RABSEL: The CERD Educational Journal

ISSN 2957-8019(Online) | ISSN 2077-4966(Print) |25(1) 49-59
Journal homepage: Journal.pce.edu.bt

Review on the Readiness of Bhutanese Education System for Science, Technology, Engineering, and Mathematics (STEM) Subjects

Author: Thinley Wangmo
Associate Lecturer, College of Science and Technology
Corresponding author: thinleywangmo.cst@rub.edu.bt

http//doi.org/10.5281/zenodo.14512286 /Accepted October 2024 / Published December 2024

Abstract

This narrative review explores the status and readiness of the Bhutanese education system for Science, Technology, Engineering, and Mathematics (STEM) education, focusing on science, mathematics, and Information Communication and Technology (ICT). It traces the country's gradual shift toward prioritizing STEM subjects in response to global educational trends, while highlighting the challenges faced by both learners and teachers. The study identifies key issues, including a fragmented and complex curriculum, as well as teacher apprehension in delivering STEM content. Drawing on international research, the review emphasizes the critical role of early childhood education in establishing foundational skills for STEM learning, particularly in numeracy. Additionally, the paper highlights the need for targeted professional development programs to build teachers' confidence and competence in STEM teaching. While the review acknowledges some progress in Bhutan, it also identifies significant gaps, particularly in the implementation of proposed reforms. The paper calls for further research into practical strategies for enhancing STEM education, ensuring its accessibility, and aligning Bhutan's educational system with global best practices.

Keywords: Bhutanese Education, STEM, Pedagogy

Introduction

Science, Technology, Engineering, and Mathematics (STEM) play a crucial role in the development of nations by fostering novel ideas, discoveries, and innovations. From advancements in medical treatments to the construction of infrastructure, the impact of STEM on human life is all-encompassing. Moreover, STEM education is critical for a country's economic, social, and political development as innovative technologies continue to transform lives. Countries aiming to reduce poverty or improve socio-economic conditions must adopt advanced scientific research and technological

innovations. STEM is seen as a driving force in improving healthcare, the economy, and infrastructure (Organization for Economic Co-operation and Development [OECD], 2000).

In Bhutan, STEM education has begun gaining attraction at the forefront of the country's recent educational transformation. Since the mid-2010s, Bhutan's education system has gradually focused on integrating STEM into the curriculum, with the goal of producing a generation equipped with the critical thinking and problem-solving skills necessary for innovation and development. This shift is in line with Bhutan's broader socio-economic goals, where STEM education is influential in driving economic growth and stability by fostering an innovative and technically skilled workforce. As highlighted by Zollman (2012), STEM education not only enhances employability but also empowers individuals with the competencies needed to contribute to national economic productivity.

The influence of STEM extends beyond economic factors, and it plays a significant role in skill creation. STEM subjects emphasize hands-on learning with real-world applications, which nurtures vital human skills such as critical thinking, creativity, problem-solving, decision-making, leadership, and entrepreneurship (Montgomery & Fernández-Cardeñas, 2018; Kinley et al., 2021). These skills are pivotal in shaping a generation that can address complex global challenges while contributing to Bhutan's economic progress.

A recent reform in Bhutan's higher education sector underscored the importance of STEM. In 2023, Bhutan removed arts and humanities courses from many tertiary education courses, institutionalizing new courses such as Digital Communication, Project Management, Data Science, and Data Analytics (Lamsang, 2023). This reform retained courses such as computer science, engineering, and management, emphasizing STEM components to ensure the production of employable graduates with relevant skills. According to research, STEM graduates tend to have higher employment rates and earn higher wages compared to those in non-STEM fields (Carnevale et al., 2011). By focusing on STEM education, Bhutan hopes to foster economic resilience and ensure its graduates are competitive in the global market.

While STEM is vital, humanities subjects continue to play an essential role in this era of rapid technological advancement. Humanities foster emotional intelligence, ethical reasoning, and cultural awareness, which are crucial in shaping well-rounded individuals. Carnevale et al. (2011) also stated that STEM graduates often chose non-STEM occupation as the desire for autonomy, social service, and other personal fulfilment are better met in non-STEM occupations. Non-STEM subjects complement STEM by providing the ethical framework necessary for the responsible application of technological advancements.

