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A Cause-Effect Analysis of Entrepreneurship and STEM Education

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Abstract

The motivation behind integrating science, technology, engineering, and mathematics (STEM) in the education process is not commercial profit, but a desire to nurture human potential. STEM education and entrepreneurship share common success factors that rely on the qualities, skills, abilities, and competencies of learners. These two fields are interconnected by interdisciplinary relationships that promote creativity, critical thinking, and problem-solving skills. This study aims to investigate how closely the business life cycle and lifelong learning are associated with the study context in these two areas. The study will examine definitions, theories, principles, and models to show how both the business world and STEM education can solve real problems. Ultimately, this article provides an original and comprehensive explanation of the steps needed to achieve success in both entrepreneurship and STEM.

Keywords: causality, competencies, entrepreneurship, STEM education, sustainability, well-being

1. INTRODUCTION

STEM education plays an important role in preparing students for success in modern economies. As technology becomes increasingly important in many industries, students with strong scientific and technical foundations are likely to be more competitive in the job market (Stef et al., 2023). Additionally, STEM education can contribute to the promotion of creativity and critical thinking skills, which are valuable in many fields (Shen, 2023). There is a complex interplay between entrepreneurship, STEM education, and well-being, and they can complement each other in improving the quality of life sustainably. STEM education provides a foundation for entrepreneurial success, which can lead to greater financial stability, autonomy, life satisfaction, and a higher level of happiness. Pursuing a career in STEM education can increase the likelihood of successful entrepreneurship, which in turn can contribute to financial stability and improved well-being.

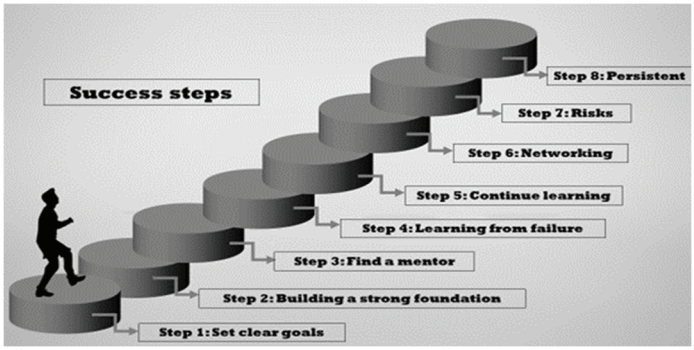
The present approach is based on systems thinking, which is a problem-solving method that emphasizes understanding the complex interactions and feedback loops between different parts of a system (Bhardwaj et al., 2023). Therefore, systems thinking includes analyzing the interdependence between STEM education and entrepreneurship, including how advances in STEM education can create new opportunities for entrepreneurs and how entrepreneurs can lead to innovation in STEM fields (Williams et al., 2023). By understanding the complex relationship between STEM education and entrepreneurial activity, stakeholders can identify opportunities to strengthen both fields and promote economic growth. This, in turn, can stimulate further innovation in the STEM field and create a virtuous cycle of economic growth. In general, systems thinking approaches for STEM education and entrepreneurship can help stakeholders identify the root causes of the challenges and opportunities in these fields and lead to more effective policies and strategies that promote innovation and economic growth. The objective of STEM education is to provide students with a comprehensive understanding of these fields, their interrelatedness, and their application in the real world (Stohlmann et al., 2012).

2. THE RESEARCH METHOD AND DEBATES ON THE RESULTS

2.1. Introduction

Hsu et al. (2023) discuss trends in STEM education using the Web of Science database. They identified and selected 761 articles published after 2016 from an initial dataset of 1032 articles, using the co-word analysis method. The authors concluded that there is a consensus that "professional development was a critical research niche that followed STEM initiatives in 2016, leading educators to invest more in the professional development of both learners and teachers" (Hsu et al., 2023). In Kennedy and Odell's (2023) paper, they support the idea of "STEM Education as a Meta-discipline." The authors argue that stakeholders, including schools, community organizations, and enterprises, need to recognize the fundamental link between economic prosperity and the importance of developing an ongoing innovation culture to address current and future social problems, as well as jobs dependent on science and technology. While the existing literature on STEM education and entrepreneurial activities provides valuable insight into the steps required for success, other steps that have not yet been fully explored may help to achieve the goals (Picture 1):

