

Steps toward Integrating STEM Education into School Curricula

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Introduction

Digital technologies drive innovation in many different spheres of life. The level of digital skills of the population very much conditions the innovative capacity of technology. No wonder there is a strong correlation between education and skills and the uptake and use of digital technologies in various spheres of life (OECD, 2016). STEM graduates commonly continue to learn STEM skills and knowledge nearly forty years after graduation. Even many non-STEM jobs require STEM expertise—and a revised view of STEM employment (Skrentny & Lewis, 2022).

As the world changes dramatically, the future will grow mainly in education, creativity, and innovation. Innovation must be introduced in the educational system to change the economy. Academic Institutions must be enabled with pedagogies that appeal to these variables. The curriculum should be the processor to convert knowledge into skill sets. A study at Oxford says that 20 years from now, nearly half of the jobs will be automated, and we need to redefine our education system considering the challenges ahead (UNESCO 2020, WEF 2022). The study also shows that 80% of future jobs are related to careers in STEM (science, technology, engineering, and mathematics); education embraces the idea that STEM learning could include all or some of these disciplines. However, it is not as simple as that, as STEM learning also embraces the development of inquiry skills and thinking capabilities such as through project-based learning pedagogy that allows students to acquire knowledge and skills, practice inquiry across multiple disciplines, and make meaningful connections across STEM disciplines (National Science Foundation 2020).

Building 21st-Century Skills

STEM is integral to many of the required knowledge, and how they are integrated is a new 21st-century skill that students should acquire. Understanding STEM components and their connection helps students develop a better and deeper understanding of their contents. However, STEM is still taught in a traditional approach, i.e., in silos which only refers to science and math with little reference to engineering and technology (IBE UNESCO, 2020). Therefore, those developing curricula and teaching STEM subjects must also understand STEM and STEM education well.

In high-quality programs today, 21st-century skills require more rigorous content than the traditional curriculum provides. They should include skills and knowledge needed for these competencies, such as critical thinking, problem-solving, effective communication and collaboration, project-based learning with high technical skills.

Young students today need to develop a deep skillset to succeed in a world where automation is only a click away. When they become comfortable working with others, thinking creatively, and expressing their ideas persuasively at an early age, they will enter a world overflowing with opportunities.

What distinguishes STEM from traditional science and math education is the blended learning environment that is centered on teaching students how the scientific method can be applied to everyday life by connecting learning outside the classroom and using technology to engage students in scientific and engineering practices and projects that require deep science and math conceptual knowledge. (Said 2016a, Said 2016b, Said 2021, Said et al. 2023).

STEM Approach builds a strong foundation in the critical 4C skills (Collaboration, Critical Thinking, Communication, and Creativity), which they apply to solve real-world challenges grounded in science, technology, engineering, and math content (Reeve, 2016).

Early in the last decade, discussions worldwide, educators and curriculum developers in Various countries have begun to debate ways to help students understand the “island of disciplines” and “fractured disciplinary knowledge through interdisciplinary learning and curriculum integration. Interdisciplinary learning can break through academic borders to enhance students’ fundamental competencies by merging course design content with cross-border teaching and implementation (Ye, P. & XU; X., 2023).

There is also a comprehensive discussion in the literature on how STEM education is most effectively implemented (Briner et al., 2012). STEM education often implies something innovative and exciting, yet it may remain disconnected subjects (Abell & Lederman, 2007; Sanders, 2009; Wang et al., 2011). However, an integrated curricular approach could be applied to solve global challenges of the modern world concerning energy, health, and the environment (Bybee, 2010; Kelly & Knowles, 2016). Researchers agree that a real-world problem is a critical component of integrated STEM teaching (e.g., Kelley & Knowles, 2016; Moore, Stohlmann, et al., 2014; Sanders, 2009).

Sanders (2009) described integrated STEM education as “approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and between a STEM subject and one or more other school subjects.” He suggested that outcomes for learning at least one of the other STEM subjects should be purposely designed in a course—such as a math or science learning outcome in a technology or engineering class (p.21).