Sousa and Pilecki (2013) explored the integration of the arts into the traditional STEM curriculum, transforming it into Science, Technology, Engineering, Arts, and Mathematics (STEAM). The authors argue that incorporating the arts can not only enhance creativity, it also helps in enhancing problem-solving, critical thinking, communication, self-direction, initiation, collaboration, and analytical skills collectively referred to as 'twenty-first-century skills'. They assert that the "real purpose of schooling is to prepare students for their life after high school, whatever their choice may be" (2013, p. 28). Their research delves into cognitive and social neuroscience, highlighting how arts activities develop various cognitive functions. They affirm that the arts play a crucial role in human development, fostering the growth of cognitive, emotional, and psychomotor pathways in the brain. Additionally, learning the arts provides a higher quality of human experience throughout a person's lifetime as it evokes emotions, which in turn, enhance learning and improve retention. While Bhutan undergoes its educational transformation, an integrated approach that balances STEM with humanities can equip students with a diverse skill, essential for holistic development.

This narrative review explores the current status of STEM education in Bhutan, analyze the approaches taken to institutionalize STEM subjects, and evaluate the Bhutanese education system's readiness to fully embrace STEM. Additionally, it provides recommendations for making STEM education accessible and inclusive to all.

Current Scenario of Bhutanese Education System

Science education in Bhutan traces its roots to the introduction of western education in the early 1960s. However, it was soon observed that the curriculum required significant reform to align with the unique learning needs of Bhutanese children. This realization led to the introduction of the New Approach to Primary Education (NAPE) in 1985, a pivotal reform designed to transform the education system. The approach called NAPE was developed to address the growing recognition that traditional educational models were not adequately fostering critical thinking and problem-solving skills among Bhutanese students. According to Kinley et al. (2021), NAPE introduced an innovative curriculum, requiring teachers to adopt student-centered learning approaches and new teaching-learning materials. Before the NAPE, Bhutan used to depend on Indian curricula, Indian textbooks, and followed rote learning. Bray (1996) claimed that the need to revise curriculum using local environment of school, district, and country as a source of learning brought NAPE system in Bhutanese education system.

In NAPE, English, Dzongkha, and Mathematics were seen as 'tool subjects' which allowed learners to access other aspects of learning. One of the most significant changes NAPE brought to the education system was the introduction of environmental science (EVS) in place of history, geography, science, and other subjects. The EVS curriculum aimed to integrate Bhutan's natural and social environment into learning, fostering investigative skills in students through real-world applications (Dorji, 2016; Kinley et al., 2021). Zangmo (2016) agrees that this integrated curriculum could engage learners with their immediate environment, promoting curiosity and environmental awareness from a young age. Bray (1996) also asserts that EVS curriculum aimed to develop self-confidence, creative thought, and problem-solving abilities. These shifts represented a major step towards a more holistic and context-driven education system in Bhutan.

Despite the success of NAPE in its time, the Bhutanese education system has gradually moved away from this framework. NAPE faced several challenges such as the need of well-trained teachers, its framework contradicting Buddhist values of obedience and respect for authority, too many concepts to be taught in a single subject, etc. (Bray, 1996). The focus has shifted towards other reforms in response to modern educational needs. As of now, NAPE is no longer actively used, though it played a crucial role in shaping Bhutan's educational landscape during its implementation. According to Division of Education, "the new approach with all its element but without necessarily the acronym would be continued as heretofore as a regular feature of … education system" (as cited in Bray, 1996, p.22).

Similarly, mathematics education underwent major revisions under the NAPE system. The revised curriculum was designed to foster a deeper understanding of mathematical concepts, emphasizing reasoning, pattern recognition, and contextual learning relevant to Bhutanese culture (Dendup et al., 2021). The goal, as stated by the School Curriculum Division (2022a), was to cultivate learners with mathematical skills that could contribute to the development of statisticians, data scientists, and competent citizens for Bhutan's evolving economy.