Picture 1: Necessary steps for success



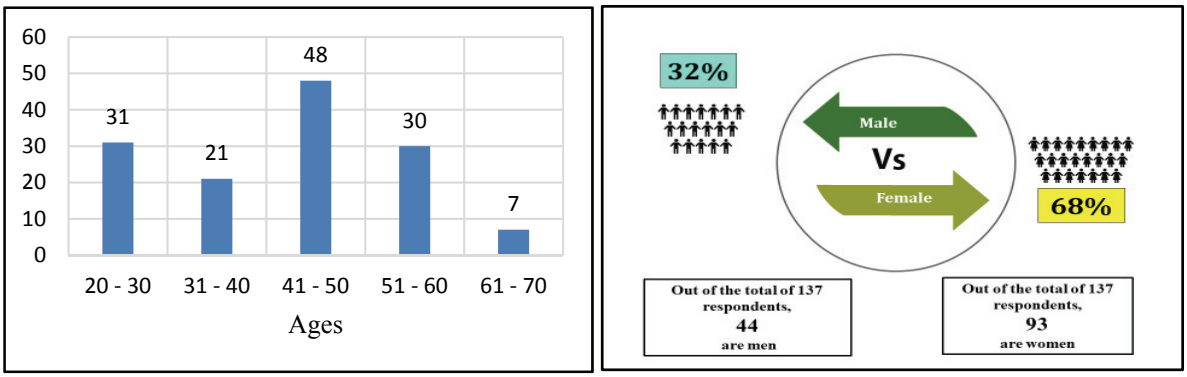
Authors' own contribution

2.2. A survey on STEM skills and career guidance

To investigate the extent of the relationship between the common competencies of entrepreneurship and STEM education, an applied research study was conducted by the authors, utilizing a specialized questionnaire designed for this purpose called "STEM: Skills and Orientation in Professional Careers." The questionnaire can be accessed via the following link: https://docs.google.com/forms/d/1C_PESIls946RZGnwApG8pIe4tlP782ib5NwmjBxwf-M/prefill. The research sample included 137 respondents who were from the Western Development Region of Romania. The participants included entrepreneurs, entrepreneurial educators, economists, as well as STEM teachers/trainers, professors, Ph.D. candidates, students, engineers, school principals, school inspectors, and members of non-governmental organizations.

The responses received highlighted the value of real-world challenges in educational and business settings, adding authenticity to the experiences of participants, whether they are teachers, coaches, or students. These challenges feature relevant and identifiable assessment questions that enable participants to address high-priority issues individually and as a team, supporting sustainable thinking and knowledge in the long term. It is important to consider the demographics of the sample to determine which category of participants understands the study's concept (as depicted in Picture 2). After reviewing and completing the questionnaire, all but one of the 50 teachers asked for clarifications and were eager to learn how to implement STE(A)M education and integrate it into the educational process.

Picture 2: Demography of the research sample



a. Respondents' age dispersion

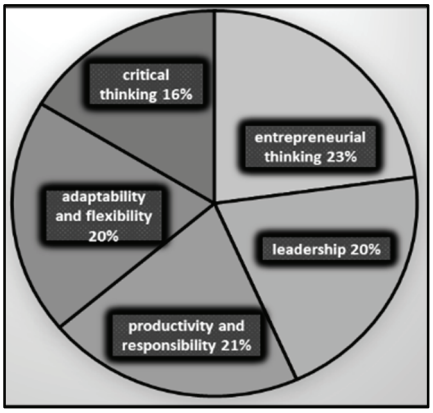
b. Respondents' gender proportion

According to the European Commission, one of the special objectives of the Horizon Europe 2023 Framework Programme (HORIZON) is to "... Increased *cooperation between relevant... actors from academia, the private sector, and national administrations to promote women and girls' participation in STEM studies and careers*" (https://ec.europa.eu/info/funding-tenders/). This topic related to gender in terms of STEM careers was also addressed in 2017, by American sociologists (Simon et al., 2017), and three other researchers studied the subject earlier (Hughes et al., 2013). Given that variety is widely regarded as a key component of entrepreneurial human capital, gender differences in entrepreneurship could be rooted in the formation of such a variety of skills. In Europe, (Krieger et al., 2022) emphasize the importance of "skill variety" as a "key component of entrepreneurial human capital, and gender differences in entrepreneurship could be rooted in the formation of such a skill variety".

