recruited graduates with skills in demand by industry to grow the Industry 4.0 workforce. The necessary skills for Industry 4.0 are divided into three categories (i) behavioural skills, (ii) technological skills, and (iii) analytical skills (Fig. 4) and are complemented by (iv) entrepreneurial skills.

Behavioural skills such as adaptability and being a team player within a business are core. Entrepreneurs evolve in a deep reflective environment when they are adaptive in their capacity to lead a team or collaborate with others successfully embracing novel technologies and automations. Communication and presentation skills remain highly valuable to companies, considering that technical contexts require different communication abilities than non-technical contexts do (McLeish, 2002). However, freshly graduated students are less competent in written communication than oral communication (Al-Shehab, et al., 2020) and both of these skills remain equally important.

Leadership can be considered the top emerging necessary skill in Industry 4.0. There is evidence that women leadership characteristics and behaviours differ to those of men and are necessary to address the new challenges leading to a paradigm shift for female leaders (Chuang & Eversola, 2022). Women's leadership strengths are their ability to be sensitive to other people's needs and feelings, being emotional, devoting themselves to

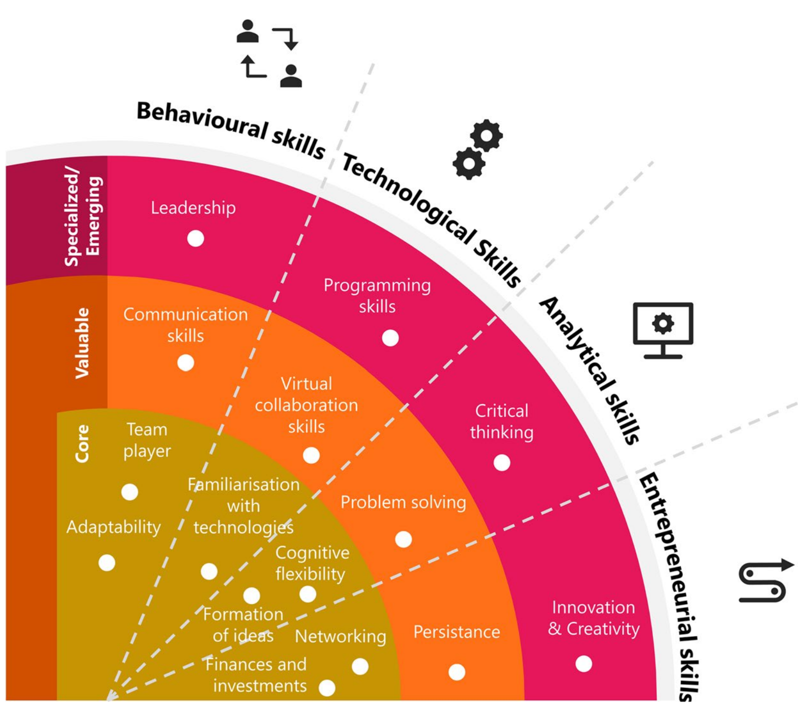

Fig. 4 Essential skills for Industry 4.0 entrepreneurs

help others, developing war relationships with others, and utilizing idealized attributes and inspirational motivation (Martin, 2015; Tench et al., 2017). Cimirotić et al. (2017) identified several personal enabling factors such as social and interpersonal skills, specialized knowledge, professionalism, ambition, hard work, ability to assert oneself, and enjoyment of one's job, that can assist women in advancing to higher levels of leadership in this competitive Industry 4.0 work environment. Exploiting the unique women's traits and strengths is critical in unleashing their leadership potential making gender differences an opportunity and not a barrier (Chuang & Eversola, 2022).

According to the Multifactor Leadership Questionnaire, there is no difference found in leadership effectiveness between genders, and actually, more similarities in leadership behaviour were found between executive men and women than no-executive such as assertiveness, decisiveness, and strategic thinking (Stempel & Rigotti, 2018; Yan et al., 2018). However, several differences were discovered in global leadership strengths such as demonstrated superior interpersonal impact and cosmopolitan outlook for men and greater diplomacy and intercultural empathy for women (Wille et al., 2018). One main barrier that should be overcome is the lack of confidence in women. Even in several studies in which women scored significantly higher than men on leadership effectiveness, women considered themselves less effective in self-ratings (Sheppard, 2018).

There are demonstrated biological differences between women's and men's brains that can explain why they see and do things differently (Li, 2014). Women have more persistent amygdala responses to familiar, negative information, which makes them more vulnerable to affective disorders resulting in anxiety and depression (Andreano et al., 2014). However, women tend to perform better on object location and recognition such as remembering faces, and verbal memory (Li, 2014). In terms of multitasking skills, women have demonstrated increased activation in functional networks from the inferior frontal gyrus of the brain, especially for verbal dual-tasking as women can be processing information on a subconscious unattended level (Tschernegg et al., 2017; Zhang et al., 2018). Women have significantly more active areas related to the emotional (limbic) and memory (hippocampus) tasks which explain why females tend to be more emphatic, intuitive, and collaborative than males (Amen et al., 2017).

