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Anupreet Kaur Kalsi
Ph.D. Research Scholar, Department of Education, Central University of Punjab, Bathinda, Punjab, India

Dr. Shamshir Singh Dhillon
Associate Professor, Ph.D. Supervisor, Head, Department of Education, Central University of Punjab, Bathinda, Punjab, India

Corresponding Author:
Anupreet Kaur Kalsi
Ph.D. Research Scholar, Department of Education, Central University of Punjab, Bathinda, Punjab, India

From traditional to contemporary: Integrating IKS into STEM education to enhance higher order thinking skills of secondary stage students

Anupreet Kaur Kalsi and Shamshir Singh Dhillon

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Abstract
Higher-order thinking Skills (HOTS) and proficiency in science and maths are crucial as we move into the twenty-first century to fulfill the educational requirements of STEM (Science, Technology, Engineering, and Mathematics) education. Teachers must devise creative ways to get students interested in STEM education subjects while preparing them for today's and tomorrow's challenges. Problem-based learning, Inquiry-based Learning, Blended Learning, Cooperative learning, and Collaborative Learning are instructional pedagogies that can hold students' interest, encourage multidisciplinary STEM practices among students, and develop higher-order thinking skills (HOTS). The social constructivist approach to teaching and learning, which incorporates problem-based learning, encourages self-regulated learning that is strengthened by discussion, cooperative social activities, and self-discovery, which helps to inculcate HOTS among students. Indigenous knowledge systems (IKS) include philosophical, intellectual, emotional, and spiritual traditions and practices that serve as the foundation for Indigenous education. Indigenous Knowledge Systems are rational, comprehensive, and based on experiences. This paper sought to determine the significant implications of IKS-integrated STEM education-based instructional strategies and their effect on HOTS in secondary-stage students. This study is grounded on adopting a responsive STEM curriculum that provides Indigenous learners with enhanced opportunities to engage with scientific Knowledge and to improve their efficacy towards STEM disciplines. The findings of this study will have significant implications for indigenizing the curriculum and enhancing and redesigning the experiences in teaching and learning the STEM education process.

Keywords: IKS (Indigenous knowledge system), STEM education, HOTS (Higher order thinking Skills), secondary stage students

1. Introductions

Education aims to enable people to reach their most significant potential as human beings so they can understand and support themselves and others. Teachers can act as facilitators in the educational process, helping students reach their learning objectives (Sudarsana, 2016) [19]. Along with significant educational implications, recent developments in ICT (information and communication technology) continue to impact society in science and mathematics. Technology and ICTs are also critical to nations that want to pioneer the scientific and technological race. The belief that science lectures are not particularly applicable to students' lives and futures is a significant learning obstacle many students face (Stuckey *et al*., 2013) [20]. The absence of links between science instruction and students' daily lives, the primary reason for the lack of a sense of relevance in science education, appears to be society (Childs *et al*., 2015; Hofstein *et al*., 2011) [21, 22]. To increase the relevance of science education, many changes to curriculum and pedagogy are needed (Eilks & Hofstein, 2015) [23]. Science education should be grounded in real-world events and social contexts, which promote conceptual learning and help students understand the significance of science education (Greeno, 1998). As a pertinent component of education generally, STEM Education should be crucial in equipping students to think critically and autonomously about the problem of "How scientific advancements and technology affect society?" (Holbrook & Rannikmae, 2007; Stuckey *et al*., 2013) [25, 20]. Schools have, therefore, adopted the fundamental goal of producing people who have a conceptual understanding of science and mathematics, can relate these ideas to everyday occurrences, and can use the Knowledge they acquire in school to solve problems in their daily lives to avoid falling behind in the technological race

(Cepni, 2017) [26]. According to the National Research Council, the nation's strength is primarily derived from the production of highly qualified people and the flow of scientific and technological advancements they produce. According to the National Curriculum Framework for Teacher Education (NCFTE, 2009), science, social trends, technological advancements, and research growth contribute to education.

