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Entry

Interdisciplinary and Integrated STEM

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Definition: Science, Technology, Engineering, and Mathematics (STEM) is an approach and movement in innovative educational practices from the primary level internationally. This would provide a platform for an inquiry approach, creativity, and innovation in young children and formulate a path for changes in existing practices. The STEM approach is widely accepted as a key educational practice; however, it is dealt with as a combination of disciplines in actual teaching and learning practice. Coherence in this interdisciplinarity and integration has yet to be evolved as a practice in synthesising and designing instruction and could be harbinger for an effective design for future practice. Integrated and interdisciplinary STEM can only generate powerful knowledge to deal with issues that are affecting the planet and bring abiotic and biotic equilibrium. Interdisciplinary and integrated powerful knowledge (IIPK) can act as a roadmap for innovation that can bring changes in existing practices, produce informed citizens, build capacity for informed decisions, and generate sustainable living practices. Interdisciplinary and integrated STEM could lay foundations for IIPK and generate a mindset, approach, and practice. IIPK could lead to the formation of new paths for energy generation, transport, agricultural practices, medical treatment, and clean environment. Interdisciplinary and integrated STEM is not seen in actual practice anywhere nowadays. For coherence in curriculum, implications in instructions need reform and development by the governments across the world. That could lead to a new policy for interdisciplinary and integrated STEM.

Keywords: interdisciplinary integrated powerful knowledge; STEM

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1. Introduction

A 21st century education and research needs to prepare young people for contemporary life practices and future workplaces with a new vision of this planet to generate an interdisciplinary and integrated powerful knowledge. The interdisciplinary and integrated powerful knowledgebase could deal with the events and trends that society faces during challenging times, such as climate change and the COVID-19 pandemic. While extensive technological, scientific, and medical research has changed the world in the last decade, there are also several difficulties that need to be faced, understood, and responded to, such as climate change and pandemics, such as COVID-19. STEM education and research has a role in producing a future generation capable of making changes in existing lifestyles and practices to deal with challenging and complex situations [1]. To achieve this, it is vital to develop interdisciplinary and integrated STEM teaching and learning practices and research capacity building for innovations that could change life practices [2]. By focusing on interdisciplinary and integrated initiatives, future citizens could be able to develop STEM practices that help to build the skills and knowledgebase to meet the challenges facing society. STEM education and research could be a key in informing future citizens of some of the current problems that exist on our planet and seeking ways to reduce these problems. Exploitation of biotic and abiotic systems to build comfort and convenience for human beings has created disequilibrium and chaos in the natural balance and equilibrium of the planet. Innovative STEM technological practices could deal with these challenges by formulating new life practices and supporting the better utilization of biotic and abiotic systems.

During challenging times such as that of COVID-19, there is a need to formulate new paths and ways of "life practice" in terms of food, energy and water use, buildings, transportation, and health practices. Existing life practices that emerged from the post-industrial revolution have limitations and have led to the overuse of resources, such as the atmosphere, forests, water systems, and soils. STEM education and research are significant as the impacts of contributions from the industrial revolution and the advancement of material comforts has created more issues regarding the natural balance and equilibrium of this planet in terms of biotic and abiotic coexistence. Post-COVID-19, societies are going to face challenges in conserving and effectively using the biotic and abiotic resources of this planet cooperatively and diligently across all the nations of the world. Interdisciplinary and innovative STEM technological practices could deal with these challenges by formulating new life practices and supporting the acceptance of the reality that this planet is not only for human beings but for all forms of biotic and abiotic systems. Abiotic platforms such as atmosphere, oceans, rocks, forest, soil, and rivers provide the basic existence for biotic systems, and future life practices should not disturb the dynamism and equilibrium of these systems. New life practices will emerge with the interdisciplinary and innovative STEM approach and have connections to international economics, politics, and coexistence for peaceful life on this planet [3]. A new vision of the world capable of dealing with post-COVID-19 life practices will almost certainly emerge and draw from interdisciplinary, integrated, and innovative STEM education and research.