In addition, the responses to the following questions have been analyzed in relation to this study: "Select the skills that you believe are necessary to address real-life problems from the following list: self-confidence, emotional intelligence, distributive attention, open-mindedness, receptivity, cooperative attitude, creativity and adaptability to change, team collaboration, scepticism, risk-taking responsibility, and critical thinking." The distribution of research results is presented in Picture 3a. Similarly, Picture 3b shows the distribution of responses to the question: "Choose from the following list of competencies/skills that you consider essential for business success: critical thinking, leadership, adaptability and flexibility, competitive value, productivity, responsibility, information search, analysis, and synthesis, understanding of globalization, understanding of innovation processes, and entrepreneurial thinking."

Picture 3: Skills Variety

a. Essential skills



b. Business success skills

Based on the research results presented in Picture 3, the following comments have been made:

- Mindfulness: the practise of being fully present and engaged in the present moment while cultivating self-confidence, self-awareness, and self-reflexion;
- Adaptability: the capacity to be flexible and adaptable in response to changing circumstances and to embrace new challenges and opportunities;
- Creativity: the ability to think outside the box, generate new ideas, and approach problems from different angles;
- Collaboration: the ability to work effectively in teams, build positive relationships, and find common ground with others.

These competencies and skills can contribute to professional success and personal satisfaction by promoting self-awareness, positive relationships, and a sense of purpose and in meaning at work and personal life (Sarfraz et al., 2021). A key skill/competition will be more important than other skills to succeed in future jobs not yet invented and at the same time to STEM fields: adaptability. Today's rapidly evolving technology landscape requires rapid adaptation to emerging new tools, technologies, and processes, including teleworking and remote working modes (Tleuken et al., 2022). This includes not only technical skills but also the ability to be flexible, creative, and open to new approaches to problem solving.

3. CONCLUSIONS

The results of applied research suggest that STEM education may play a critical role in the promotion of entrepreneurial activities and innovation. By providing people with the skills and knowledge needed to pursue careers in STEM-related fields, STEM education can help create a culture of innovation and entrepreneurship that drives economic growth and development.

The first link between entrepreneurship and STEM education is that STEM education equips students with the knowledge and skills needed to succeed in the field. Since STEM fields are associated with innovation and entrepreneurship, students who study STEM are more likely to become entrepreneurs and create their businesses. Additionally, entrepreneurship often involves the use of technologies and innovative solutions, which STEM education can help develop, thereby increasing the likelihood of successful entrepreneurial activities.

The second link between entrepreneurship and well-being is that entrepreneurship can have a positive impact on one's sense of purpose, autonomy, self-esteem, and financial stability, leading to an overall improvement in quality of life. However, since entrepreneurship can also be stressful and challenging, especially in the early stages, entrepreneurs should prioritize self-care and maintain a healthy work-life balance to ensure their well-being.

The third link between STEM education and well-being is that STEM education can lead to rewarding careers and financial stability, which can positively impact an individual's well-being. Pursuing a STEM career can also provide a sense of achievement and purpose, as it contributes to important advances and innovations in science. However, STEM education can be challenging and stressful, particularly for those who struggle with math and science. While causality may not necessarily aim to achieve the same results in terms of economic and educational well-being, it can help us understand the relationships between them.

Can we conclude that well-being indicators are an effect of the link between STEM education and entrepreneurship? No, we cannot conclude that the indicators of well-being are solely the effect of the connection between STEM education and entrepreneurial work. STEM education and entrepreneurial opportunities are important factors in determining happiness, but health care, economic stability, social support, and cultural factors play an important role. Moreover, the relationship between STEM education, entrepreneurship, and well-being is complex and can vary depending on specific contexts, individual characteristics, and cultural standards. Although the questionnaire study suggests that STEM education can promote entrepreneurship, the causal relationship between the two is not fully understood (Chu et al., 2022; Holmes et al., 2018).