Another biological difference that impacts leadership management style between genders is the ability to process information. Women process information more elaborately, seeking information between their self-generated and outside information, and before concluding, women evaluate all available information (Bhaduri & Ha-Brookshire, 2015). In terms of problem-solving style, women are more intuitive and have exhibited greater levels of creative problem-solving and positive perceptions of the general process (Hardy & Gibson, 2015). But at the same time, women tend to have low self-efficacy and are more affected by excessive information and conflicting information such as non-credible information (Hoogerheide et al., 2016).

Technological skills are paramount considering the exponential growth of Industry 4.0 which requires continuously remaining up-to-date and current in the technical knowledge and skills as well as learning about emerging technologies for current and future markets. Virtual collaboration, defined as the capability to make effective collaboration between virtual team participants via technology, has developed into a core skill in this new era (Islam, 2022). Computer and software programming and development skills are technical expertise through which a set of software could be developed and created (Islam, 2022; Santos & Roux, 2018). Current society has realized this demand and this is reflected in the education systems as policymakers are increasingly demanding inclusion of programming skills in their curricula. There is controversy on this topic as what may look like a necessity for others, is an unnecessary luxury for others considering that many students have not mastered basic literacies. Several advantages have been attributed to teaching programming in schools as this will help students acquire professional skills relevant to the future's job market, develop problem-solving skills, understand the nature of the world around them, serve as a gateway to further study in STEM subjects, and allow for new avenues of creativity and expression (Should All Students Learn How to Code, 2023).

Within **analytical skills**, strong critical thinking and problem-solving skills are crucial. A critical thought process involves weighing the arguments, observations, facts, and evidence that is accessible before making a decision. Critical thinking allows a person to employ logic and reasoning to identify the weaknesses and strengths to alternate solutions, and approaches to problems and draw conclusions. Critical thinking involves cognitive skills that imply intellectual abilities allowing a learning process. Cognitive skills support not only mastery of a certain task, but also agility and ability to perform it. Relevant to critical thinking, problem-solving skills are crucial not only to identify complex problems but mostly on reviewing information to introduce alternative solutions in solving issues involving cognitive flexibility. Industry 4.0 is a high-end industry that necessitates a high cognitive load management capability and constant technological advancement. Thus, it is crucial to grasp and improve the cognitive abilities required to comprehend and prioritize key elements across multiple areas that are interconnected. Finally, solving problems requires not only analytical skills, but also creative skills, as ideation is a fundamental part of the thought process that involves developing, articulation, and expressing novel ideas (Al-Shehab, et al., 2020; Islam, 2022).

An entrepreneur has to possess innovation and creativity skills which are related to the generation of novel ideas within the analytical skill set. But, a broader range of skills including key psychological and soft skills such as a high degree of persistence and continuity are key for successful entrepreneurs. Customer communication and engagement cannot be underrated to the success of entrepreneurs. For an entrepreneur, a technological and a curious understanding of the product is vital for the company. In majority of novices, the technological part tends to not be an issue, but the business and financial management skills remain barriers. Possessing networking skills are useful to succeed as an entrepreneur as they need to be surrounded by the correct people to support them and shift the balance towards success (Wahl & Munch, 2021).

A training programme to empower women in Industry 4.0

The Global Entrepreneurship Monitor (GEM) Women's entrepreneurship Report offers a trend analysis of women's entrepreneurship in 50 countries around the globe (GEM, 2021). A Spanish report in 2019–2020 revealed that women initiated entrepreneurial activities at a significantly less percentage than men (43 vs 57%) (GEM, 2021). This gender gap was reduced in 2021–2022, when women reported start-up rates equal to or greater to men along with other four countries: the Dominican Republic, Kazakhstan, Morocco, and Romania but remains at the last 8 position in terms of other high income countries. However, when comparing the total early-stage entrepreneurial activity, Spain has one of the lowest percentages (about 5%) in the world (GEM, 2021). Entrepreneurship is considered more a necessity rather than an opportunity in most cases with a significant deficit in entrepreneurial activity in STEM-related fields, especially in Higher Education. The low number of women in STEM in Spain is in contrast to number reported in the Latin America and Caribbean (LAC) region led by Brazil (15%), Peru (11%) Argentina (9%) with 10% of women entrepreneur companies in the HealthTech areas (wX Insights, 2020).