Similarly, Moore et al. (2014) described integrated STEM education as “an effort to combine some or all of the four disciplines of science, technology, engineering, and mathematics into one class, unit, or lesson that is based on connections between the subjects and real-world problems” (p. 38). Integrated STEM curriculum models can contain content learning objectives primarily focused on one subject, but contexts can come from other STEM subjects.

While some researchers suggest integration across all four of the STEM disciplines (e.g., Burrows et al., 2018; Chandan et al., 2019), others call for integrating at least two of the STEM disciplines (e.g., Moore et al., 2020). Given the prominence of engineering, many approaches to integrated STEM specifically include an engineering context or engineering design problem as the context for learning (e.g., Berland & Steingut, 2016; Moore, Stohlmann, et al., 2014).

Mpofu (2019) suggested a continuum approach that borders on four different levels ranging from the lowest level 1 (the disconnected) to the highest level 4 (the integrated). The other possible ways of STEM integration this approach provides are connected and complementary in levels 2 and 3, respectively. In the disconnected level, individual STEM subjects are taught and learned separately. These subjects, such as chemistry, biology, physics, and mathematics, exist parallel in school curricula. Each subject is taught by teachers trained to teach it. STEM integration within this level entails introducing the subjects like engineering and technology into the school curricula, which are usually excluded in schools.

Wei & Chen (2020) synthesized various standpoints of policymakers and educators on the relationship between STEM integration and education. At the national macro level, policymakers regard STEM integration as a correlation between school education and the development of the social economy. Educators view STEM integration at the individual micro level as an educational approach that might help students become critically literate citizens and procure financially secure employment in their adult lives. Both policymakers and educators point to the interconnection between STEM integration and education.

The literal meaning of integration is combining two or more things. STEM integration naturally has this meaning; nonetheless, it is not equal to the integration of four disciplines, as the acronym of this term indicates. Thus, examining the integration of the STEM field should take a holistic and coherent view, that is, it comes to educational fields and links to areas like society and the economy. However, studying STEM practices can better understand each domain and help teachers identify key learning outcomes necessary to achieve STEM learning. (Kelley & Knowles 2016).

Framework for STEM Integration

Based on the above discussion, good STEM education is featured by enabling students to integrate knowledge and skills across different STEM disciplines as well as its connection to real-life issues and community. However, pursuing the

integration of all four STEM disciplines at one time is unnecessary. Instead, the curriculum exemplifies the cross-curricular learning that is the foundation of a 21st-century curriculum. The emphasis is on raising awareness of the importance of knowledge integration and realizing the usefulness of different STEM-related subjects.

However, it is also essential to state that integrated STEM is not promoted to the exclusion of other important learning goals within a science classroom. Not all science content can and should be taught using an integrated STEM approach. Attention should also be paid to the nature of science and engaging students in learning science concepts through inquiry-based learning (Roehrig et al., 2021). Most important is that the integration should enhance understanding and achieve positive student learning outcomes, which is central to the conceptual framework for STEM (Figure -1).

