


From Concepts to Innovation: Experiential Learning Through ‘Stem Education’ In K–12

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Abstract: In contemporary times, when technology is evolving at an unprecedented rate and rapid advancements are happening in every field, young students must be equipped with practical knowledge that teaches them relevant and important skills. In the context of K-12 education, the rote learning of facts has often taken precedence over experiential learning. While it is essential to acquire theoretical knowledge, equal emphasis must be placed on the development of technological skills. STEM education is an integrated approach that combines Science, Technology, Engineering, and Mathematics rather than teaching them as individual subjects. This interdisciplinary approach helps students develop strong conceptual understanding, rather than merely learning facts in isolation. K-12 students tend to construct understanding by connecting new knowledge with their prior experiences, a concept central to the Constructivist Learning Theory.

This present research paper explores STEM education as an effective model of experiential learning, which has become necessary for school students across the world. A major part of a student’s school life is spent memorising facts and figures that may increase memory retention but not conceptual understanding and innovative ability. The modern world is faced with countless social and environmental challenges that need people who can formulate solutions to help the masses. To develop critical thinking, children must learn in an environment that encourages innovation and active thinking. A strong foundation in basic STEM education can foster a much stronger intellectual growth in the future and be equipped with real-world skills that will make them employable as well as capable of great positive change.

Keywords: STEM Education Experiential Learning, Conceptual Understanding, Constructivist Learning Theory, K–12 Education

Introduction: A commonly cited example of technological advancement is that it took humanity’s ancestors 2.4 million years to control fire, but it took merely 66 years to go from the first flight to humans landing on the moon. This rapid technological boom is growing by the second, creating a need for technologically literate students in the job market. For students to create something of their own or work with an existing institution, they need practical skills, whether they are soft skills or technological expertise. Their conceptual understanding has become a mark of differentiation that sets them apart from a crowd which has merely learnt how to memorise facts and not the implementation of theoretical knowledge.

The Constructivist learning theory, pioneered by Swiss psychologist Jean Piaget and the Soviet cognitive theorist Lev Vygotsky, posits that *“Intelligence is not an innate internal characteristic of the individual but arises as a product of the interaction between the person and his or her environment”*¹. This theory emphasizes that learning does not take place in isolation and is not rooted in rote memorisation but rather becomes a dynamic

process which is developed through the transaction between the learner and their environment. Experiential understanding, which students develop through the course of STEM education, not only equips them with practical skills but also teaches them how to think critically in any situation. David A Kolb also stresses the importance of such teachings when he writes, *“Learning is the process whereby knowledge is created through the transformation of experience”*²

Main Text: Traditional K-12 education is based on the principles of memorisation and recall. Students are taught how to remember, but hardly how to think or how to challenge the prevalent notions of society. Complacency is drilled into their minds, which takes away their cognitive ability to think critically. However, researchers have always found that this method of education is hardly the best for students: *“From the perspective of what is currently known about cognition and learning, integration may be effective because basic qualities of cognition favor connected concepts over unconnected concepts so they are better organized for future retrieval and meaning making.”*³ This paper seeks to highlight how STEM education, being an interdisciplinary approach to learning, becomes a model of experiential learning that improves conceptual understanding and develops an innovative mindset in K-12 students.

Experiential learning for school students originated from the early “learning by doing” philosophies espoused by John Dewey in the 20th century. These ideas were later developed and formalised by David Kolb, a psychologist, in the 1970s. At the heart of this theory of education is the assertion that knowledge is not an independent entity that can be acquired but rather has to be created through a continuous process of construction and invention. Kolb describes its integrated function in the following terms:

“Experiential learning is not a molecular educational concept but rather is a molar concept describing the central process of human adaptation to the social and physical environment. It is a holistic concept, much akin to the Jungian theory of psychological types (Jung, 1923), in that it seeks to describe the emergence of basic life orientations as a function of dialectic tensions between basic modes of relating to the world.”⁴

Kolb mentions that learning takes place in a cyclical or spiral manner in which the learner, *‘touches all the bases’—experiencing (CE), reflecting (RO), thinking (AC), and acting (AE)*⁵. This cycle involves a continuous process of feeling, watching, thinking and doing, but every time one goes through this cycle, it is not a tedious repetition but rather cements their understanding of the world and allows them to form stronger mental associations leading to long term memory retention.

Experiential and constructivist learning both centre a student's understanding on the ability to create and retain knowledge by actively engaging and developing already formed concepts. Constructivists posit that children come to school with certain pre-existing beliefs and understanding that affect how they interpret new information. The Piagetian concept of assimilation (new information is fitted into existing schemas) and accommodation (changing internal structures fit new information) is complementary to the idea of learning cycles (by Kolb).