In fast developing economies such as China, only 9.3% of women engage in entrepreneurship, compared to 12.2% in Korea and 8.7% in India, which is in contrast with southeast Asian countries such as Thailand (19.3%) and Malaysia (20.1%) or higher levels reported in Vietnam and Indonesia (Franzke et al., 2022; Surangi, 2022). In developing Asian countries, female entrepreneurs often have a low level of education and work in the informal sector, driven by economic necessity, whereas many female entrepreneurs in transitioning/developed Asian countries are highly educated and work in high-growth industries (Surangi, 2022). Culture and different religions, e.g. Islam and Hinduism, are major sources of constraints for the education and financing of female entrepreneurs in Asia. The low representation of women in STEM fields in China and gender differences are shaped by the social construction of gender roles, lower career expectations from parents and gender stereotypes from the culture negatively impacting on women's achievement motivation (Lingas, 2013; Xueyan & Gao, 2021). In middle East, a relationship between faculty characteristics and their entrepreneurial orientation in Higher Education has been detected. Female faculty are more proactive than men, but males are innovative and risk-takers to some extent modulating the entrepreneur behaviour (Abidi et al., 2022).

A pilot study was performed at the University Complutense of Madrid, the largest public research university and one of the oldest operating universities in the world located in Madrid (Spain) enrolling over 86,000 students (the third largest non-distance European university by enrolment). By Royal Decree of 1857, the University of Madrid was the first and only institution in Spain authorized to grant doctorate degrees throughout the Spanish Empire. In 1909, the University of Madrid became one of the first universities in the world to grant a doctorate degree to a woman (Maria Goyri, 2023). A total of 25 participants were enrolled in the study including academic staff members (40%) and postgraduate Ph.D students and postdoctoral researchers (60%). Women represented 80% of the participants. The study was conducted after participants engaged and completed a training programme on "Entrepreneurship in STEM-related fields in Higher Education" to introduce the participants to the entrepreneurial world. The training was delivered by the Business Professional Women (BPW) Association of Madrid (Spain) (Bussiness professional Women Association, 2023). BPW represents the International Federation of Business Professional Women (IFBPW) that is a non-governmental organization representing founded in Geneva in the year 1930 by Dr. Lena Madesin Phillips and is currently the world's largest organization of business and professional women fighting for the defense and rights of business and professional women on 5 continents and in more than 110 countries around the world in Spain. BPW obtained its own special ECOSOC

(Economic and Social Council) before the United Nations on 2nd of August 2019 and is the voice of Spanish businesswomen, professionals and managers before the United Nations, UNECE (UN Economic Commission for Europe), CSW (Commission on the Status of Women), and CEDAW(UN Committee on the Elimination of Discrimination against Women) (BPW Madrid, 2023). The training programme was structured in three blocks. The first block comprised a 36 h training session covering the following modules: business canvas design, development of minimum viable product (MVP), market evaluation, finance analysis using the Growbox platform, introduction to venture capital, and human resources management. The second block included 125 h of individual mentoring sessions and the third block was organized Demoday pitching event. In Table 1, the distribution of the following packages is summarised.

“Business canvas design” guided each participant to develop or consolidate their business canvas model clarifying the need or the pain/challenge that the participants are solving with their business idea. Based on this premise, participants then were coached on drafting their value proposition. The next step involved identifying the market/customer segment that the business was targeting and how to engage their customers by developing appropriate communication channels either direct or virtual. The third element of the canvas model was to identify the key partners, the key activities, and the key resources needed to start the business. Weighing the needs, the product, and the segment of clients that the participants were targeting, the revenue stream and the cost structure was established and delineated via active coaching.

Once all participants drafted their own Business Canvas model, the second module of the training course focused on the design and development of the MVP. For entrepreneurs stemming out from Higher Education researchers, the MVP arises, in many situations, from research performed by the participants which may be patentable but not necessary in all cases. During this module, the need and process of patenting prior publication was discussed to empower participants to maintain their intangible, but sometimes only assets within their own start-up. During the patenting process as well as during the MVP development, it is crucial to perform an exhaustive market evaluation to determine the real novelty of the MVP, highlight competitors and define the window of opportunities for the business.

The fourth module focused on finance analysis. Participants were provided with the Growbox Innovation platform that involves a detailed intuitive spreadsheet for

Table 1 Training programme implemented at Universidad Complutense University of Madrid on Entrepreneurship in STEM-related fields in Higher Education

Block	Number of hours	Learning methodology
Training session	12	Face-to-face group sessions
	6	Virtual group sessions
	18	Self-paced-study
Competency test: progression to next block and allocation of mentor to mentees		
Mentoring session	125	Individual mentor–mentee sessions combining face-to-face and virtual blended learning meetings
Demoday	3	Pitch of the business plan

participants summarizing and highlighting the main costs associated with the development of their MVP and a prediction of profit generated by future revenue streams (TheGrowBOx Innovation Platform, 2023). When patents are the main commercializable assets, a deeper discussion followed with coaches to understand how this intangible asset can be valued.