1.1 Concept of STEM (Science, technology, engineering, and mathematics) education

STEM Education is a method that enhances students' understanding of science and math while encouraging involvement through engineering and technology (William 2011) [28]. STEM education breaks down barriers between disciplines by allowing students to view the world as a whole rather than as its components (Lantz, 2009) [29]. By acquiring skills and information through a comprehensive approach to education, STEM education seeks to empower people to view problems from a distinct perspective across professions (Sahin *et al*., 2014) [30]. In 1990, the National Science Foundation (NSF) in the United States coined the phrase STEM, which stands for "Science, Technology, Engineering, and Mathematics" (Sanders, 2009) [31].

1.2 Definition of STEM

STEM education is defined by the United States Department of Education (2007) as an educational program that incorporates the study of science, technology, engineering, and mathematics into its primary goals to improve instruction. "S" stands for science, which is primarily focused on teaching students to think and behave like genuine scientists, pose questions, formulate hypotheses, and carry out investigations using accepted scientific methods (Kelley & Knowles, 2016) [33]. "T" stands for technology, which is the alteration of the natural world to satisfy the needs and desires of humans. The letter "E" stands for engineering. This profession uses judgment, mathematics, and natural Knowledge to develop more efficient ways to use natural resources and forces for the benefit of human beings. "M" for Mathematics is the science of patterns and relationships that provide the exact language for technology, science, and engineering (Dugger, 2010) [34]. Naturally, the STEM method in education is incorporated into the learning process. The four STEM components are involved every time the learning stages are implemented. Each implementation involves the following steps:

1. The Science component is the ability to use scientific Knowledge and scientific methods to understand natural phenomena and manipulate them for implementation.
2. The Technology component is the ability of learners to understand how new technologies can be developed, how to use recent technology, and how technology can be used to facilitate human work.
3. The Engineering component is the ability to operate or assemble and engineer something
4. The mathematics component is the ability to analyze, provide justification, solve problems, and interpret solutions.

1.3 Higher Order Thinking Skills (HOTS)

The learning process alone cannot retain and store information in the brain; pupils require instruction that fosters critical thinking (Subiantoro, 2017) [35]. Thinking skills are mental processes that enable people to interpret different types of information they have learned to create pertinent Knowledge for problem-solving. Thinking skills help people solve problems and make decisions by encouraging them to think critically and creatively (Subiantoro, 2017) [35]. These cognitive abilities are referred to as Higher-Order Thinking Skills (HOTS). Bloom's Taxonomy is the source of higher-order cognitive skills (1956). The Cognitive Domain of Bloom's Taxonomy comprises six orders: memorization, comprehension, application, analysis, evaluation, and creation (Afandi & Sajidan, 2017) [36]. Bloom's Taxonomy classified thinking skills into higher and lower-order thinking skills. Memorizing, understanding, and applying are lower-order thinking skills, and analyzing, evaluating, and creating are higher-order thinking skill.

According to revised Bloom's taxonomy, given by Anderson & Krathwohl (2001) [37], the cognitive process dimension comprises six levels and multiple indicators. Remembering (C1) is the first level involving retrieving information from long-term memory. Recalling and recognizing are signs of remembering. The second stage is comprehending (C2), which consists of creating meaning from the information learned, including what the teacher says, writes, and illustrates. Interpretation, modeling, classification, summarization or conclusion, comparison, and explanation are the indicators. The third stage is applying (C3), or employing a process in specific situations. Executing and implementing are among the indicators. Analyzing (C4), the fourth level involves breaking the content into multiple components and figuring out how each relates to the others. Differentiating, organizing, and crediting are the indications. The fifth stage is evaluation (C5), where choices are made using criteria or standards, including critiquing and verifying. Creating (C6) is the sixth level, which blends multiple components to create something fresh and unique. Formulating, planning, and producing are the signs.

Besides the Bloom taxonomy, the Panchakosha theory, a foundation of ancient wisdom, provides a comprehensive framework for comprehending the multidimensional nature of humans, emphasizing the nurturing of all five levels of being. Using this theory in education can transform our understanding of child development by integrating the physical, emotional, intellectual, and spiritual elements. Educators may nurture holistic growth in children by combining aspects such as Yoga Nidra, meditation, yoga philosophy, and mindful nutrition, as well as teach valuable social and personal disciplines that promote better focus, tranquility, learning, and memory. Educational ideas from both Eastern and Western traditions and contributions from renowned thinkers shape a wide range of effective teaching methods to enhance HOTS among students.