Through these theories of learning, one can understand the ineffectiveness of mere memorisation in forming a deeper understanding of the subject. When subjects are taught in isolation, they not only become difficult to keep track of but also create a shallow understanding that becomes a problem for students in their future. Through K-12 STEM education, students move away from isolated subjects and develop a holistic understanding of science and technology that has the potential to become a catalyst for positive social change. C.P. Lim also reiterates the same idea when he writes, *“[E]ducation for global citizenship is essential in*

preparing our children and young people to be agents of change rather than just passive observers of world events; and at the same time, to live together in an increasingly diverse and complex society”⁶

STEM education, an acronym for Science, Technology, Engineering and Mathematics, was first introduced as SMET by the National Science Foundation and the term was later re-arranged into STEM to symbolise interdisciplinary connection and collective effort in learning science and technology. STEM was traditionally used to refer to these subjects individually but modern education has tried to approach it using a more integrated method that deals with all the subjects as a whole. Scholars of STEM also highlight the benefits of this integrated approach:

“Advocates of more integrated approaches to K–12 STEM education argues that teaching STEM in a more connected manner, especially in the context of real-world issues, can make the STEM subjects more relevant to students and teachers. This in turn can enhance motivation for learning and improve student interest, achievement, and persistence”⁷

The necessity of teaching these subjects together has not only increased in the past few decades owing to the technological advancements, but it is also supported by research that shows this approach has many benefits for K-12 students. From a cognitive perspective, this approach not only helps students in gaining an in-depth understanding of foundational scientific concepts but also allows them to learn their real-world application. This integrated approach can make real-world issues more relevant for students, motivating them towards a more problem-solving mindset. The 21st century also requires a workforce that is competent in critical thinking, problem solving, collaboration and team work. STEM education teaches students this flexibility by engaging them with multiple disciplines at once. Educational research of cognitive aspects of students’ minds further reinforces this idea:

“From the perspective of what is currently known about cognition and learning, integration may be effective because basic qualities of cognition favor connected concepts over unconnected concepts so they are better organized for future retrieval and meaning making. It is these connected knowledge structures that can support learners’ ability to transfer understanding and competencies to new or unfamiliar situations”⁸

STEM education becomes the bridge between theory and application through its focus on engineering. The scientific and mathematical concepts that students learn in the classroom are used directly by giving them a chance to become part of the “engineering design process” at a very nascent stage. Students are taught ‘to learn, to do, to make’ sequence, which motivates students to explore theoretical foundations and find their tangible technological applications. When engineering is taught as a team sport rather than a subject, it teaches students how to cooperate with each other and tolerate someone else’s point of view. This approach nurtures the innovative capacity of students by promoting engineering habits, allowing them to personalise their learning in a meaningful manner.

By definition, STEM education is experiential in practice. The aforementioned cycle of ‘to learn, to do, to make’ is the primary method through which STEM students learn how to tackle real-life problems and find appropriate and efficient solutions. A child’s problem-solving abilities directly relate to their critical thinking mindset, and every student who learns concepts through implementation is bound to retain them for a longer duration. The projects that students are taught to create are entirely an expression of their own creativity and a reflection of how well they have grasped theoretical concepts. This method of learning awakens the ‘life force’ that Kolb describes in the following terms:

“The learning way is about awakening the learning life force that lies within all of us. It is a power that we share with all living things, autopoiesis, the power of self-making. To open oneself and receive this life energy conveys magical powers of self-transformation. Learning from conscious experience is the highest form of the learning life force”⁹

In STEM education, students are presented with loosely structured real-world problems that portray authentic human solutions. This problem-based learning teaches students how to conduct research and formulate new and creative ideas that can solve problems in an effective manner. It challenges the ‘banking’ approach to education, where children are passive depositories of information and not active agents who challenge and create understanding on their own terms. Students become equipped with 21st century skills that make them employable as well as knowledgeable.