The training course continued with a module focused on how the participants can get access to funding coming from venture capital or business angels and which are the implications of this source of funding on equity. Finally, the last part focused on human resource management, which are key elements to form balance core teams. As most participants were coming from a research background, it was key to provide advise on how to link and select business lawyers and other personnel with administrative (e.g. human resources) and business skills.

Twenty participants were shortlisted based on a custom-made developed Entrepreneurial competency test developed by theGrowbox Innovation Ltd sponsored by the BPW (BPW Madrid, 2023; TheGrowBOx Innovation Platform, 2023). Participants that obtained at least 5 out of 10 points were shortlisted to be part of the training programme and their results allowed for identification of the best mentor to their learning needs. The test evaluated the motivation, skills, and aptitude toward entrepreneurship. Motivation is the fuel that drives every entrepreneur, because without it there is no incentive and no winning spirit. It is not just about making money, but about the feeling and thrill of competition, the quest for adventure, and the pleasure of creation. Aptitude is the innate capacity of people to adequately develop a given activity or task. Skill is the development of that aptitude, acquired by learning. The skills are learned and trained and aptitudes are always there waiting for a stimulus to develop. Ten competencies were assessed in the test: need for achievement, power, ambition, autonomy, perseverance, self-confidence, stress management, creativity, influence of power, and proactivity. After the training, participants performed a matching test to be paired with one of the mentors from the BPW Association. A total of 125 h of individual mentoring sessions was implemented between mentor and mentee. Once the training and mentoring sessions were finalized over a 6-month period, participants presented their pitch to show their entrepreneurial projects in a Demoday (pitch) event in front of a range of specialists in start-ups development. Finally, all participants filled out an anonymous survey consisting of 12 open questions at the end of the programme to understand the impact of the training received towards awakening the entrepreneurial spirit in academics and researchers in Higher Education in STEM-related fields. This study was performed under the Ethical Committee approval by Universidad Complutense of Madrid (CE_20221110-15_SOC).

Unlocking the potential of entrepreneurship in Higher Education in STEM-related fields

The competency test performed was a useful indicator to discriminate which individuals possess adequate innate skills to succeed as an entrepreneur. Eighty percent of the participants (n = 20) showed a final average score of five points or above in the evaluation (Fig. 5). Results are represented by business skills grouped in motivation, overall skills and aptitude (Fig. 5a), while the key competencies for entrepreneurship were also summarized (Fig. 5b).

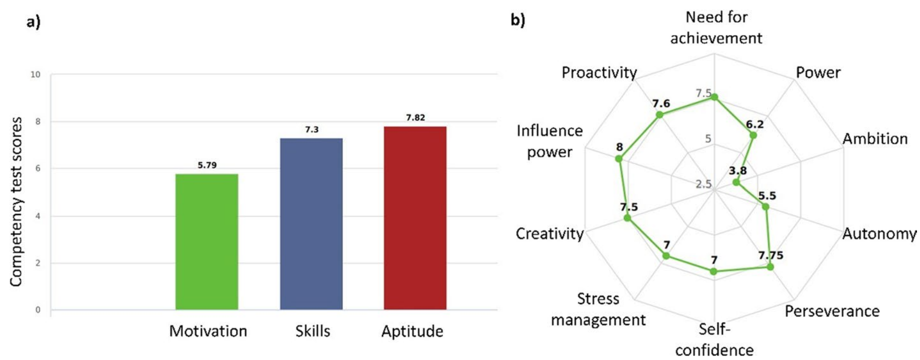

Fig. 5 Results obtained from the competency test

The need for achievement is reflected in the desire to progress, excel, and surpass oneself. Entrepreneurs who have this characteristic like to set goals and obtain positive feedback on what he/she to do to excel. These individuals often have a strong competitive spirit, especially against themselves. The desire for power can be aligned with positive competencies for entrepreneurship. Power is related to management, which is essential when creating a new start-up. Challenge and ambition are closely related to the need for fulfillment. Ambitious people are those who seek to permanently embark on difficult projects to make their dreams come true with a constant need to learn. Effective decision-making is a valuable skill in any workplace. Measuring the degree of autonomy can be related to the ability to make decisions on time. Aligned with autonomy is self-confidence showing optimism about the process. Perseverance is identified by persistence in efforts and determination in the search for solutions to problems and is crucial for an entrepreneur when optimal approaches are required for encountered problems. The ability to manage stress appropriately is important as usually entrepreneurs need to coexist well with ambiguity and uncertainty and have a strong capacity for adaptation. A certain degree of creativity is essential in an entrepreneur with a high capacity for problem-solving. Some people attribute their success to luck and others to their efforts. People whose profile is entrepreneurial tend to believe that they have the power to influence events by the actions they take. Finally, a fundamental characteristic of entrepreneurs is that they are action-oriented. Speed of action and diligence are quite common traits in entrepreneurial phenotypes.