The focus on student learning during the 21st century education needs to be capable of producing future citizens with skills in Science, Technology, Engineering, and Mathematics (STEM) and who can deal with challenging complex life practices, which is best to be developed throughout the education, starting from primary schools [4]. The concept of an ecosystem of social networks of peers, educators, friends, and families to support in school and out of school contexts of learning offers promise in developing this for schoolteachers and students and finding appropriate societal contexts for connecting to educational practices [5]. An early focus with appropriate experiences connecting to real-world settings and the concept of ecosystem can influence and foster innovation in STEM. Interdisciplinary, integrated, and connected to the real-world approaches of the school experience are a way to focus on STEM education and provide insight into innovation for new life practices for everyone. Schools and future teachers need to prepare young people for contemporary life practices and future workplaces with a new vision of this planet. A thorough overhaul of STEM education and teacher preparation is necessary in primary, secondary, and post-compulsory education. STEM education and research is not only the slogan, but it should also have a clear purpose to connect curricula, capable of generations in workplaces producing innovations that could develop new paths for the world [2]. Future STEM education programmes and research need this focus to be able to have the capacity to develop innovative new pathways towards lifestyle changes that lead to sustainability.

2. Interdisciplinary and Integrated STEM

A coherent conceptual approach to interdisciplinary and integrated STEM (I-STEM) is needed to guide classroom practices in terms of cross-disciplinary content learning and its underlying teaching, bonding to specific learning objectives [6,7]. Due to the possibility of seamless integration of materials from different domains, I-STEM could strongly link to real-world experience in STEM fields. This integration has the potential to promote and improve the learning of each discipline involved [8]. In order to effectively integrate different STEM disciplines, it is necessary to bring together ideas and principles from disparate disciplines [9] PBL (problem-based and/or project-based learning) [10] and interdisciplinary scientific inquiry [6,11] are some of the pedagogical approaches that have been used to support I-STEM education. I-STEM success relies heavily on the PBL process, which is generally recognized as a key component of I-STEM [12]. The real process of scientific inquiry cannot always be compartmentalized in such a tidy manner, and for achieving a solution, several disciplines necessarily need to link together. The goals of I-STEM include, but are not limited to, improving the students' STEM literacy, 21st century skills, STEM job preparation, STEM interest and engagement, and the capacity to draw connections across STEM disciplines [13]. Interdisciplinary and integrated approaches to teaching and learning, and teacher preparation that translates to classroom practices are key aspects to be focused on to produce a responsible generation that is capable of using the STEM knowledgebase for changes in practices [14]. The interdisciplinary integrated approach of STEM education needs to ensure that democratic civic-informed decision making aligns with the Next Generation Science Standards [2] and National Research Council [5]. This approach could generate a knowledgebase for problem solving and could lead to democratic civic practices for attaining capacity for informed decisions. Effective use of interdisciplinary and integrated STEM involves different ways of thinking, solving problems, and communicating, and these approaches need consideration in building teachers' capacity for innovation in classroom practices. Students not only used these approaches to learn a range of technological activities to plan, analyse, evaluate, and present their work, but also learn the valuable reasoning and thinking skills to find alternatives in socio-scientific issues and problems when they are used in classroom projects. These aspects are essential for functioning both within and outside the school environment and are about creativity, design principles, and processes involved. These are essentially required in interdisciplinary and integrated STEM knowledgebases. The nature of post-COVID-19 learning is innovative and interactive, enabled using the virtual online platforms where teachers and students take the initiative in generating active learning that emphasises the interaction rather than just the content. In this context, there is a possibility to incorporate societal issues that are connected to the daily life of the learner and involve multidisciplinary concepts to develop alternatives. These steps could better start from early ages and from primary schools to build interdisciplinary and integrated STEM education as an inquiry approach for problem solving.