2. Indigenous knowledge and IKS (Indigenous Knowledge System)

Indigenous Knowledge is variously presented in the literature as 'indigenous knowledge/technology' (Dekkers, 2005; Maluleka, Wilkinson & Gumbo, 2006; Snively & Corsiglia, 2000) [38, 39, 40]; 'traditional ecological knowledge' (Turner, Ignace & Ignace, 2000) [41]; 'indigenous local knowledge' (Atteh, 1992) [42] 'traditional/local knowledge' (Mazzochi, 2006) [43], 'indigenous/native science'

(Aikenhead, 2006a) [44]. Indigenous knowledge systems (IKS) are an integrated pattern of human Knowledge, beliefs, and behavior (Atteh, 1992) [42]. Language, ideas, beliefs, customs, taboos, rituals, ceremonies, folk stories, artifacts, and techniques constitute IKS. IKS is thus a "combination of knowledge systems encompassing technology, social, economic and philosophical learning, or educational, legal and governance systems" (Odora Hoppers, 2002a, p. 9,10) [45]. IKS is “a conglomeration…a redemptive, holistic, and transcendental view of human experience with the cosmos…” (Ogunniyi, 2007a, p. 965) [46].

IKS is not just about crafts and traditional dances but includes the thinking behind those practices and artifacts. It is a "…systematic reference to the knowledge and practices of indigenous communities constitutive of their meaning and belief systems, as well as the substantive dimension of their practices and customs" (Nel, 2005:7) [47]. Because IKS has a spiritual dimension, it has to be understood as an inclusive way of life, and a way for people to understand themselves (Keane, 2008a; Mbiti, 1969) [48, 49]. IKS includes technologies and practices indigenous peoples used in the past and present for survival in various environments (Onwu & Mosimege, 2004) [50]. Indigenous Knowledge (IK) is a component of IKS. IK constitutes those aspects of IKS that are more likely to be identifiable in the field as part of the lifeways of participants and which could be used in the science classroom (Otulaja, Cameron & Msimanga, 2011) [51]. The Indigenous Knowledge System (IKS) is the foundation of any nation's knowledge system. Traditional or local Knowledge refers to people's abilities, insights, and experiences that help them sustain or improve their living standards. It is the sum of experiences. Wisdom and information unique to a particular culture, society, or community. This information is unique to a specific ecosystem and accumulated over generations. It encompasses firsthand Knowledge in the following fields: agronomy (polyculture, natural pest control, microclimate management, and soil regeneration); taxonomy; natural resource management (wildlife and agro-forestry systems); aquaculture (certain water purification technologies); animal husbandry; meteorology; human and veterinary medicine; plant, animal, and human nutrition; mathematics; architecture; communications; social and consensus management systems, child-rearing etc. (Obomsawin, 2002; Warren, 1991) [52].

IKS is retained in people's recollections and actions. Stories, songs, proverbs, folklore, dances, myths, cultural values, beliefs, rituals, local language, taxonomy, agricultural techniques, tools, materials, plant species, animal breeds, etc., are examples of how it is expressed. IK is transmitted through particular examples and cultures. Indigenous ways of organizing and communicating are essential to maintaining, advancing, and disseminating IKS and local decision-making processes. (Grenier, 1998) [4]. IKS is retained in people's recollections and actions. Stories, songs, proverbs, folklore, dances, myths, cultural values, beliefs, rituals, the local language, taxonomy, agricultural techniques, tools, materials, plant species, animal breeds, etc., are examples of how it is expressed. IK is transmitted through particular examples and cultures. Indigenous ways of organizing and communicating are essential to maintaining, advancing, and disseminating IKS and local decision-making processes. (Grenier, 1998) [4]. However, modern scientific Knowledge and indigenous wisdom are at odds with one another; the former is regarded as superior. In some ways, contemporary scientific Knowledge has emerged as a threat to Indigenous Knowledge, much like contemporary ecotourism to Indigenous cultures & homelands (Johnston, 2000) [6].

3. Importance of IKS integrated STEM education-based instructional strategies

The benefits of both systems are optimized through the integration of STEM and Indigenous Knowledge. STEM provides analytical frameworks and technological advancements, whereas Indigenous wisdom offers profound ecological insights and holistic approaches. They can better address complex problems by combining traditional wisdom with scientific methods.