Participants showed a positive reaction to the results obtained from the test as it allowed them to self-reflect and self-evaluate. The objective of the test was not to demotivate individuals, but reflect on their strengths and weaknesses. Finding the right core team is essential for the success of a start-up. Complementary personalities with different skill sets tend to be more competitive in the Industry 4.0 environment, but finding the right partners to encompass all the required skills in a team can be a hard task. This type of questionnaire was useful to demonstrate complementarity.

Participants were working in academia either at the Ph.D. or postdoctoral level or as assistant or associate professors in STEM-related fields such as pharmaceutical engineering, pharmacology, chemical engineering, chemistry, and microbiology. Three-quarters of the participants were novices to the entrepreneurial world, this being their first time to receive entrepreneurial training. However, all researchers came from an applied research background and they were product or process-oriented. Sadly though, the most common primary goal of the participants was aimed towards publication of the results in specialized research journals. After the training, all the participants were able to fuel their ideas into an MPV or consultancy business as shown in the pitch presented on the Demoday. The areas with the poorest degree of competence were finance and marketing. The training allowed the participants to strengthen their understanding of these topics suggesting the need for collaboration with a business-background members such as those available in the BPW.

Quantitative data collected from the survey filled out at the end of the training period are summarized in Fig. 6. Fifty percent of the participants showed a high satisfaction degree with the training received and for the rest of the participants, the training fulfilled their expectations in an excellent manner (Fig. 6a). At the end of the training, the participants expressed their feelings on the likelihood to create a start-up within the next 5 years. Surprisingly, none showed a low probability of embarking on an entrepreneurial project. However, mixed feelings were observed regarding the complexity and feasibility of the process (Fig. 6b).

All the participants showed enthusiasm for the training received. Novel blended learning methodologies should be incorporated in entrepreneurship training in Higher Education (Fraguas-Sanchez et al., 2022; Serrano et al., 2019). However, they would have preferred a longer training course to deepen learning in all the areas. Currently, novel methodologies on entrepreneurship have just been introduced at the university, but there is still a reluctance to incorporate them into the curricula of scientific disciplines. One of the advantages of this pilot study was the limited number of participants, which allowed individualized monitoring and mentoring of each participant and their business project. Researchers and academics considered essential for a successful entrepreneur the following skills: perseverance, creativity, being data-driven, leadership, teamwork capacity, proactivity, curiosity, diplomacy, taking initiative, and learning skills.

Participants, on the other hand, believe that they need to improve in certain areas prior embarking on an entrepreneurial project. They highlighted the lack of self-confidence, ambition, and knowledge on market research along with limited knowledge on the processes of patent filling, legal requirements, finance management, and scaling up their product manufacturing. In some cases, poor clarity of the company objectives was also noted. Addressing these issues in entrepreneurship training aimed at Higher Education staff and students will fuel and drive entrepreneurship goals and outputs.

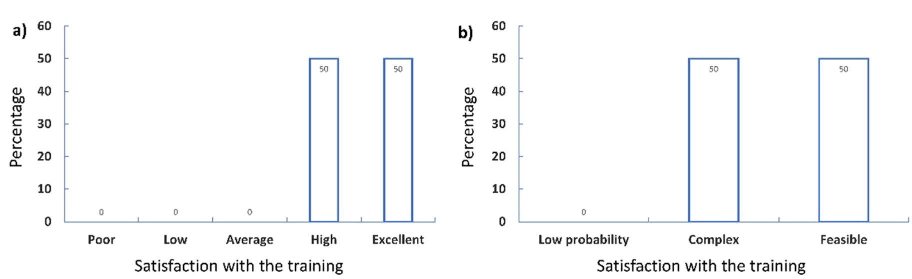

Fig. 6 Data collected from the final evaluation survey. Key: **a** degree of satisfaction with the training received, **b** self-reflection for the likelihood of creating a start-up within the next five years

After the training received, four participants shared their ideas on starting their business. The start-ups were mainly focused on pharma consulting companies with established intellectual property aimed at the development of novel formulations and personalized medicines. The main prohibitory factor was the need for equipment and facilities provided by the University to establish the start-up objectives and provide laboratories and facilities required for scale-up and consolidation of these high risk and high gain companies. These participants (both academics and post-graduate students), however, managed to secure funding (12K Euros) from the Universidad Complutense Incentive Program that enabled them to initiate their start-up and provide them with office based space for the start-up and is an early indicator of success of our programme.