Apart from these subjects, Information and Communication Technology (ICT) also gained prominence, particularly in light of the COVID-19 pandemic. The shift to online learning revealed the

need for enhanced digital literacy among students and teachers. His Majesty the King of Bhutan, in the Royal Edict on December 17, 2020, emphasized the importance of integrating technology into education:

> In preparing our youth for the future, we must take advantage of available technologies, adopt global best practices, and engineer a teaching-learning environment suited to our needs... To ensure that teachers are not disconnected from their students, the professional development of teachers should integrate technology, digitalization, artificial intelligence, and automation (The Bhutanese, 2021, para 7).

One specific initiative aligned with this vision is the introduction of CodeMonkey, a game-based coding platform launched in Bhutanese schools to equip students with essential coding skills. This initiative, first introduced in 2021, aimed to empower youth with digital literacy and coding expertise, in line with the country's broader push toward STEM education (Kuensel, 2021). The objective was to create a generation of digitally competent students who could thrive in a technology-driven world, preparing them for the global market while also fostering employability within the nation.

The current Bhutanese education system is closely aligned with His Majesty's vision of progress. With the introduction of digital courses in tertiary education and the growing emphasis on STEM, the education system has evolved to meet the demands of the digital age. Science, mathematics, and ICT are now core subjects from primary to middle secondary school, and mathematics serves as a foundation for students pursuing the science stream in higher education. These reforms reflect a strong alignment with His Majesty's call for a technologically progressive education system that nurtures future-ready citizens.

Bhutan's education system has undergone significant transformations since the introduction of NAPE. While NAPE is no longer in active use, it laid the groundwork for the system's evolution toward a more holistic and student-centered approach. The current emphasis on STEM and ICT demonstrates the country's commitment to fostering a skilled and employable generation, equipped to thrive in a rapidly changing world.

Methodology

The objective of this review is to summarize and critically evaluate the literature on the perception of STEM subjects by learners and teachers and the readiness of Bhutanese academic institutes for STEM. The review aims to address the following research questions:

1. What are the prevailing perceptions and attitudes of learners towards STEM subjects in Bhutanese academic Institutes?
2. How do teachers in Bhutanese academic institutes perceive STEM subjects?
3. What are teachers' attitudes toward integrating STEM into their teaching?
4. To what extent are Bhutanese academic institutes prepared to implement and support STEM education, considering factors such as infrastructure, curriculum, and teacher training?

Literature Search Strategy

A comprehensive literature search was conducted using multiple databases, including Google Scholar, ResearchGate, and governmental documents (specifically, the Education Curriculum

Framework), as well as print media sources such as Kuensel, The Bhutanese, and other newspapers. The search was performed between August 2023 and July 2024, employing keywords such as "STEM education in Bhutan," "learners' and teachers' perspectives on STEM," "academic performance in STEM subjects," "challenges in learning STEM," "challenges in teaching STEM," and "recommendations for overcoming challenges."

Selection of Literature

The studies included in this review consisted of 25 peer-reviewed journal articles and reports published between 2017 and 2024. A few significant papers published around 2010 were also included due to their foundational insights into STEM education. Additionally, recent print media publications from 2023 and 2024 were selected, focusing on those that specifically addressed STEM education. The review covered general educational settings to capture perceptions of both students and teachers regarding STEM. The inclusion criteria for the literature were studies that focused on STEM education in primary, secondary, or tertiary education. The researcher also took into consideration of whether the document provided empirical data on learners' and teachers' perceptions or experiences with STEM; whether the literature was published in peer-reviewed journals or reputable sources; and whether it offered recommendations for improving STEM education. Studies that lacked empirical evidence, did not focus on STEM, or were published prior to 2010 without significant relevance were excluded from the review. In addition to global perspectives, a thorough analysis of the Bhutanese education curriculum was conducted to understand the local context. This comprehensive review allowed for gathering a wide range of insights and recommendations on how to enhance STEM education, particularly from the perspectives of learners and educators.