At this juncture, it is imperative to discuss the ‘Engineering Design Process’(EDP), which is an important aspect of STEM research worldwide. The EDP engages students with a much more hands-on learning style than traditional rote learning. The ‘to learn, to do and to make’ concept invoked earlier is a part of this framework, and it includes the following:

- To Learn: These activities explore fundamental scientific knowledge.
- To Do: These activities focus on designing, drawing, and idea generation about engineering.
- To Make: These activities include building, constructing design, using processes, tools, and materials of Technology.”¹⁰

Teamwork is a central part of the EDP process, and it teaches students to collaborate on projects and develop their ideas in a constructive manner that does not diminish any person’s point of view. These teams are not always successful in creating the best possible solutions, but they are taught to learn from their mistakes, and they improve upon their designs until the final product is precisely what was needed. This not only reduces the fear of failure but teaches K-12 students how vital it is to look at struggle in a positive light. This model is also closely linked to Kolb’s cycle, *“The combination of Kolb’s cycle and engineering design process in the K-12 STEM curriculum can significantly support and engage students’ interaction, engagement, competency and interest, and foster STEM literacy”*¹¹

STEM education becomes exponentially important in the context of conceptual understanding and long-term memory retention. There is a fundamental difference between memorization and conceptual learning which is often ignored by schools in K-12 education. While the former focuses on depositing facts into memory, the latter organises information in a meaningful manner that makes it easily applicable and retrievable by organising it around major theoretical concepts that define a discipline. While this understanding develops during school years, it remains with an individual for their entire lives. The National Academy of Science defines the importance of conceptual understanding in long-term retention when they mention,

“Experts have a vast repertoire of knowledge that is relevant to their domain or discipline, but only a subset of that knowledge is relevant to any particular problem. Experts do not have to search through everything they know in order to find what is relevant; such an approach would overwhelm their working memory”¹²

The importance of long-term memory does not reveal itself very early on to any student, but it becomes an integral part of their professional lives. One does not always have time to find basic information; some things

professionals are expected to have integrated into their thinking. This process of integration does not take place solely through memorisation; it requires association and practice to become a permanent part of an individual's mental setup.

Collaborative problem solving, which is an integral part of STEM education, also becomes a relevant point of discussion for K-12 education because it teaches students how to handle a professional environment where discussions, arguments, support and negotiation take place on a regular basis to come up with a solution that everyone agrees with and is in everyone's best interest. *"Though fundamental to all learning experiences, social and cultural experiences such as those which require students to work with each other and actively engage in discussion, joint decision making, and collaborative problem solving may be particularly important in integrated learning."*¹³ This collaborative approach will not only help students in their professional careers but also in their personal lives where they have to negotiate situations and balance expectations that may be contradictory. Hence, this form of education prepares students for the future in many ways.

To absorb all the above-mentioned benefits of STEM education, it is imperative that the current K-12 education curriculum undergo reforms that shift the focus of education from rote learning towards a more modern and integrational approach that prepares students for the rapidly changing world. The main focus of education in India today is examination and testing an individual's ability to memorise and recall facts and theories. Little to no attention is paid, on a large scale, to the practical skills that children learn through the course of their school lives. This problem is also highlighted by the National Academy of Sciences, *"students often have limited opportunities to understand or make sense of topics because many curricula have emphasized memory rather than understanding. Textbooks are filled with facts that students are expected to memorise, and most tests assess students' abilities to remember the facts."*¹⁴

The implementation of these theories, however, still has certain barriers that need to be addressed. In India, not all schools are equipped with enough technological infrastructure to sustain these changes. Many schools in tier 2 and tier 3 cities struggle to procure enough computers and labs for their students to learn efficiently. Teacher training remains another significant problem that needs to be addressed if these changes are to be implemented. Educators will have to be given subject-specific and technology specific training so that they may be equipped with enough knowledge to teach students and motivate them to pursue STEM research in the future. Although, through the National Education Policy (2020), the Government of India has made significant strides towards promoting STEM research in India. Agencies like the STEM India foundation have partnered with over 20,000 institutes to adopt STEM curricula, and the government has established over 10,000 Atal Tinkering Labs in schools across India, which are designed specifically for giving practical exposure to students. These changes have made a significant difference in the country's outlook towards STEM but there is still a long road ahead because many schools still remain on the periphery of these changes. The importance of STEM in the coming years can hardly be understated because of the rapid technological advancement across the globe that cannot be ignored. K-12 students need to be trained in practical implementation alongside theoretical learning to increase their employability and make them capable of societal change.

The concept of STEM education is still relatively new in India, and it is still paving a way for itself, but that does not diminish its global importance. Adoption of these new strategies might seem unfamiliar to schools, but they have become absolutely necessary for young students. The uncertainty and apprehensions that people may have about implementing these drastic changes in the 'traditional' school system might be helped by Kolb, who describes the learning way as follows: *"The learning way is about approaching life experiences with a learning attitude. It involves a deep trust in one's own experience and a healthy scepticism about received knowledge. It requires the perspective of quiet reflection and a passionate commitment to action in the face of*

uncertainty”¹⁵. Hence, India must also approach the STEM adoption with Kolb’s learning way and equip K-12 students with the much-needed tools of global empowerment.

NOTES AND REFERENCES

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