Conclusions and future perspectives

Women entrepreneurs need to overcome numerous structural, administrative, and gender-related challenges to initiate and success in the Industry 4.0 era. Lack of access and reach to networks and opportunities, established glass ceiling in their institutions or industries, limited training in IT, difficulties in obtaining finances from non-family sources, as well as functional knowledge of legal and financial procedures to initiate and run a business. Clearer understanding of legal processes for protection of intellectual property also endangers the financial exploitation of technological novelty developed from their research that is patentable. Family and societal demands and expectations affect women differently around the globe but still play a role. In the absence of a sufficient number of state-run institutional interventions, any action coming from autonomous, voluntary private sector initiatives providing counselling and up-skilling to women such as "The Mellon Skills Accelerator" in Greece are great alternatives to trigger entrepreneurship and generate new opportunities for women (Tsimas, 2020).

It is essential to change the skills that the educational systems are transferring to the students and researchers to ensure matching with those skills demanded by Industry 4.0, such as programming. Inclusion of entrepreneurship methodologies in the curricula of Higher Education is also a necessary step change that should embraced and embedded in all disciplines. This pilot training programme has been successfully implemented and has grown essentials skills required to create a start-up offering a 360º vision on the legal, financial, and technical needs required. A major transformation should target the STEM-related fields in Higher Education moving from the mass production of publications to patent protection and the creation of start-ups that bring novel solutions for the current problems that society is facing up. This transformation must be supported by the Higher Education institutions removing the pressure to publish, but promoting and giving economical support for intellectual property protection and creation of start-ups. At governmental level, there is an urgent need to pave the way for creating a start-up by facilitating the administrative procedures and granting microcredits, which would remove the barrier of economical familiar dependence.

Abbreviations:

3D	Three dimensional
BPW	Business and Professional Women
CEDAW	United Nations Committee on the Elimination of Discrimination against Women
CPS	Cyber Physical Systems
CSW	Commission on the Status of Women

GDP	Gross domestic product
GEM	Global Entrepreneurship Monitor
ECOSOC	Economic and Social Council
EU	European Union
IFBPW	International Federation of Business and Professional Women
IT	Information technology
LAC	Latin America and Caribbean
MVP	Minimum viable product
OECD	Organisation for Economic Co-operation and Development
PCT	Patent Cooperation Treaty
STEM	Science, technology, engineering and mathematics
UCM	Universidad Complutense Madrid, Spain
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNECE	United Nations Economic Commission for Europe
WIPO	World Intellectual Property Organization

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Author contributions
Conceptualization: DRS, AIFS, EGB; methodology: DRS., AIFS, EGB, AL, PM, CL; formal analysis: DRS, AIFS, EGB; investigation: DRS, AIFS, EGB, AL, PM, CL; resources: DRS, AIFS, EGB, AL, PM, CL; writing—original draft preparation: DRS; writing—review and editing: DRS, AL, AIFS, EGB; project administration: DRS, AIFS, EGB; funding acquisition: DRS. All authors have read and agreed to the published version of the manuscript.

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Data availability
Data made available upon request.

Declarations

Ethics approval and consent to participate
This study was performed under the Ethical Committee approval by Universidad Complutense of Madrid (CE_20221110-15_SOC).

Consent for publication
Informed consent was obtained from all subjects involved in the study.

Competing interests
The authors declare no conflict of interest.

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References

Abidi, O., Nimer, K., Bani-Mustafa, A., & Toglaw, S. (2022). Relationship between faculty characteristics and their entrepreneurial orientation in higher education institutions in Kuwait. *Journal of Innovation and Entrepreneurship, 11*, 12.

Al-Shehab, N., AL-Hashimi, M., Madbouly, A., Reyad, S., & Hamdan, A. (2020). Do employability skills for business graduates meet the employers' expectations? The case of retail Islamic banks of Bahrain. *Higher Education, Skills and Work-Based Learning, 14*, 349–366.

Amen, D. G.,Trujillo, M., Keator, D., Taylor, D. V., Willeumier, K., Meysami, S., & Raji, C. A. (2017). Gender-based cerebral perfusion differences in 46,034 functional neuroimaging scans. *Journal of Alzheimer's Disease, 60*(2), 605–614.

Andreano, J. M., Dickerson, B. C., & Barrett, L. F. (2014). Sex differences in the persistence of the amygdala response to negative material. *Social Cognitive and Affective Neuroscience, 9*(9), 1388–1394.

Bhaduri, G., & Ha-Brookshire, J. (2015). Gender differences in information processing and transparency: Cases of apparel brands' social responsibility claims. *Journal of Product & Brand Management, 24*, 504–517.

BPW Madrid. Retrieved August 23, 2023, from https://bpw-spain.org/conoce-bpw-spain/que-es-bpw/

Brower, A., & James, A. (2020). Research performance and age explain less than half of the gender pay gap in New Zealand universities. *PLoS ONE, 15*(1), e0226392.