Perception towards Science and Mathematics in Bhutan

Utha et al. (2021) observed that among the three core science subjects, chemistry was perceived by students as the most challenging, often associated with memorization, anxiety, stress, and poor performance. In contrast, biology and physics were generally seen as more engaging, with biology eliciting less anxiety and physics garnering more interest. Mathematics, however, proved to be polarizing. Some students found it enjoyable and easy, while others viewed it as difficult and anxiety-inducing. This highlights the global challenge of motivating students to engage with and perform well in science and mathematics subjects, which is a key concern in educational research (Renninger, Neiswandt, & Hidi, 2015). Several studies have confirmed a correlation between low academic performance in science and mathematics and negative student experiences, often driven by anxiety and self-doubt. Ashcraft and Kirk (2001) specifically link learners' negative attitudes toward these subjects to the development of poor self-belief in their abilities.

Dorji et al. (2022) interviewed 21 in-service teachers to examine issues and challenges of Bhutanese science curriculum. They found that science curriculum for grade four to six was focused on scientific inquiry. It was developmentally appropriate, and concepts were logically arranged and contextualized to Bhutanese settings. It was also found that the curriculum was not very content-heavy. However, grade 7 – 12 science curriculum lacked depth in scientific inquiry and contextualization. It was also often not age appropriate. In other words, the content was heavy and voluminous with high lexical density, and concepts were not always logically connected. Their study suggested the need for

improvements in the upper grade science curriculum to better align with educational goals and philosophies.

The findings from a study by Rifandi et al. (2020) on pre-service teachers in mathematics and science showed that they held positive views towards STEM education, recognizing its importance in linking classroom lessons with real-life applications. However, Rifandi et al.'s study did not explore the pedagogical skills required in teacher education to successfully implement the STEM paradigm. This review indicates that while many students continue to struggle with certain STEM subjects, particularly chemistry and mathematics, there is also recognition among educators of the significance of STEM education in making learning more relevant to everyday life. Thus, it is important to consider both student perceptions and teacher preparation when addressing the challenges of STEM education.

However, the exploratory study on the issues and challenges of the Bhutanese mathematics curriculum revealed that Bhutanese students' performance in mathematics was significantly below that of many other Asian nations (Dorji & Tshering, 2020). Key findings, based on interviews with 12 mathematics teachers, identified several major themes contributing to these issues. Firstly, the curriculum from 4^{th} – 12^{th} grade was described as bulky and voluminous, with teachers expressing frustration over the need to employ accelerated pacing, theory-driven lectures, and extra classes to cover the extensive syllabus. The mathematics problems in grades 11 and 12 were also noted for requiring lengthy, exhaustive steps, which teachers found impractical. Additionally, the curriculum was perceived as rigid and prescriptive, limiting both teachers' and students' flexibility to explore topics beyond the prescribed content. Teachers reported feeling pressured to focus on exam preparation, which detracted them from adopting more engaging and meaningful teaching approaches. Moreover, the assessment-driven instruction within the curriculum further exacerbated these issues. Participants called for a shift from traditional paper-pencil tests to performance-based assessments that would better reflect students' understanding and capabilities. These findings underscore the need for a reform of the mathematics curriculum to allow for more flexibility in teaching methods and assessments, which can improve the quality of mathematics education in Bhutan.

Similar to Utha et al.'s (2021) study, Dorji and Tshering's research focused on higher-grade teacher participants, such as those from 11^{th} and 12^{th} grades. However, their study was also limited to providing recommendations and did not propose a revised curriculum that could address the current challenges faced in mathematics or science education. Nevertheless, Utha et al. (2021) advocated teachers to focus on practical learning such as hands-on experiences in the classroom. They also recommend refining curriculum for deeper exploration of content, equipping teachers with skills to adept curriculum, and implement strategies to reduce anxiety associated with assessment and subject difficulty.

Meanwhile, the study by Dendup et al. (2021) indicated that there were not many disparities in academic performance between male and female students. Although female students outperformed males in science colleges, it was found that differences were insignificant in arts colleges. It was postulated that male students might not perform well academically due to their excessive engagement in extracurricular activities contrary to female students who were more enthusiastic about their academic pursuits. Their study found that students did not hold stereotypical perceptions regarding gender roles in STEM and arts subjects, indicating a lack of gender bias in their academic choices and performance. The findings also indicated that factors such as family background and self-efficacy had positive influence while peer influence had a negative impact.