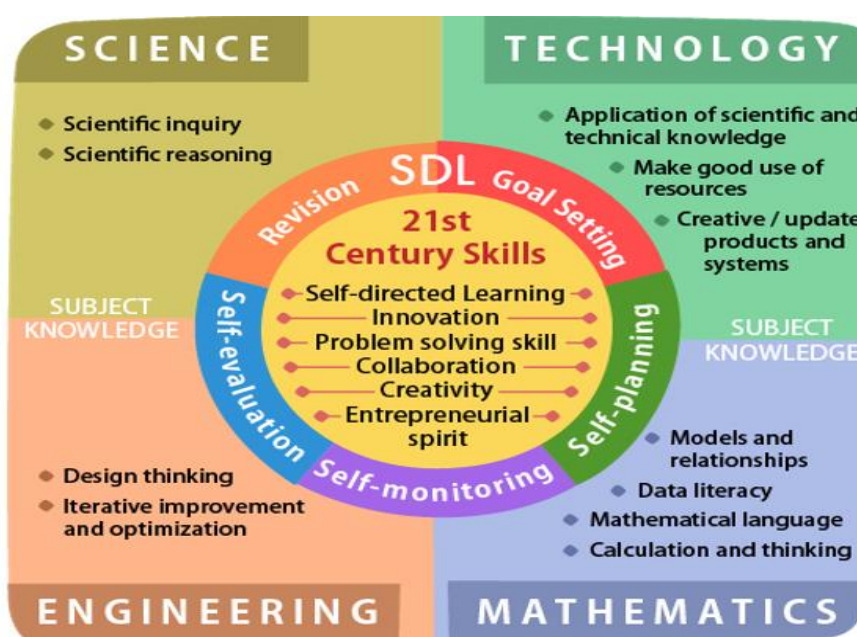


Figure-1. Framework of STEM integration (source: University of Hong Kong 2021)

To achieve these objectives of enhancing learning outcomes and raising positive students' attitudes and career aspirations in STEM, integration requires a holistic approach encompassing outstanding characteristics for successful integration. Unfortunately, the path to STEM integration remains elusive in practice and policy. Program and practice challenges remain to be addressed at national and school levels (IBE-UNESCO 2019).

This paper highlights a holistic approach based on the simplified theory of change using a logic model framework (LeCroy, 2018). The approach suggests a step-by-step implementation of STEM integration that addresses the above challenges.

A literature review was conducted to identify obstacles to STEM education; the majority were mentioned in the introduction section, with some mentioned below. Additionally, to present a specific context, we interviewed 50 science and math teachers from Qatar preparatory and secondary school teachers, equally distributed among genders, grades taught, and specialties. This interview is part of a broader project to train STEM teachers on STEM delivery through project-based learning. The main objective of this interview was to identify challenges to STEM delivery in

science and mathematics classrooms. Then we utilized the principles of the theory of change (Clark & Taplin, 2012) to suggest a roadmap to address these challenges.

Barriers to STEM Implementation in Classrooms

The above literature review identified about ten barriers; seven critical factors were identified in some studies (e.g., Ejiwale, 2013, Dong & Yang et al., 2020). These are school structure, lack of time, the impact of exams and assessments, teachers' lack of experience in engineering and Technology, Lack of professional development, poor lab facilities, lack of inspiration on the part of students, and lack of planned hands-on activities for students.

Fadelmula et al. (2022), in a systematic review of STEM research in GCC countries, and based on Van den Hurk et al. (2019) model on interventions in education to prevent STEM pipeline leakage, focused on three broad types of factors: (1) environmental factors (e.g., the social context and social environment); (2) school-level factors (e.g., instruction, teachers, and pedagogy); and (3) student-level factors (e.g., students' attitudes, motivation and aptitude). The authors recommended that to be relevant to policy-making, future studies should address identified gaps in these three broad factors.

El-Deghaidy and Mansour (2015), based on views from teachers in Saudi Arabia, believe that a direct dialogue between science teachers, mathematics teachers, scientists, and engineers about STEM applications and activities would be essential for promoting STEM education in schools. Project-based learning (PBL) can provide a vital context for such a dialogue.

As part of the results from our interview of science and mathematics teachers in Qatari schools on addressing the above gaps, teachers perceive eight persisting factors to enable successful STEM education in their classrooms. These are depicted in Figure-2.

The figure shows that the most important gap to be addressed is the teachers' lack of experience. In the second rank are the suitability of laboratories and the availability of adequate lab equipment. All other factors are important and similar to those mentioned in the previously reviewed research. Some of these are associated with the school system (e.g., Timetabling, recruitment, teachers' training) and curriculum (e.g., assessment and pedagogy). Some teachers also emphasized the importance of raising students' attitudes towards STEM and practical activities by focusing on hands-on activities and projects based-learning associated with real-life problems. Some teachers attributed students' low engagement and interest in practical activities to the low weighting of these activities in the assessment of STEM subjects.

The most important driver of change to address the above gaps is curriculum modification.