- **Holistic problem-solving**

Indigenous Knowledge emphasizes the interconnectedness of ecosystems, which helps enhance comprehension of the ecological issues that STEM fields seek to address. For example, Traditional Environmental Knowledge (TEK) may have an impact on sustainable land management practices that are supported by science.

- **Innovation**

By combining the experience and Knowledge of Indigenous practices with the creative potential of STEM domains can create new ecologically sustainable and culturally appropriate technologies. This collaboration can lead to agricultural, renewable energy, and conservation innovations.

3.1 Benefits to society

- **Ecological methodologies**

Combining STEM with sustainable Indigenous practices promotes improved ecosystem health and efficient resource management. Sustainability in STEM is depends upon the development of adaptive methods that are ecologically sound and culturally appropriate, which is promoted by this combination.

- **Preservation of culture**

Indigenous Knowledge is included in STEM education to foster cultural diversity and maintain cultural legacy. This enhances society and honoring varied knowledge systems promotes respect and social cohesiveness, essential for inclusive STEM in India.

- **Indigenous groups are becoming stronger**

More equitable outcomes in STEM disciplines are achieved when communities are included in policy-making processes. In India, combining modern technology with customs fosters STEM innovation, improves livelihoods, and opens up new economic prospects.

- **Improved academic outcomes**

The development of interesting and relevant learning possibilities brought forth by this integration increases interest in STEM education. Diverse perspectives foster critical thinking and innovative problem-solving, two skills that are essential for prospective STEM professionals.

- **Addressing social issues**

Issues like food security and health disparities can be resolved by combining STEM and Indigenous knowledge. Through effective STEM practices, communities can become more resilient by better adjusting to environmental and social changes when they have a diverse knowledge base. A number of initiatives in India show how STEM and Indigenous knowledge can be effectively combined.

- **Water conservation**

Rajasthani communities have integrated traditional rainwater gathering technologies, such as johads (check dams), with modern water management strategies. Water supplies in arid regions have expanded due to this integration, which shows a blending of old Knowledge and contemporary technology.

- **Medicinal plants**

With the help of traditional healers and scientific researchers, indigenous medicinal plants have been documented and investigated. In addition to encouraging sustainable bio-prospecting, initiatives like the Traditional Information Digital Library aim to preserve and safeguard this data.

- **Agroecology**

The Alliance for Sustainable and Holistic Agriculture (ASHA), which promotes the use of Indigenous farming methods in tandem with scientific research, is one organization that supports sustainable agricultural practices, empowers local farmers, and enhances food security.

4. Challenges in IKS integration

There are many benefits of incorporating the Indian Knowledge System into the educational system, but there are drawbacks as well that need to be considered:

- **Curriculum Development and Implementation**

A thorough and organized strategy is needed to incorporate IKS into the curriculum. Educators and policymakers must collaborate to carefully choose and integrate pertinent IKS elements into the many subject areas to ensure a smooth and significant integration. The creation of relevant teaching and learning resources, in-depth research and expert consultation may all be part of this process.

- **Teacher capacity building**

Teachers' ability and readiness are crucial to successfully integrating IKS into the educational system. Extensive training programs must be created to give teachers the information, abilities, and pedagogical strategies they need to successfully teach and integrate IKS-based concepts and practices in the classroom. Continuous assistance and professional development will be essential to guarantee a successful curriculum implementation that incorporates IKS. Resolving Prejudices and Misconceptions: Several prejudices, misunderstandings, and even disdain have been directed at the Indian Knowledge System over the years by some intellectual and academic community segments. It will be tough to overcome these prejudices and demonstrate the legitimacy and applicability of IKS in the contemporary setting. To refute these, thorough investigation, scholarly discussion, and awareness-raising initiatives will be required.

- **Balancing tradition and modernity**

When incorporating IKS into the educational system, a careful balance must be struck between maintaining traditional Knowledge and modifying it to meet the demands of the contemporary world. To ensure that different IKS-based concepts and practices align with current issues and are presented in a way that appeals to students, policymakers and educators must carefully consider their applicability and relevance.