Even though there is not much of differences in academic performance, women's participation in STEM-related careers remains relatively low, globally. According to UNESCO's data (2014-2016),

around 30 percent of female students take STEM-related courses in tertiary education and 10 percent female take STEM careers (as cited in WOMEN IN STEM, 2024). To encourage women to pursue STEM careers, initiatives such as the 'Girls Mentorship Programme' by Women in STEM Bhutan were launched (Pradhan, 2023). This program supports girls from grades 9 – 12 in taking up STEM-related activities, with guidance from 10 registered mentors. Another initiative is a university-to-school mentorship program funded by UNICEF, which aims to empower rural youth in STEM, bridging the digital divide and educating them on the significance of STEM (Wangchuk, 2023; Sharma, 2023). Future studies can evaluate the status of STEM education after the implementation of these initiatives.

Findings from the Reviewed Literature

The reviewed literature highlights several areas of potential exploration for researchers, particularly regarding the effective delivery of STEM education and understanding the most suitable teaching pedagogies. Although the Bhutanese education system has placed importance on the study of science, mathematics and STEM, many of the issues and challenges faced in delivering these subjects remain consistent with global experiences. The existing literature mainly focuses on the challenges and perceptions of STEM from the perspectives of students or teachers, with theoretical recommendations offered to overcome these issues. However, few studies have addressed the implementation of these recommendations, particularly in the Bhutanese context, and much of the research has concentrated on middle and higher secondary education, leaving early STEM education relatively underexplored.

Pre-primary education, according to the United Nations International Children's Emergency Fund [UNICEF] (2023), is essential for establishing a strong foundation for a child's social and emotional well-being. Research indicates that children who do not attend pre-primary education often lag behind their peers and are more likely to drop out of school or fail to reach their full potential. Patrick et al. (2009) found that meaningful early experiences in science enhance children's self-belief and can foster life-long interest in learning science. Similarly, Hunting et al. (2012) noted that mathematical skills developed in early childhood are strong predictors of later academic success.

In the context of Bhutan, Sydon and Phuntsho (2022) emphasized the importance of play-based learning for early STEM education but noted that limited attention is given to training teachers in this area. Their study highlighted the need for high-quality STEM education in early childhood, supported by stakeholders such as parents, teachers, and policymakers. They also observed that teachers' self-efficacy in delivering STEM education is a key factor in its success, although there is limited evidence on how this self-efficacy impacts early childhood development in STEM fields.

One significant challenge identified in the literature is the lack of sufficient understanding of technology integration in STEM classrooms. Deghaidy and Mansour (2015) noted that STEM teachers often struggle to effectively use technologies such as laptops, iPads, and cameras, which are crucial for modern STEM teaching. They advocated for replacing traditional professional development with 'partnership-based' development, where teachers collaborate with engineers and scientists to design models and scientific investigations. Peker and Dolan (2012) supported this approach, suggesting that such partnerships provide insights into how teachers can assist students in understanding scientific concepts through hands-on learning.

Hudson et al. (2015) introduced the concept of 'Pedagogical Knowledge Practice', a framework aimed at making STEM learning more accessible and meaningful. 'Pedagogical Knowledge Practice' refers to the knowledge and skills teachers use to facilitate effective teaching and make learning

accessible to students. It encompasses various components such as planning lessons, preparing resources, implementing teaching strategies, and managing classroom dynamics. The findings suggest that effective teaching practices based on this framework positively impact students' understanding, skill development, and attitudes toward STEM subjects. Each practice is interrelated, meaning that improvements in one area can positively influence others, contributing to overall educational effectiveness (Hudson et al., 2015).

In terms of career aspirations, Holmes et al. (2017) observed that school-related factors such as prior achievement in reading and numeracy significantly predict students' interest in pursuing STEM careers. Deghaidy and Mansour (2015) further emphasized the importance of school culture in fostering STEM engagement. They argued that STEM education requires a unique school environment that encourages collaboration and support among all stakeholders, creating a community dedicated to STEM learning.