On the one hand, the introduction of STEM materials can provide students with the technical skills, knowledge, and mindsets they need to develop innovative products, services, and processes that solve real-world problems and create value for others (Chien & Chu, 2018; Ku et al., 2022). Students learn to code, design, analyse data, develop prototypes and collaborate with peers, which developing skills such as creativity, critical thinking, problem solving, communication, and leadership that are highly valued by employers and investors (Brown & Bogiages, 2019; Chang & ChangTzeng, 2020; Lin et al., 2022; Mansfield, 2014). On the other hand, the entrepreneurial mindset of identifying opportunities, taking risks, and creating value can also inspire and motivate students to pursue STEM education as a means of achieving their goals (Carter, 2018; Charleston, 2012; Heras et al., 2020; Mejias et al., 2021; Quigley & Herro, 2016).

Students can discover ways to use their STEM skills to address social needs and personal interests, such as starting a business, establishing a non-profit organization, or pursuing careers in STEM fields. It's important to note that while STEM education has many positive aspects, there are also negative aspects to consider, which are not limited to the following examples (Ellison & Allen, 2018; McGee, 2020; Mejias et al., 2021):

- Lack of diversity and lack of creativity: with a focus on technical skills rather than artistic or creative expression;
- Additionally, real-world applications focus on limited areas and place too much emphasis on theory. This makes it difficult for students to see the relevance of what they learn and makes it difficult for them to apply their knowledge in the practical environment;
- STEM is highly competitive and profitable. This pressure can lead to stress, exhaustion, and mental health problems, especially for students who struggle or feel unsuitable.

Finally, we must continue diligently toward success, using Picture 1 steps:

- Set clear goals: Define short- and long-term objectives that are specific, measurable, and achievable (Ivanova et al., 2018);
- Build a strong foundation: Focus on understanding the basics of mathematics, science, and technology in STEM education, and develop marketing, financial, and management skills in entrepreneurship (Stef & Mirea, 2021);
- Find a mentor: Seek guidance and valuable advice from successful entrepreneurs and STEM professionals who can help navigate challenges (Fine et al., 2022);
- Learn from failure: Embrace failure as a learning opportunity in both fields and use it to improve (Allina, 2018);
- Continuously learn: Improve knowledge and skills in both areas by participating in workshops, seminars, and training programmes (Kotha et al., 2023);
- Network: Build a network of like-minded individuals who share a passion for entrepreneurship and STEM education by attending events, conferences, and meetings (Reid et al., 2023);
- Take calculated risks: Be prepared to step outside of the comfort zone and face new challenges in both fields (Mondal & Jimenez, 2015); and
- Be persistent: Maintain focus on goals, work hard, and never give up in order to achieve success in entrepreneurship and STEM education (Reid et al., 2023).

A promising open direction would be to develop research into the relationship between science and technology, respectively, enterprise, addressing its resilience to external factors and structural changes

in the fields of science, technology, and enterprise. This direction may propose to investigate how technological innovation, market fluctuations, changes in government regulations, and changes in the structures and behaviours of STEM entrepreneurs and researchers can influence these relationships. The study of the robustness of this link can help to understand how to improve and strengthen the link over time, and it can provide valuable information on the development of public policies and development strategies in STEM and entrepreneurial fields.

The integration of STEM in education currently represents ways of adapting to the unstoppable development of technologies, respectively, ways of training the very young and those who will be born in the coming years. In conclusion, the future employment market is full of potential and uncertainty. As we prepare for jobs that do not yet exist, it is important to stay ahead of the curve, adaptable, and optimistic. By learning new skills, looking for training programmes, and educating ourselves, we can be ready to use the new opportunities as they arise. We embrace the future with enthusiasm and confidence and know that tomorrow's jobs promise a better tomorrow for everyone.