- **Ensuring accessibility and inclusivity**

The contributions of several communities, geographical areas, and customs are all included in the vast and varied Indian Knowledge System. As a key factor we will ensure that all students, regardless of their socioeconomic, cultural, or geographic backgrounds, can access and benefit from incorporating IKS in the classroom. Creating strategies to recognize and consider various opinions and representations within the IKS-Integrated Curriculum is necessary.

- **Sustaining academic rigor and quality**

The highest academic rigor and quality standards must be upheld while incorporating IKS into the educational system. Without sacrificing the curriculum's scientific and analytical underpinnings, the integration of IKS must be done in a way that improves education overall. One of the main challenges will be striking a balance between conventional and contemporary Knowledge.

- **Interdisciplinary collaboration and partnerships**

Academicians, researchers, traditional knowledge holders, and community representatives are just a few stakeholders who must work closely together and form partnerships to successfully integrate IKS into the educational system. For the IKS-integrated curriculum to be implemented successfully, it will be essential to cultivate these interdisciplinary collaborations and promote the sharing of information and skills. Techniques for Effective IKS Integration in Education The following tactics might be taken into consideration to get past the obstacles and guarantee the successful integration of the Indian Knowledge System into the educational system

5. Methodology and educational approaches

There are many approaches to implementing IKS and integrating STEM-based education at the secondary stage. Combining these two knowledge systems may help us tackle complex issues more thoroughly and culturally, encouraging innovation that respects and considers different viewpoints.

From a different perspective, STEM professions usually focus on quantitative data and empirical approaches, while Indigenous Knowledge often includes qualitative insights and narratives that highlight relationships and context. STEM strongly emphasizes controlled experimentation and reproducibility, whereas Indigenous knowledge values experiential learning and wisdom derived from oral traditions and lived experiences.

6. Techniques of instruction

Combining STEM education with Indigenous Knowledge in school settings can lead to a more thorough education that respects and recognizes different points of view. In the context of STEM in India and STEM education, the following practical strategies can aid in this integration:

6.1 Curriculum development

Develop an extensive, organized curriculum that skillfully incorporates pertinent elements of the Indian Knowledge System into various subject areas. Extensive research, professional advice, and a complete comprehension of the breadth and depth of IKS should all be part of this process. Provide STEM courses that integrate Indigenous Knowledge. For example, a science curriculum can include modules on traditional ecological practices and environmental science ideas to emphasize the importance of STEM education in local contexts.

- **Geo-based learning**

Make use of Indigenous wisdom and practices that are suitable for the local ecology and culture. Given India's abundant biodiversity, this approach not only encourages learning but also a sense of community and belonging, which is particularly crucial in STEM courses there.

6.2 Collaborative learning

- **Community partnerships**

Promote collaborations between educational institutions and Indigenous communities. By giving students direct access to people who have experienced the field, inviting Indigenous elders and knowledge keepers to share their knowledge can increase the impact of STEM education.

- **Field studies and experiential learning**

Arrange field trips to Native American lands so that students can participate in hands-on learning activities like water conservation or traditional farming. This would support highlighting the usefulness of STEM in India.

- **Encourage collaborative research and dialogues**

To investigate and validate the scientific and practical relevance of IKS and support cooperative research projects, including academic institutions, traditional knowledge holders, and community leaders. Encourage discussions and opportunities for exchanging Knowledge to foster a deeper understanding and appreciation of the Indian Knowledge System.

6.3 Teacher training

- **Building teacher capacity**

Investments in comprehensive programs have to be made that prepare teachers to teach and integrate IKS-based concepts and practices in the classroom by giving them the pedagogical techniques, Knowledge, and abilities they need. These programs should be created in conjunction with pedagogy and IKS specialists. To advance their professional growth, teach educators the importance of Indigenous Knowledge and its connection to STEM professions. This category includes workshops that highlight the need of using culturally sensitive teaching methods and a variety of perspectives in the classroom.

- **Cultural competency**

Teachers must have a deep awareness of Indigenous histories, values and worldviews to improve STEM education outcomes and guide their teaching practices.

- **Develop engaging teaching-learning materials**

Make interactive and engaging teaching-learning materials, like multimedia resources, textbooks, and practical exercises that successfully convey to students the ideas and uses of the Indian Knowledge System in a relatable and way up-to-date.