Despite the importance of STEM, Chedup et al. (2022) identified a gap in platforms and learning tools available to students, which has hindered their curiosity and ability to engage with STEM subjects creatively. To address this, workshops on STEMSEL micro-controller and runlinc – an online IoT and AI application development platform were initiated as study tool. Students who participated in this workshop reported an increased understanding of STEM's significance and were able to apply basic programming skills to create 3D models. This hands-on approach boosted their motivation and creativity, showcasing the importance of experiential learning in STEM education.

Dorji et al. (2022) recommended that science teachers develop a deep understanding of the 'nature of science' (NOS) to promote scientific literacy. Their study concluded that most teachers had limited understanding of NOS, albeit there are no differences between male and female science teachers. They claim that understanding NOS is crucial for both teachers and students as it influences how science is taught, learned and applied in various contexts. It was also argued that NOS could be effectively taught through inquiry-based learning, where teachers engage students in authentic scientific investigations. Lederman (as cited in Dorji et al., 2007) stressed the need for professional development programs that focus on inquiry-based teaching, allowing teachers to create lesson plans aligned with NOS principles.

Professional development programs that emphasize inquiry-based learning have shown promising results. Nadelson et al. (2014) demonstrated that a collaborative STEM professional development program, 'SySTEMic Solution' significantly increased elementary teachers' knowledge, confidence, and efficacy in teaching STEM. The two-year program highlighted the importance of sustained collaboration between educators and engineers to address the challenges faced by STEM teachers.

In early childhood education, MacDonald et al. (2019) evaluated the 'Little Scientists' program, which provided professional development for early childhood educators in STEM. The program emphasized play-based, interdisciplinary learning, outdoor activities, and child-led exploration. Teachers reported increased confidence in teaching STEM and recognized the importance of fostering a collaborative learning environment where students and teachers explore STEM together. The paper also asserted fostering communities for STEM inquiry where learners and educators collaborate to learn and research together; with learners' self-directed and play-based explorations.

Conclusion

STEM education in Bhutan is gaining increased attention, with significant focus on science, mathematics, and ICT subjects. However, much of the research to date has centered around the challenges students face in learning these subjects, particularly in middle and higher secondary education. The

existing literature reveals that Bhutanese students experience difficulties due to a curriculum that is often described as vast, and fragmented. Teachers, too, have been found to be nervous and hesitant when teaching STEM subjects, suggesting a need for improved training and professional development.

When comparing Bhutan's progress in STEM education to global trends, it becomes clear that early childhood education plays a crucial role in establishing a foundation for future STEM learning. International research emphasizes the importance of numeracy skills and the need for professional development programs that equip teachers with the knowledge, skills, and confidence to effectively teach STEM subjects. However, while Bhutan has made some progress in incorporating STEM into its curriculum, the lack of studies on the implementation of these international recommendations remains a significant gap. This suggests not just a deficiency in study design, but a lack of research itself into the efficacy of revised STEM curricula.

Moving forward, research scholars and academicians in Bhutan should focus on implementing the solutions provided by international research and conducting more studies on the effectiveness of the revised STEM curriculum. Furthermore, future research can explore how Bhutan can make STEM education more accessible and inclusive, particularly in rural areas. Comparative studies that examine how Bhutan's STEM education efforts align with those of other countries can provide valuable insights into where the country stands in relation to global progress. It is also important to integrate STEM and humanities education, which will contribute to a holistic educational experience for Bhutanese learners. By addressing these gaps in research and focusing on practical implementation, Bhutan can continue to improve its STEM education system, preparing students to meet the demands of a rapidly changing, technology-driven world

REFERENCES

Ashcraft, M. H., & Kirk, E. P. (2001). The relationship among working memory, math anxiety, and performance. *Journal of Experimental Psychology, 130*(2), 224-237. https://doi.org/10.1037/0096-3445.130.2.224

Bray, M. (1996). Educational reform in a small state: Bhutan's new approach to primary education. *International Journal of Education Reform, 5*(1), 15-25.