BUssiness professional Women Association Retrieved March 05, 2023, from https://bpw-madrid.org/la-asociacion/

Chuang, S., & Eversola, B. A. W. (2022). Organization development and effectiveness: Essential female leadership competencies for industry 4.0 transformation. *Advancing Women in Leadership Journal, 41*, 1.

Cimirotić, R., Duller, V., Feldbauer-Durstmüller, B., Gärtner, B., & Hiebl, M. R. (2017). Enabling factors that contribute to women reaching leadership positions in business organizations: The case of management accountants. *Management Research Review, 40*, 165–194.
de Kleijn, M., et al. (2020). *The researcher journey through a gender lens: An examination of research participation, career progression and perceptions across the globe*. Elsevier.
EIGE. (2017). Economic Benefits of Gender Equality in the EU: How Gender Equality in STEM Education Leads to Economic Growth. European Institute for Gender Equality: Vilnius. Retrieved March 03, 2023, fromhttps://eige.europa.eu/gender-mainstreaming/policy-areas/economic-and-financial-affairs/economic-benefits-gender-equality/stem
Fox, C. W., & Paine, C. E. T. (2019). Gender differences in peer review outcomes and manuscript impact at six journals of ecology and evolution. *Ecology and Evolution, 9*(6), 3599–3619.
Fraguas-Sanchez, A. I., Serrano, D. R., & González-Burgos, E. (2022). Gamification tools in higher education: creation and implementation of an escape room methodology in the pharmacy classroom. *Education in Science, 12*, 833.
Fraguas-Sanchez, A. I., et al. (2023). Does the Ph.D. degree correlate with a high-paying job? Assessment of the impact of Ph.D. Studies on Students' satisfaction and career prospects. Educational Sciences.
Franzke, S., Wu, J., Froese, F. J., & Chan, Z. X. (2022). Female entrepreneurship in Asia Asian business and management. *Asian Business & Management, 21*, 343–372.
GEM 2021/22 Women's Entrepreneurship report: From crisis to opportunity. Retrieved March 05, 2023, from https://gemconsortium.org/report/gem-202122-womens-entrepreneurship-report-from-crisis-to-opportunity
Hardy, J. H., & Gibson, C. (2015). Gender differences in the measurement of creative problem-solving. *The Journal of Creative Behavior, 51*, 153–162.
Hoogerheide, V., Loyens, S. M., & Gog, T. (2016). Learning from video modelling examples: Does gender matter? *Instructional Science, 44*, 69–86.
Huang, J., Gates, A. J., Sinatra, R., & Barabási, A. L. (2020). Historical comparison of gender inequality in scientific careers across countries and disciplines. *Proc Natl Acad Sci U S A, 117*(9), 4609–4616.
Huyer, S. (2015). Is the gender gap narrowing in science and engineering? In: UNESCO Science Report: Towards 2030. S. Schneegans and D. Eröcal (eds). ISBN: 978-92-3-100129-1. UNESCO Publishing: Paris. pp. 84–103.
Islam, A. (2022). Industry 4.0: Skill set for employability. *Social Sciences & Humanities Open, 6*, 100280.
ITU. (2017). Fast-forward Progress: Leveraging Tech to Achieve the Global Goals. International Telecommunication Union: Geneva. Retrieved March 03, 2023, from https://www.itu.int/en/sustainable-world/Pages/report-hlpf-2017.aspx
Kiser, Grace and Yoan Mantha. (2019. Global AI Talent Report 2019. Element AI. Retrieved March 04, 2023, from https://jfgagne.ai/talent-2019
Kumar, A. (2019). Industry 1.0 to 4.0. Retrieved from https://www.linkedin.com/pulse/industry-10-40-ayush-kumar
Li, R. (2014). Why women see differently from the way men see? A review of sex differences in cognition and sports. *Journal of Sport and Health Science, 3*(3), 155–162.
Lingas, K. (2013). Family businesses and the gender of entrepreneurship. *Journal of Innovation and Entrepreneurship*, *2*.
Maria Goyri. Retrieved August 23, 2023, from https://fundacionramonmenendezpidal.org/biografia-maria-goyri/
Martin, J. (2015). Transformational and transactional leadership: An exploration of gender, experience, and institution type. *Portal: Libraries and the Academy, 15*, 331–351.
McLeish, A. (2023). Employability skills for AUSTRALIAN small and medium sized enterprises. Retrieved March 05, 2023, from https://www.voced.edu.au/content/ngv%3A3781.
Santos, M. D., & Roux, G. A. (2018). Programming skills in the industry 4.0: Are chemical engineering students able to face new problems? *Education for Chemical Engineers, 22*, 69–76.
Serrano, D. R., Dea-Ayuela, M. A., Gonzalez-Burgos, E., Serrano-Gil, A., & Lalatsa, A. (2019). Technology-enhanced learning in higher education: How to enhance student engagement through blended learning. *European Journal of Education, 54*, 273–286.
Serrano, D. R., Kara, A., Yuste, I., Luciano, F. C., Ongoren, B., Anaya, B. J., ... & Lalatsa, A. (2023). 3D printing technologies in personalized medicine, nanomedicines, and biopharmaceuticals. *Pharmaceutics, 15*, 2.
Shen, Y., Webster, J., & Shoda, Y. (2018). Persistent underrepresentation of women's science in high profile journals. *BioRxiv, 2*, 275362.
Sheppard, L. D. (2018). Gender differences in leadership aspirations and job and life attribute preferences among U.S. undergraduate students. *Sex Roles, 79*, 565–577.
Should All Students Learn How to Code? Pros and Cons. Retrieved March 05, 2023, from https://www.wise-qatar.org/coding-cognitive-abilities-michael-trucano.
Stempel, C. R., & Rigotti, T. (2018). Leaders' gender, perceived abusive supervision and health. *Frontiers in Psychology, 9*, 2427.
Surangi, H. (2022). A critical analysis of the networking experiences of female entrepreneurs: A study based on the small business tourism sector in Sri Lanka. *Journal of Innovation and Entrepreneurship, 11*(1), 61.
Tench, R., Topić, M., & Moreno, A. (2017). Male and female communication, leadership styles and the position of women in public relations. *Interactions: Studies in Communication & Culture, 8*, 231–248.
TheGrowBOx Innovation Platform. Retrieved August 23, 2023, from https://be.linkedin.com/company/growbox-international?trk=public_profile_topcard-current-company
Tschernegg, M., Neuper, C., Schmidt, R., Wood, G., Kronbichler, M., Fazekas, F., ... & Koini, M. (2017). FMRI to probe sex-related differences in brain function with multitasking. *PLoS ONE, 12*(7), e0181554.
Tsimas, K. (2020). Bespoke career up-skilling: the case of Mellon Skills. *Journal of Innovation and Entrepreneurship, 9*(6), 1–7.
UNESCO. (2018). Telling SAGA: Improving Measurement and Policies for Gender Equality in Science, Technology and Innovation. UNESCO STEM and Gender Advancement (SAGA) project. UNESCO: Paris. Retrieved March 05, 2023, from https://unesdoc.unesco.org/ark:/48223/pf0000266102
UNESCO. (2021). To be Smart, the Digital Revolution will Need to be Inclusive, UNESCO Science Report. Retrieved March 03, 2023, from https://unesdoc.unesco.org/ark:/48223/pf0000375429.locale=en
UNESCO. Women a minority in Industry 4.0 fields. Retrieved August 23, 2023, from https://www.unesco.org/en/articles/women-minority-industry-40-fields