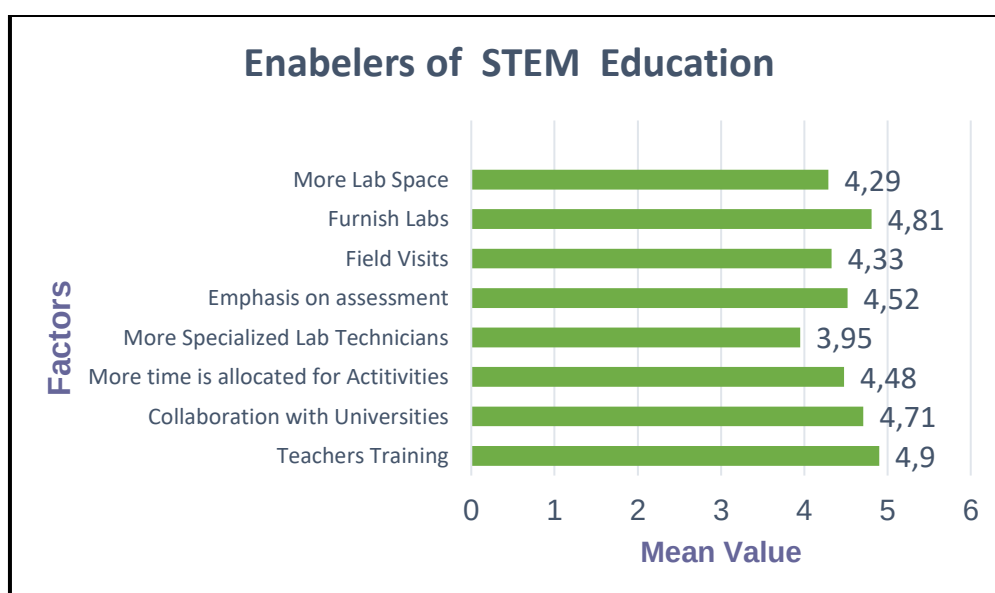


Figure2. Teachers' perceptions on factors enabling STEM Education at the school level (scale 1-5).

Theory of Change for Integrating STEM Education in School Curriculum

Theory of Change (ToC) comprehensively describes and illustrates how and why a desired change is expected to happen in a particular context. It is focused in particular on mapping out or “filling in” what has been described as the “missing middle” between what a program or change initiative does (its activities or interventions) and how these lead to desired goals being achieved. It does this by identifying the desired long-term goals and then working back from them to identify all the conditions (outcomes) that must be in place (and how these relate to one another causally) for the goals to occur. These are all mapped out in an Outcomes Framework (Clark & Tapline, 2012; Centre for Theory of Change, n.d.).

ToC is a method that explains how a given intervention, or set of interventions, is expected to lead to a specific development change, drawing on a causal analysis based on available evidence. The Theory provides a framework for learning both within and between programming cycles by articulating the causes of a development challenge, making assumptions explicit on how the proposed strategy is expected to yield results, and testing these assumptions against evidence—including what has worked well, or not, in the past. The theory of change helps ensure a sound logic for achieving change (United Nations Development Assessment Framework, UNDAF 2017).

A logic model framework provides a visual summary showing the relationship between the program's resources, activities, outputs, and outcomes. It is a tool that helps individuals see the interrelationships between the different components of a program. In addition, the tool highlights the program's underlying approach, the service activities, and the organizational structure for accomplishing program outcomes. Developing a logic model assists developers, evaluators, and other stakeholders understand a program's assumptions and evaluate the logical links between what programs are doing and the outcomes they hope to achieve. Because of their utility logic, models have become widely used in social service programs (LeCroy, 2018; McLaughlin, 2015).

UNESCO -UNEVOC (2022) recommends using the ToC logic model, stating that it helps institutions and organizations to:

1. Identify the ultimate goals and desired outcomes of a program or intervention and the underlying assumptions about how the change will occur.
2. Map out the causal pathways and the relationships between the various elements of an intervention, such as inputs, activities, outputs, and outcomes.
3. Analyze the strengths and weaknesses of an intervention and identify areas where improvements can be made.
4. Monitor and evaluate progress over time by tracking changes in intermediate outcomes, inputs, and activities and measuring the effectiveness of the intervention. (UNESCO-UNEVOC 2022).