Deghaidy, H. E., & Mansour, N. (2015). Science teachers' perceptions of stem education: Possibilities and challenges. *International Journal of Language and Teaching*, *1*(1), 51-54. https://www.ijlt.org/uploadfile/2015/0824/20150824063944539.pdf

Dorji, J. (2016). International influence and support for educational development in Bhutan. In *Education in Bhutan* (pp. 109 – 124). Springer.

Dorji,K., & Tshering, P. (2020). Issues and challenges of Bhutanese mathematics curriculum: A view from the exploratory study. *Turkish Journal of Mathematics Education*, *1*(1), 1-9.

Dorji, K., Jatsho, S., & Choden, P. (2022). Issues of Bhutanese science curriculum: A view from the exploratory study. *RABSEL: the CERD Educational Journal.* https://doi.org/10.17102/rabsel.22.2.5

Dorji, K., Jatsho, S., Choden, P., & Tshering, P. (2022). Bhutanese science teachers' perceptions of the nature of science: A cross-sectional study. *Disciplinary and Interdisciplinary Science Education Research, 4*(4). https://doi.org/10.1186/s43031-021-00044-9

Dendup, T., Wangmo, S., & Yangchen, U. (2021). Academic performance of undergraduate

students in stem and arts subject in Bhutan: A gender perspective. *Indonesian Journal of Social Research (IJSR), 3*(3), 190-200. https://doi.org/10.30997/ijsr.v313.147

Chedup, S., et al., (2022, July 27). Early access to technologies imperative to accelerate stem education from grassroots: An experiment study in Bhutan. *TechRxiv.* https://www.techrxiv.org/doi/full/10.36227/techrxiv.20362944.v1

Capps, D. K., & Crawford, B. A. (2013). Inquiry-based professional development: What does it take to support teachers in learning about inquiry and the nature of science? *International Journal of Science Education, 35*(12), 1947–1978. https://doi.org/10.1080/09500693.2012.760209

Carnevale, A. P., Smith, N., & Melton, M. (2011). *Stem: Science technology engineering mathematics.* https://eric.ed.gov/?id=ED525297

Dendup, T., Wangmo, S., & Yangchen, U. (2021). Academic performance of undergraduate students in stem and arts subjects in Bhutan: A gender perspective. *Indonesian Journal of Social Research (IJSR), 3*(3), 190-200.

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

Hunting, R., Mousley, J., & Perry, B. (2012). A study of rural preschool practitioners' views on young children's mathematical thinking. *Mathematics Education Research Journal, 24*, 39–57.

Hudson, P., English, L., Dawes, L., King, D., & Baker, S. (2015). Exploring links between pedagogical knowledge practices and student outcomes in stem education for primary schools. *Australian Journal of Teacher Education*, *40*(6), 134-151. https://files.eric.ed.gov/fulltext/EJ1064621.pdf

Kinley, Rai, R., & Chophel, S. (2021). A journey towards stem education in Bhutan: An educational review. *STEM Education from Asia* (1st ed.). Routledge.

Kuensel. (2021, September 6). *CodeMonkey in Bhutanese schools*. https://kuenselonline.com/code monkey-in-bhutanese-schools/

Lamsang, T. (2023, February 5). More than 6,000 arts students wonder what to do after RUB axes arts courses from govt colleges. *The Bhutanese*. https://thebhutanese.bt/more-than-6000-arts-students-wonder-what-to-do-after-rub-axes-arts-courses-from-govt-colleges/

MacDonald, A., Huser, C., Sikder, S., & Danaia, L. (2020). Effective early childhood stem education: Findings from the little scientist evaluation. *Early Childhood Education Journal*, *48*, 352-363. https://doi.org/10.1007/s10643-019-01004-9

Montgomery, C., & Fernández-Cárdenas, J. M. (2018). Teaching stem education through dialogue and transformative learning: Global significance and local interactions in Mexico and the UK. *Journal of Education for Teaching, 44*(1), 2–13.