REFERENCES

Allina, B. (2018). The development of a STEAM educational policy to promote student creativity and social empowerment. *Arts Education Policy Review*, *119*(2), 77–87.

Bhardwaj, R., Srivastava, S., Bindra, S., & Sangwan, S. (2023). An ecosystem view of social entrepreneurship through the perspective of systems thinking. *Systems Research and Behavioural Science*, *40*(1), 250–265.

Brown, R. E., & Bogiages, C. A. (2019). Professional development through STEM integration: How early career math and science teachers respond to experiencing integrated STEM tasks. *International Journal of Science and Mathematics Education*, *17*(1), 111-127.

Carter, L. (2018). STEM Education As a GERM: Reviewing Australia's STEM Discourse. In *Globalisation and education reforms: Paradigms and ideologies* (pp. 79–91). Springer, Cham.

Chang, D. F., & ChangTzeng, H. C. (2020). Patterns of gender parity in the humanities and STEM programmes: The trajectory under the expanded higher education system. *Studies in Higher Education*, *45*(6), 1108–1120.

Charleston, L. J. (2012). A qualitative investigation of African Americans' decision to pursue computing science degrees: Implications for cultivating career choice and aspiration. *Journal of Diversity in Higher Education*, *5*(4), 222–243.

Chien, Y. H., & Chu, P. Y. (2018). The different learning outcomes of high school and college students on a 3D-printing STEAM engineering design curriculum. *International Journal of Science and Mathematics Education*, *16*(6), 1047–1064.

Chu, W. W., Hafiz, N. R. M., Mohamad, U. A., Ashamuddin, H., & Tho, S. W. (2022). A review of STEM education with the support of visualizing its structure through the CiteSpace software. *International Journal of Technology and Design Education 33*(1), 39–61.

Ellison, S. & Allen, B. (2018). Disruptive innovation, labor markets, and Big Valley STEM School: Network analysis in STEM education. *Cultural Studies of Science Education*, *13*(1), 267–298.

Fine, C. H., Padurean, L., & Naumov, S. (2022). Operations for entrepreneurs: Can Operations Management make a difference in entrepreneurial theory and practice? *Production and Operations Management*, *31*(12), 4599–4615.

Heras, M., Ruiz-Mallén, I., & Gallois, S. (2020). Staging science with young people: Bringing science closer to students through stand-up comedy. *International Journal of Science Education*, *42*(12), 1968–1987.

Holmes, K., Gore, J., Smith, M., & Lloyd, A. (2018). An integrated analysis of school students' aspirations for STEM careers: Which student and school factors are most predictive? *International Journal of Science and Mathematics Education*, *16*(4), 655–675.

Hsu, Y. S., Tang, K. Y., & Lin, T. C. (2023). Trends and Hot Topics of STEM and STEM Education: a Co-word Analysis of Literature Published in 2011–2020. *Science and Education*.

Hughes, R. M., Nzekwe, B., & Molyneaux, K. J. (2013). The Single Sex Debate for Girls in Science: a Comparison Between Two Informal Science Programs on Middle School Students' STEM Identity Formation. *Research in Science Education*, *43*(5), 1979–2007.

Ivanova, E., Doncheva, J., & Georgieva, C. (2018). Teaching roles and competences in the century of high technologies. *New Trends and Issues Proceedings on Humanities and Social Sciences*, *5*(5), 91–99.

Kennedy, T. J., & Odell, M. R. L. (2023). STEM Education as a Meta-discipline. In *Contemporary Trends and*