6.4 Use of technology in IKS and STEM integration

- **Digital storytelling**

Record and share Indigenous scientific and environmental stories and practices using technology. This expands the reach of STEM education by storing material and making it accessible to a larger audience.

- **Collaborative online platforms**

Establishing online platforms where students can work with Indigenous communities, exchange content, and participate in conversations on topics they are interested in. This will help to create a network of STEM learning in India.

- **Leverage digital technologies**

Use digital tools like virtual simulations, online learning platforms, and multimedia materials to expand the reach and accessibility of educational content that incorporates IKS, especially in rural and underdeveloped areas.

6.5 Raise awareness and advocacy

Launch extensive efforts to raise awareness and advocate for the Indian knowledge system's importance, applicability, and contributions. Students, parents, teachers, legislators, and the general public are just a few of the stakeholders these campaigns can reach to promote a greater awareness and respect of IKS.

- **Create interdisciplinary partnerships**

Research institutions, academia, traditional knowledge holders, and community organizations should form solid interdisciplinary partnerships to share information, skills, and best practices for the successful integration of IKS into the educational system.

- **Ensure inclusive and equitable implementation**

Create strategies to ensure that the integration of IKS into the educational system is inclusive and accessible to all students, regardless of socioeconomic, cultural, or geographical background. This may include identifying and incorporating different perspectives and representations into the IKS-integrated curriculum.

6.6 Continuous evaluation and refinement

Establish rigorous monitoring and evaluation methods to measure the efficacy of IKS integration into the educational system. To guarantee that the IKS integrated education is constantly improving and relevant, collect input from stakeholders on a regular basis, evaluate data, and revise the curriculum and implementation techniques. Combining these two knowledge systems may help us tackle complex issues more thoroughly and culturally, which will encourage innovation that respects and considers different viewpoints.

7. Indigenous views on STEM education

- **Ethics and sustainability**

Talk to students about the ethical implications of science and technology, including Indigenous values that emphasize sustainability and respect for the natural world. Examine how STEM and Indigenous peoples relate to each other.

- **Creative research projects**

Encourage students to engage in critical and creative research projects that tackle issues relevant to STEM in India and the real world.

- **Create IKS centers of excellence**

Create specific Centers of Excellence for the Indian Knowledge System that can act as centers for dissemination, education, and research on IKS-related practices and Knowledge. These centers can work with educational institutions, community groups, and legislators to promote IKS integration in the classroom.

- **Encourage collaborative research and dialogues**

To investigate and validate the scientific and practical relevance of IKS and support cooperative research projects, including academic institutions, traditional knowledge holders, and community leaders. Encourage discussions and opportunities for exchanging Knowledge to foster a deeper understanding and appreciation of the Indian Knowledge System.

8. Conclusion

It is viewed that implementing IKS Integrated STEM Education-based Instructional Strategies and its effect on HOTS of Secondary Stage Students will empower indigenous local communities, thereby propelling nations on a better trajectory toward ensuring inclusive and equitable quality education for sustainable development. Currently, there are persisting disparities between indigenous and non-indigenous learners in terms of STEM access and achievement. The review aimed to collect and critically synthesize empirically based information on how to effectively incorporate (or integrate) IKS into classroom STEM curriculum. Based on the situated cognition theory, we investigated how schools might use the rich cultural knowledge that surrounds them to improve and increase Indigenous students' engagement with STEM curriculum. The question that came up as we undertook this study was: Why are most education systems still struggling to effectively integrate IKS into the STEM curriculum? While we agree that this is a complex matter, it is not insurmountable. We believe that the starting point in the de-westernization of the STEM curriculum is the realization and acknowledgment of Indigenous Knowledge as an alternative form of Knowledge. This calls for a collaborative effort among government leaders, curriculum developers, community people, education agencies, and instructors. This partnership should be driven by the philosophy that STEM education should assist us to characterize an environment in ways that allow its inhabitants to control it to their advantage. At the implementation stage, I-STEM suffers because teachers, in most cases, are not originally from these local areas and are unfamiliar with indigenous knowledge. There is no one-size-fits-all solution to these limitations. IKS is highly localized, and there is a need for more intensive research that is more contextualized and domain-specific.

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