Nadelson, L.S., Callahan, J., Pyke, P., & Hay, A. (2014). Teacher stem perception and preparation: Inquiry-based stem professional development for elementary teachers. *The Journal of Education Research, 106*, 157-168. Doi: 10.1080/00220671.2012.667014

Organization for Economic Co-operation and Development [OECD]. (2000). *Science, technology, and innovation in the new economy*. https://www.oecd.org/science/inno/1918259.pdf

Patrick, H., Mantzicopoulos, P., & Samarapungavan, A. (2009). Motivation for learning science in kindergarten: Is there a gender gap and does integrated inquiry and literacy instruction make a difference? *Journal of Research in Science Teaching, 46*(2), 166–191.

Peker., & Dolan, E. (2012). Helping students make meaning of authentic investigations: Findings

from a student–teacher–scientific partnership. *Cultural Studies of Science Education, 7*, 223–244.

Pradhan, D. (2023, April 22). Women in stem Bhutan launch girl's mentorship program. *BBS*. http://www.bbs.bt/news/?p=184777

Renninger, K.A., Nieswandt, M., & Hidi, S. (Eds.). (2015). *Interest in mathematics and science learning*. American Educational Research Association.

Rifandi, R., Rahmi, Y.L., Widya., Indrawati, E.S. (2020). Pre-service teachers' perception on science, technology, engineering, and mathematics (stem) education. *Journal of Physics: Conference Series*. Doi: 10.1088/1742-6596/1554/1/012062

School Curriculum Division. (2022a). *National school curriculum: Mathematics curriculum framework class PP-XII* (2nd ed.). MoESD.

School Curriculum Division. (2022b). *National school curriculum: Information and communication technology curriculum framework class PP-XII* (2nd ed.). MoESD.

Sousa, D.A., & Pilecki, T. (2013). *From stem to stem: Using brain compatible strategies to integrate the arts*. Corwin.

Sharma, K.P. (2023, March 23). Stem camp helps rural students in Samdrupjongkhar and Pemagatshel. *Kuensel*. https://kuenselonline.com/stem-camp-helps-rural-students-in-samdrupjongkhar-and-pemagatsel/

Sydon, T., & Phuntsho, S. (2022). Highlighting the importance of stem education in early childhood through play-based learning: A literature review. *RABSEL: the Centre Educational Journal, 22*(1), 1-19.

The Bhutanese. (2021). Royal kasho on education reform. *The Bhutanese.* https://thebhutanese.bt/royal-kasho-on-education-reform/

Torres, J., Moutinho, S., & Vasconcelos, C. (2015). Nature of science, scientific and geoscience models: Examining students and teachers' views. *Turkish Journal of Science Education, 12*(4), 3–21. https://doi.org/10.12973/tused.10148a

Torres, J., & Vasconcelos, C. (2015). Nature of science and models: Comparing Portuguese prospective teachers' views. *Eurasia Journal of Mathematics, Science & Technology Education*, *11*(6), 1473–1494. https://doi.org/10.12973/ eurasia.2015.1407a

United Nations International Children's Emergency Fund [UNICEF]. (2023). *Pre-primary education*. https://data.unicef.org/topic/education/pre-primary-education/

Utha, K., Subba, H.B., Mongar, B.B., Hoopwood, N., & Kilborn, K.P. (2021). Secondary school students' perceptions and experiences of learning science and mathematics: The case of Bhutan. *Asia Pacific Journal of Education*. https://doi.org/10.1080/02188791.2021.1901652

Wangchuk, K. (2023, January 29). Stem camp for rural youth in Samdrup Jongkhar and Pemagatshel. *BBS*. http://www.bbs.bt/news/?p=180949

WOMEN IN STEM. (2024). *Women in stem: Bhutan.* https://womenstem.bt/?page_id=31

Zangmo, S. (2016). Grade 10 and 12 Bhutanese students 'attitudes toward science in the Thimphu district of Bhutan. *Journal of Turkish Science Education*, *13*(3), 199–213. doi: https://doi.org/10.12973/tused.10180a

Zollman, A. (2012). Learning for stem literacy: Stem literacy for learning. *School Science and Mathematics, 112*(1), 12–19. https://doi.org/10.1111/ j.1949-8594.2012.00101.x