UNESCO-UNVOC Centre (2022) developed a step-by-step template for implementing those assumptions. The template was adapted from United Nations Children's Fund (UNICEF2014) Supplementary Programme. The change process consists of five phases which include

- Identifying the problem,
- suggested approaches and strategies to solve the problem,
- the outputs (activities-enacted actions)
- short-term outcomes, and
- Long-term outcomes.

Mclaughlin and Jordan (2018) also developed a similar logic model comprising six phases; the authors added an intermediate outcomes phase (P.76). However, this is flexible and depends on the specific problem to be addressed.

Each of these phases is interlinked and helps to build a comprehensive understanding of the intervention, including the causes of the problem, the desired outcomes, the resources required, and the activities and processes that will be undertaken to achieve the desired results. The ToC approach is flexible and can be adapted to suit the needs of different initiatives, contexts, and stakeholders. However, it is essential to ensure that all phases are well-defined and that the relationships between the elements are clearly understood to achieve the desired outcomes. The template also includes the purpose and assumptions highlighting the benefits expected from the change.

The chart in the Table 1 summarizes our suggested procedure for integrating STEM into curricula. This approach of integration encompasses addressing the gaps mentioned previously.

The problem phase includes defining all factors that cause the problem, which are (the factors) not addressed, and identifying possible partnerships (e.g., a high institution, educational institute, companies, employers, etc.).

Strategies and approaches include developing teachers 'training programs, which are critical in enhancing students' learning and skills in any education aspect that requires change. In addition, continuous Professional Development (CPD) constantly upgrades teachers to enable innovative learning designs, practices, and assessments. For students to develop mastery of knowledge content, problem-solving, critical thinking, effective communication and collaboration, and self-direction, teachers must employ a variety of pedagogical approaches and teaching

strategies. Therefore, effective professional development (PD) is the key to improving teachers' learning and delivery skills (Darling-Hammond et al., 2017). Thus, the foundation of the STEM Education Centre provides STEM education materials for schools, trains teachers and students, conducts STEM education research, and helps schools and education institutes revise their curricula (Carlisle & Weaver, 2018).

The outputs include evidence of implementing the planned activities, such as establishing a curriculum committee, the foundation of STEM center implementing professional development, and developing a teachers' certificate program with a stakeholder from a local university.

Short-term outcomes indicate that stakeholders completed the planned activities, and a beneficial effect becomes noticeable such as improvement in the attitude and skills of teachers; some classes start to apply. STEM integration and applying PBL pedagogy, students' attitude improvement, and attendance to STEM classes.

The long-term outcomes: STEM integration to a certain level is implemented and regularly practiced with all teachers in STEM subjects to obtain certificates and sufficient training. An increase in enrolment in STEM programs at high grades and an increase in students' achievement can measure these outcomes.

Table 1. Steps Towards Integrating STEM Education into K-12 School Curricula – Applying a Simplified Approach of the Theory of Change (*The original empty template was adapted from McLaughlin & Jordan 2018 and UNESCO-UNEVOC 2022*)

Purpose Statement	Integrating STEM education into K-12 Curricula			
Problem	Strategies & Approach	Outputs (1-2 years)	Short – term Outcomes (2-4 years)	Long – term Outcomes (after four years)
- STEM is still taught in a traditional approach, i.e., in silos which only refers to science and math with little reference to engineering and technology. Therefore, those involved in developing STEM curricula and teaching Science and Mathematics must also gain a good understanding of STEM and STEM education.	- Invest in teacher training and upskilling and curriculum development Using real-world problems/issues/challenges as anchors to integrate STEM and other disciplines, considering project-based learning as a teaching methodology - Promote the foundation of STEM centers where both teachers and students can be trained - Establish a STEM education certificate program for teachers	- A curriculum committee is established - Curriculum is reviewed - More teachers are being trained - More equipment is being provided - More STEM workshops are conducted	- Noticeable improvement in the attitude and skills of teachers - New curriculum approved - Some classes start to apply STEM integration and applying PBL pedagogy - Noticeable improvement in the attitude of students, improvement in attendance	- STEM integration becomes a regular unit in all subjects' components of STEM - All new Teachers in STEM subjects obtain a STEM education certificate as a requirement for teaching - More enrolments in STEM programs and