Interdisciplinary and integrated approaches could use an authentic real-world context to unpack underlying disciplines with a proper inquiry approach. Enriching the science and mathematics learning context, the meaning of integrated STEM education extends in formal school settings and provides life practice. As an example, a popular technological engineering design can be used to contextualize mathematics and science teaching and learning and approach integrated and actionable knowledge. It may provide a practical solution for STEM teachers to address implementation issues of integrated content and pedagogy [15]. The steps would start with an engaging and motivating context connected to engineering-based designs imparting mathematical and scientific content using student-centred practices, and students' learning from mistakes. These steps using authentic settings will foster collaborations and lead to ownership of knowledge that is interdisciplinary and integrated.

3. Integrated Interdisciplinary Powerful Knowledge (IIPK)

Knowledgebases differ in different disciplines, with various approaches and formulation of boundaries. Knowledgebases in mathematics and science have conceptualizations and precision, medical science may have more connections and diagnoses, and social science may lead to interpretations and ideology. However, all these knowledgebases provide skills to empower and make informed decisions [16]. A knowledgebase has some connections and links to traditions, culture, and everyday experience of human beings, and leads to innovations in changes of current practices for a new world. These knowledgebases should not only deal with discipline knowledge and fundamental knowledge, but also with conceptual knowledge. They all should link to integrated interdisciplinary knowledge and knowledgebases could be used for developing innovative changes in practices. Powerful knowledge [17] will emerge from coherent interdisciplinary integrated knowledge, and it can act as a driver for action and could sharpen current practices moving forward. To generate powerful knowledge, it is essential to integrate different discipline knowledge for the purpose of solving a problem [18]. Knowledgebases need a combination of formal and informal experiences through lenses of multidisciplinary knowledge that lead to an authentic knowledgebase for solving problems [19]. This is essentially the integrated interdisciplinary powerful knowledge (IIPK). Effectively, IIPK could formulate, filter, and find ways to use tools to deal with and solve issues and problems by combining knowledgebases of formal discipline knowledge and informal everyday experience, and creating a new knowledgebase and pathway. IIPK could essentially lead to an 'ownership' of knowledge (ownership of knowledge refers to knowledge that is life-long and always readily available within the human brain). Further, IIPK could be used to resolve open-ended issues or problems through the synthesis of essential tools from powerful knowledge [20].

The IIPK formulations could be possible by incorporating the following essential elements:

- An informal knowledgebase has many connections with bias, origin of the process, source, authenticity, alternate conceptions, culture, traditions, justifications, and the depth of the knowledge.
- A formal knowledgebase has connections with disciplines and ways it is integrated with informal knowledge, experience, applications, providing insights, and creativity.
- Synthesis of formal and informal knowledgebases to create a specific knowledgebase to solve an issue or problem.
- Building the ability to acquire ownership of knowledge by effectively using it in contexts and solving issues.

This is a capacity building approach for appropriate differentiation and integration to synthesise multi-focused and multidisciplinary knowledge to a specific knowledgebase to solve a problem or an issue.

4. Possible Pedagogical Approach, Professional Learning, and Teacher Preparation for Innovative STEM Education

A pedagogical possibility in the interdisciplinary and integrated STEM approach could emerge from a collaboration of different discipline STEM teachers, leading to an integrated evidence-based STEM approach. Different disciplines associated with STEM subjects are taught and learned differently, and this argues for a pedagogical approach that is unique [21]. Teachers are normally aligned to their own disciplines as they are in their comfort zones and resist to make changes. A constructivist approach in which teacher pedagogical content knowledge and discipline content knowledge produce an evolution and development of integrated knowledge in classroom practices is vital [22]. This is a big step and requires a diligent effort and approach to integrate based on a theme. In an interdisciplinary and integrated approach of STEM, coherent and collaborative inquiry-based problem solving would lead to an innovative mindset among students. For example, a STEM class project could be an environmental issue, such as exploring alternate forms of transportation using technological challenges and new resources, leading to innovations that could change existing practices. Innovative pedagogical thinking is necessary to implement such projects in classroom practices to solve real-world issues, and this capacity building is significant in teacher preparation.