UNESCO and Equal Skills Coalition. (2019). I'd Blush if I Could: Closing Gender Divides in Digital Skills through Education. Policy paper. UNESCO: Paris. Retrieved March 05, 2023, from https://en.unesco.org/Id-blush-if-I-could
Wahl, D. and J. Munch. (2021). *Industry 4.0 Entrepreneurship: Essential Characteristics and Necessary Skills*. IEEE International Conference on Engineering, Technology and Innovation
Wille, B., Wiernik, B. M., Vergauwe, J., Vrijdags, A., & Trbovic, N. (2018). Personality characteristics of male and female executives: Distinct pathways to success? *Journal of Vocational Behavior, 106*, 220–235.
WIPO. (2019). PCT Yearly Review 2019: The International Patent System. World Intellectual Property Organization
Witteman, H. O., Hendricks, M., Straus, S., & Tannenbaum, C. (2019). Are gender gaps due to evaluations of the applicant or the science? A natural experiment at a national funding agency. *The Lancet, 393*, 531–540.
wX Insights 2020: The Rise of Women STEMpreneurs: A Study on Women Entrepreneurs in STEM in Latin America and the Caribbean. Retrieved August 23, 2023, from https://publications.iadb.org/en/wx-insights-2020-rise-women-stempreneurs-study-women-entrepreneurs-stem-latin-america-and-caribbean
Xueyan, Y., & Gao, C. (2021). Missing women in STEM in China: An empirical study from the viewpoint of achievement motivation and gender socialization. *Research in Science Education, 51*, 6.
Yan, S., Wu, Y., & Zhang, G. (2018). The gender difference in leadership effectiveness and its Sino-US comparison. *Chinese Management Studies, 12*, 106–124.
Zhang, J., Dong, X., Wang, L., Zhao, L., Weng, Z., Zhang, T., ... & Yan, T. (2018). Gender differences in global functional connectivity during facial emotion processing: A visual MMN study. *Frontiers in Behavioral Neuroscience, 12*, 220.

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