- Science and Math teachers in K-12 schools decline to teach STEM as an integrated subject based on a lack of expertise in engineering design and laboratories shortage of equipment.		- STEM education certificate program for teachers is developed	to STEM classes and workshops - STEM education program is established and offered for new teachers	courses have noticeably increased - Performance and Achievement of students in STEM subjects have increased
Key Assumptions	STEM integration across science, technology, engineering, and mathematics curricula promotes the application of these subjects in real-world contexts. As students engage in STEM education, they develop the transferable skills needed to meet the demands of today's global economy and society and become scientifically and technologically literate citizens. In addition, integrating certain STEM-related subjects can reinforce students' understanding of each subject and their interrelationships. In high-quality advanced programs today, the 21st-century skills require more rigorous content than traditional curriculum provides			

Conclusion

This paper presents a roadmap toward the gradual achievement of a certain level of STEM integration based on applying the theory of change approach. Although the term STEM integration is widely used, there is still no agreed definition and approach to STEM.; integration remains elusive in practice, and challenges remain to be addressed at national and school levels.

At the education policy level, there is a need to be a commitment to supporting all four disciplines in schools in an integrated way. This requires greater attention to be paid to the place of engineering and technology alongside, or within, science and maths. Teachers must be trained to cope with the contributory disciplines' knowledge and epistemological and pedagogical principles to embrace integrated approaches. At program and examination levels, there needs to be a commitment to defining and assessing programs that address holistic global challenges, with adequate access to teacher resources to promote active investigation and creative design of potential solutions. Finally, at the school level, timetabling and collaborative planning opportunities must be provided for teachers of different disciplines to work together.

References

- Abell, S., & Lederman, N. (2007). *Handbook on research in science education*. Thousand Oaks: Sage.
- Berland, L. K., & Steingut, R. (2016). Explaining variation in student efforts towards using math and science knowledge in engineering contexts. *International Journal of Science Education*, 38(18), 2742–2761. <https://doi.org/10.1080/09500693.2016.1260179>. [Return to ref 2016 in article](#)
- Breiner, J., Harkness, M., Johnson, C. C., & Koehler, C. (2012). What is STEM? A discussion about conceptions of STEM in education and partnerships. *School Science and Mathematics*, 112(1), 3–11.