Post-COVID-19 demands changes in practices, including teaching, learning, and assessments, as virtual online platforms are taking over from face-to-face learning. This has happened suddenly and created a need, scope, opportunity, and commitment from everyone and everywhere across the world. Teachers' beliefs, knowledgebase, and pedagogical practices would be the key to success in challenges faced in integrating online STEM education, and it is necessary for students to use inquiry approaches. The complexities associated with preparing confident, competent, and skilled teachers to achieve an ideal interdisciplinary and integrated STEM focus requires innovation in policies and curricular changes [23]. The process of building teachers' capacity should be across primary, secondary, and tertiary education, and this will not happen in a vacuum, rather, it needs a collaborative effort. There is a need for willing and cooperative efforts for integrated interdisciplinary STEM practices by all stakeholders, and it is better to begin from building teachers' capacity for using innovative classroom practices [24].

Professional learning and professional development are important in producing interdisciplinary and integrated STEM content knowledge and pedagogical content knowledge and will enhance teachers' self-efficacy. It is always a challenge to create integrated STEM tasks identifying multi-disciplinary content to make coherent formulated strategies to implement in classroom practices. Preservice teacher education has a vital role in producing future teachers capable of using an interdisciplinary and integrated STEM approach. This includes a change in practice towards an integrated STEM content with adequate pedagogical content knowledge. There is an opportunity for training specialised STEM teachers at the primary and secondary levels. In this approach, it is recommended that teachers need to consider the following four aspects:

1. Integrated STEM content knowledge and a creative pedagogical content knowledge (needs to be considered as a necessary experience).
2. Students dealing with real-world issues for solving problems creatively and innovatively using an inquiry-based approach (needs to be considered as an essential strategy).
3. Teachers providing authentic experiences, going beyond challenges, and producing an ownership of knowledge among students to use for further innovations (needs to be considered as an ideal scenario).
4. Increase teachers' self-efficacy to promote the implementation of interdisciplinary and integrated STEM in classroom practices (needs to be considered as a strong recommendation for effective practice).

5. The Policies, Preparation, and Practices of Interdisciplinary and Integrated STEM Education and Research

Policies for STEM education and research need to present conceptually and procedurally clear arguments for the purpose of developing and implementing practices in education and research. Policies, preparation of programs, and practices need to configure with a four-dimensional framework of purpose, policy, program, and practices [25]. To create future STEM practices of research, teaching and learning should be effective in building confidence among future and existing stakeholders, and there is a need for initiatives and policies from governments and workplaces to be coherent and explicit. Practices should be guided with support materials and professional development that led to innovative approaches and align with learning objectives and outcomes related to an interdisciplinary and integrated focus in STEM education.

Post-COVID-19 scenarios across the world demand innovative and adaptive practical paths for the existence of biotic and abiotic systems and require initiative from everyone. Collective and effective use of available knowledge to deal with and solve some of the issues in this scenario will be real challenges ahead. There is a mismatch between the organisation of knowledge that is acquired from schools and universities, teaching and learning, and overall education [26]. This mismatch results in more complex conceptualizations of integrated knowledge emerging that are currently being used in adaptive workplaces. At the forefront of these more complex conceptualizations of integrated knowledge is STEM that is authentic, viable, and usable [27]. However, it is suggested that integrated STEM may be considered and conceptualized as the development of epistemic fluency, being referred to as actionable knowledge and knowledgeable action [28]. Achieving ownership of actionable knowledge from authentic integrated and interdisciplinary scenarios will foster innovation, and education overall needs to prepare young people for contemporary life practices and future workplaces with a new vision of this planet to generate powerful knowledge [29]. These IIPK should be a key to focus and use as a tool to design and create new and emerging technologies capable of changing the existing life practices [30].