Issues in Science Education (Vol. 56, pp. 37–51). Springer Science and Business Media B.V.
Kotha, R., Vissa, B., Lin, Y., & Corboz, A. V. (2023). Do ambitious entrepreneurs benefit more from training? *Strategic Management Journal*, *44*(2), 549–575.
Krieger, A., Block, J., Stuetzer, M., Obschonka, M., & Salmela-Aro, K. (2022). Closing the gender gap in entrepreneurship: The importance of skill variety. *PLoS ONE*, *17*(7 July).
Ku, C. J., Hsu, Y. S., Chang, M. C., & Lin, K. Y. (2022). A model for examining middle school students' STEM integration behavior in a national technology competition. *International Journal of STEM Education*, *9*(1), 3.
Lin, K. Y., Yeh, Y. F., Hsu, Y. S., Wu, J. Y., Yang, K. L., & Wu, H. K. (2022). STEM education goals in the twenty-first century: Teachers' perceptions and experiences. *International Journal of Technology and Design Education*.
Mansfield, K. C. (2014). How listening to student voices informs and strengthens social justice research and practice. *Educational Administration Quarterly*, *50*(3), 392–430.
McGee, E. O. (2020). Interrogating structural racism in STEM higher education. *Educational Researcher*, *49*(9), 633–644.
Mejias, S., Thompson, N., Sedas, R. M., Rosin, M., Soep, E., Peppler, K., Roche, J., Wong, J., Hurley, M., Bell, P., & Bevan, B. (2021). The trouble with STEAM and why we use it anyway. *Science Education*, *105*(2), 209–231.
Mondal, W. I., & Jimenez, L. (2015). Teaching Entrepreneurship And Micro-Entrepreneurship: An International Perspective. *Journal of International Education Research (JIER)*, *11*(3), 189–196.
Quigley, C. F., & Herro, D. (2016). "Finding the joy in the unknown": Implementation of steam teaching practices in middle school science and math classrooms. *Journal of Science Education and Technology*, *25*(3), 410–426.
Reid, J. W., Polizzi, S. J., Zhu, Y., Jiang, S., Ofem, B., Salisbury, S., Beeth, M., Mohr-Schroeder, M., Sheppard, K., Roehrig, G., & Rushton, G. T. (2023). Perceived network bridging influences the career commitment decisions of early career teachers. *International Journal of STEM Education*, *10*, 17.
Sarfraz, M., Ivascu, L., Belu, R., & Artene, A. (2021). Accentuating the interconnection between business sustainability and organizational performance in the context of the circular economy: The moderating role of organizational competitiveness. *Business Strategy and the Environment*, *30*(4), 2108–2118.
Shen, Q. (2023). From Theory to Practice: Research and Trends in STEM Education. In *Proceedings of the 2022 2nd International Conference on Modern Educational Technology and Social Sciences (ICMETSS 2022)* (pp. 876–887). Atlantis Press SARL.
Simon, R. M., Wagner, A., & Killion, B. (2017). Gender and choosing a STEM major in college: Femininity, masculinity, chilly climate, and occupational values. *Journal of Research in Science Teaching*, *54*(3), 299–323.
Stef, D., & Mirea, N. (2021). Lifelong Learning in Context of Industry 4.0. *Acta Technica Napocensis Series-Applied Mathematics Mechanics and Engineering*, *64*(1), 55-62 WE-Emerging Sources Citation Index (ESCI).
Stef, D., Teban, L., & Mirea, N. (2023). The Future Of Jobs And Lifelong Learning Implementation. *Acta Technica Napocensis - Series: Applied Mathematics, Mechanics, And Engineering*, *65*(3S). Retrieved from https://atna-mam.utcluj.ro/index.php/Acta/article/view/1971
Stohlmann, M., Moore, T., & Roehrig, G. (2012). Considerations for Teaching Integrated STEM Education. *Journal of Pre-College Engineering Education Research*, *2*(1), 28–34.
Tleuken, A., Turkyilmaz, A., Sovetbek, M., Durdyev, S., Guney, M., Tokazhanov, G., Wiechetek, L., Pastuszak, Z., Draghici, A., Boatca, M. E., Dermol, V., Trunk, N., Tokbolat, S., Dolidze, T., Yola, L., Avcu, E., Kim, J., & Karaca, F. (2022). Effects of the residential built environment on remote work productivity and satisfaction during COVID-19 lockdowns: An analysis of workers' perceptions. *Building and Environment*, *219*.
Williams, T. A., Nason, R., Wolfe, M. T., & Short, J. C. (2023). Seizing the moment—Strategy, social entrepreneurship, and the pursuit of impact. *Strategic Entrepreneurship Journal*, *17*(1), 3–18.