- Burrows, A., Lockwood, M., Borowczak, M., Janak, E., & Barber, B. (2018). Integrated STEM: Focus on informal education and community collaboration through engineering. *Education Sciences*, 8(4). <https://doi.org/10.3390/educsci8010004>.
- Bybee, R. (2010). Advancing STEM education: 2020 vision. *Technology and Engineering Teacher*, 70(1), 30–35.
- Centre for the Theory of Change (n.d.). *What is the theory of change?* - Theory of Change Community
- Chandan, D., Magana, A. J., & Vieira, C. (2019). Investigating the affordances of a CAD-enabled learning environment for promoting integrated STEM learning. *Computers & Education*, 129, 122–142. <https://doi.org/10.1016/j.compedu.2018.10.014>.
- Clark, H. & Taplin, D. (2012). *Theory of change basics: a primer on theory of change*. New York: Acknowledge. [ToC Basics Guide copy \(theoryofchange.org\)](https://doi.org/10.1016/j.compedu.2018.10.014)
- Darling-Hammond, L., Hyyler, M. E., & Gardner, M. (2017). *Effective teacher professional development*. Learning Policy Institute. <https://doi.org/10.54300/122.311>
- Dong, Y., Wang, J., Yang, Y. et al. (2020). Understanding intrinsic challenges to STEM instructional practices for Chinese teachers based on their beliefs and knowledge base. *IJ STEM Ed* 7, 47. <https://doi.org/10.1186/s40594-020-00245-0>
- Ejiwale, J. (2013). Barriers to the successful implementation of STEM education. *Journal of Education and Learning*. Vol.7 (2) 63–74.
- El-Deghaidy, H., Mansour, N., Alzaghibi, M., & Alhammad, K. (2017). Context of STEM integration in schools: views from in-service science teachers. *EURASIA Journal of Mathematics, Science & Technology Education*, 13(6), 2459–2484.
- El-Deghaidy, H., & Mansour, N. (2015). Science teachers' perceptions of STEM education: Possibilities and challenges. *International Journal of Learning and Teaching*, 1(1), 51–54. <http://doi.org/10.18178/ijlt.1.1.51-54>
- English, L. D. (2017). Advancing elementary and middle school STEM education. *International Journal of Science and Mathematics Education*, 15(1), 5–24. <https://doi.org/10.1007/s10763-017-9802-x>
- Fadlilmula, F.K., Sellami, A., Abdelkader, N., & Umer, S.(2022) *International Journal of STEM Education* <https://doi.org/10.1186/s40594-021-00319-7>
- IBE UNESCO International Bureau of Education (2020) Designing a contemporary STEM curriculum. In-Progress Reflection No. 39 *On Current and Critical Issues in Curriculum, Learning, and Assessment*. Downloaded from [Designing a Contemporary STEM curriculum - UNESCO Digital Library](https://unesco.org/368485eng.pdf).
- IBE UNESCO (2020). International Bureau of education. Exploring STEM competency for the 21st century. in-progress reflection No. 39 *On Current and Critical Issues in Curriculum, Learning, and Assessment*. Downloaded from [368485eng.pdf \(unesco.org\)](https://unesco.org/368485eng.pdf).
- Kelley, T.R. & Knowles (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, 3:11. Springer open access DOI: 10.1186/s40594-016-0046-z.
- Lecroy, C. W. (2018). Logic Models. *Encyclopedia of Social Work*. National Association of Social Work <https://doi.org/10.1093/acrefore/9780199975839.013.1273>
- McLaughlin, J.A., & Jordan, G., B. (2015). *Handbook of practical program evaluation*, 4th edition, Newcomer, K.E., Hatry, H.P, & Wholey J. S., editors. (Wiley). [Using Logic Models \(wiley.com\)](https://wiley.com)