6. Overall Picture

There should be initiatives for interdisciplinary and integrated approaches of STEM for changes in life practices to build IIPK and move towards a new safe world with effective sustainable practices. The overall success of interdisciplinary and integrated approaches of STEM education and research depends on dynamic shifts in accountability and innovations in teaching and learning, research, policy, and practice, and generating powerful IIPK and using them in contexts connecting issues in society [31]. Building IIPK, beliefs, and understanding are the driving forces for overcoming instructional challenges in any form of STEM education, and stress should be placed on their effective use in actual practice in education at all levels [32]. Teachers also face various issues in developing STEM strategically in classrooms, such as combining a pedagogical approach based on an integrated approach connecting a typical content concept in their disciplines and aligning this with the curriculum and school-based plans [33]. Implementing new plans often creates a concern that an interdisciplinary and integrated nature of the STEM curriculum is a challenge to the typical school structure, and this creates a barrier for implementing some of the new practices. However, it is vital for the effective implementation of interdisciplinary integrated STEM education, and these innovations should happen along with the traditional and routine business of teaching and learning, examinations, and reporting. Furthermore, STEM pedagogy also needs a fundamental shift towards the classroom environment, and teachers' positive attitudes and integrating STEM by teachers is always found to be a challenging process [15]. These steps will foster workplace practice and research for innovations that could change life practices and create IIPK. Education and research focused on interdisciplinary integrated STEM could bring about new pathways to deal with issues faced during challenging times such as COVID-19 as well as lead to changes of life practices.

Figure 1 presents aspects associated with approaches of interdisciplinary and integrated STEM education and research.

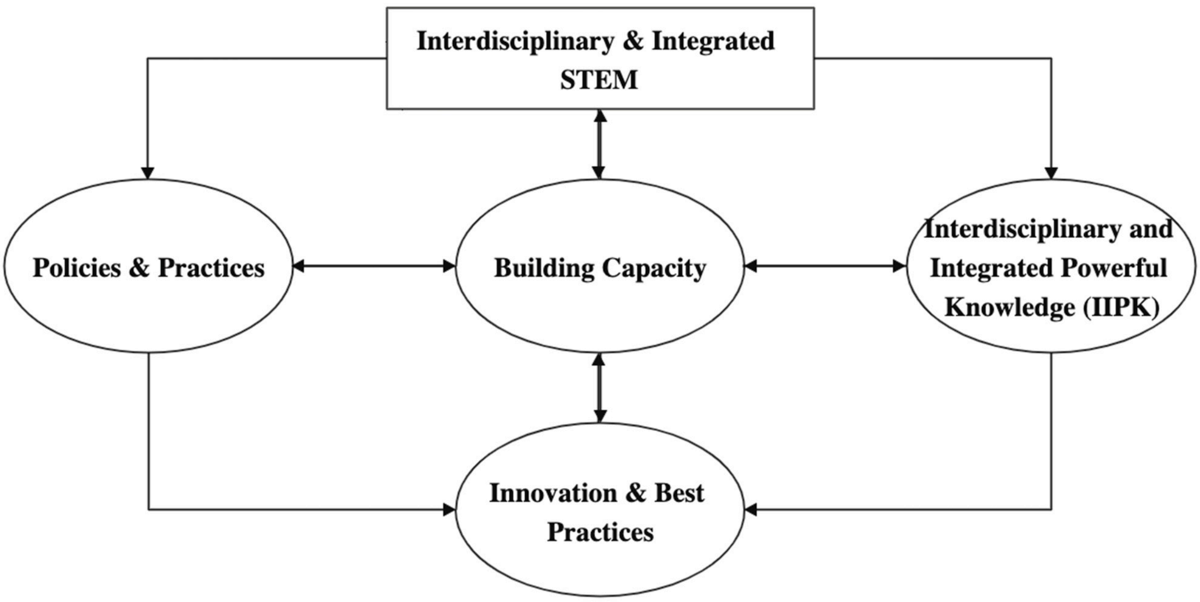

Figure 1. Overall picture of formulating best practices and innovation by building the interdisciplinary and integrated powerful knowledge of STEM education and research.

Finally, initiatives of the interdisciplinary and integrated approaches of STEM education and research could lead to innovations and best practices that could generate IIPK and change current practices. Current practices need a thorough overhaul in terms of policies, practices, and effective implementation. This would be a leading step towards post-COVID-19 life practices and generating new abiotic and biotic practices, adaptations, and equilibrium. This capacity building provides pathways for IIPK and innovations for effective and sustainable life practices.

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