- Moore, T., Stulman, M., Wang, H., Tank, K., Glancy, A., & Roehrig, G. (2014). Implementation and integration of engineering in K-12 STEM education. In S. Purzer, J. Strobel, & M. Cardell (Eds.), *Engineering in Pre-College Settings: Synthesizing Research, Policy, and Practices* (pp.35–60). West Lafayette: Purdue University Press.
- Moore, T.J., Johnston, A.C., & Glancy, A.W. (2020). STEM integration: A synthesis of conceptual frameworks and definitions. In Johnson, C.C., Mohr-Schroeder, M.J., Moore, T.J., & English, L.D. (Eds.), *Handbook of research on STEM education*. (3–16) Routledge, <https://doi.org/10.4324/9780429021381-2>.
- Moore, T. J., Stohlmann, M. S., Wang, H.-H., Tank, K. M., Glancy, A., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In J. Strobel, S. Purzer, & M. Cardella (Eds.), *Engineering in pre-college settings: Research into practice*. Rotterdam: Sense Publishers.
- Mpofu, V. (2019). A Theoretical framework for implementing STEM education, theorizing STEM education in the 21st century. *Kehdinga George Fomunyam, Intech Open*, DOI: 10.5772/intechopen.88304. Available from: <https://www.intechopen.com/chapters/68740>
- National Science Foundation (2020). *STEM education for the future*. A visioning report.
- Reeve, E. M. (2016). 21st-century skills needed by students in technical and vocational education and training (TVET). *Asian International Journal of Social Sciences*, 16(4), 65–82. Retrieved from http://aijss.org/index.php/aijss20160404/STEM_Education_for_the_Future_-_2020_Visioning_Report_NSF2020.pdf.
- Roehrig, G.H., Dare, E.A., Ellis, J.A. & Ring-Whalen E..(2021). Beyond the basics: A detailed conceptual framework of integrated STEM. *Discip Interdiscip Sci Educ Res* 3, 11 <https://doi.org/10.1186/s43031-021-00041-y>
- Said, Z. (2016a). Science education reform in Qatar: progress and challenges. *Eurasia Journal of Mathematics, Science and Technology Education*, 12(8), 2253–2265.
- Said, Z. (2021). Integrating STEM into TVET education programs in QATAR: Issues, concerns, and prospects. *The Eurasia Proceedings of Educational and Social Sciences*, 23, 15–24.
- Said, Z., Mansour, N., & Abu-Tineh, A. (2023). Integrating technology pedagogy and content knowledge in Qatar’s preparatory and secondary schools: The perceptions and practices of STEM teachers. *Eurasia Journal of Mathematics, Science and Technology Education*, 19(6), em2271. <https://doi.org/10.29333/ejmste/13188>
- Skrentny, J.D.&Lewis, K. (2022). Beyond the “STEM Pipeline”: Expertise, Careers, and Lifelong Learning. *Minerva* 60, 1–28. <https://doi.org/10.1007/s11024-021-09445-6> Springer.
- Sanders, M. (2009). STEM, STEM education, STEM mania. *The Technology Teacher*, 68(4), 20–26.
- United Nations Development Assessment Framework UNDAF (2017). Theory of Change; UNDAF Companion Guidance [Microsoft Word - UNDG-UNDAF-Companion-Pieces-7-Theory-of-Change.docx](#)
- UNICEF (2014). *Note on the theory of change, peer review group meeting*, 11 March 2014, UNICEF, New York, 2014, p. 4. [Theory of Change ENG.pdf](#)
- UNESCO (2020). The futures of work: What education can and cannot do. *Background paper for the Futures of Education Initiative*. [374435eng.pdf](#)
- UNESCO-UNEVOC (2022). TVET leadership programme. Managing change through transformative TVET Leadership. <https://unevoc.unesco.org/home/TVET+Leadership+Programme+November+2022+Learning+block+2>
- University of Hong Kong (2021). Centre for Information Technology in Education. [What is STEM? – Jockey Club Self-directed learning in STEM Programme \(hku. hk\)](#).
- Van den Hurk, A., Meelissen, M., & Van Langen, A. (2019). Interventions in education to prevent STEM pipeline leakage. *International Journal of Science Education*, 41(2), 150–164. <https://doi.org/10.1080/09500693.2018.1540897>

Wang, H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: teacher perceptions and

practice. *Journal of Pre-College Engineering Education Research*, 1(2), 1-13.

doi:10.5703/1288284314636.

Carlisle, D.L., & Weaver, G.C. (2018). STEM education centers: catalyzing the improvement of undergraduate STEM education. *IJ STEM Ed* 5, 47 (2018).

<https://doi.org/10.1186/s40594-018-0143-2>

Wei, B., & Chen, Y. (2020). *Integrated STEM education in K-12: Theory development, status, and prospects*. Theorizing STEM Education in the 21st Century. doi:10.5772/intechopen.88141.

World Economic Forum, WEF (2020). Catalysing education 4.0 Investing in the Future of Learning for a

Human-Centric Recovery *INSIGHT REPORT MAY 2022*

Ye, P. & Xu, X. (2023). A case study of interdisciplinary thematic learning curriculum to Cultivate “4C

Skills. *Front. Psychol.*, 07 March 2023, Sec. Educational Psychology Volume 14 - 2023

<https://doi.org/10.3389/fpsyg.2023.1080811>

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Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of paper titled “**Steps toward Integrating STEM Education into School Curricula**” belongs to the authors.