STEAM Pedagogy as an Approach for Teacher Professional Development

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Abstract

The ongoing in-service teacher learning or formal teacher professional development (TPD) is too conventional and de-escalating as the disciplinary skills and knowledge of teacher is insufficient to solve real world problems which are multi-disciplinary in origin. Thus, there is a critical need to explore and introduce multidisciplinary pedagogy with wise integration of science, technology, engineering, arts and mathematics (STEAM) concepts as an approach for TPD. This paper aims to explore the possible approaches of introducing STEAM pedagogy as an approach for TPD. This argumentative paper is prepared with the help of relevant and useful literatures. We argue the urgent need to integrate arts and technology in subject disciplines and design STEAM projects and training module as a neo-approach for TPD. This approach is equally useful for pre-service as well as in-service school teachers to develop multidisciplinary ways of knowing and solving real world problems.

Keywords: Teacher Professional Development, STEAM approach, Pedagogy, ICT-integrated pedagogy.

Introduction

Learning is an inherent part of being which enriches the individual with personal and professional development. The knowledge and skills one inveterate during the professional role is akin to the professional development (PD) or success in his/her workplaces. Precisely speaking, "Teacher development is the professional growth a teacher achieves as a result of gaining increased experience and examining his/her teaching systematically" (Glatthorn, 1995, p. 41). Development of teacher in his/her profession requires examining the content of the experiences, the process by which the professional development will occur, and the contexts in which it will take place (Ganser, 2000; Fielding & Schalock, 1985). To meet these new expectations, teachers should be critical in the on-going process of teacher development and examine the new approaches and standards being proposed. This prioritized plan of actions which prepares teachers in their job, on their job and for their job is called Teacher Professional Development (TPD). In context of Nepal, teachers are being asked to develop and reflect neo-approaches voluntarily or should be helped to develop. The new panorama of PD is a long-term, collaborative process based on constructivism and transformative model in which teacher is conceived as a reflective practioner.

Teacher Professional Development in Nepal: Policies and Practices

In the year 1971, National Education System plan (NESP) has put together the requirement of academic qualification and professional qualification as a legal provision in their policy. Teachers were required to enroll in at least ten months training course. Training was viewed as an important means of improving teaching and learning. It makes teachers highly competent at transforming skills they have acquired in their regular teaching practices at classroom. "Worldwide, professional development of teachers is increasingly seen as a career-long process, with continuous feedback loops between theory, practice and research" (Department of Education, 2018, p. 41). Although, TPD includes such activities as life-long training, networks of learning teachers, action research, community relations, evaluation and accountability (Bhumi & Suwal, 2014, p. 66), NESP manifested training alone as vignette of TPD. In the year 1993, National Center for Educational Development (NCED) was formed under the Ministry of Education, Nepal with a fundamental role of organizing TPD programs for in-service teacher.

Through its Educational Training Centers (ETCs), NCED gave continuation to the earlier provision of taking ten months training courses for teachers in three phases. These three phases were completed in period of 2.5 months, 5 months, and 2.5 months respectively. And, also for secondary school teachers, in-service trainings of similar patterns were followed. By the year 2009, the ten months training course reached to 98.2% of permanent teachers of community schools (NCED, 2009). Thus, NCED felt needless to operate such trainings, however few programs under TPD has been running out.At present, NCED comes up with a 30-day professional development opportunity offered under TPD in 3 phases, each phase consisting of 10 days. The RP and roster trainers (Co-opted high school teachers) deliver professional courses containing face-to-face, self-study exercise and instructional counseling.

Critically observing TPD programs run by NCED, there are barely any follow-up training programs. Classroom level mentoring or support to teachers is also vacuous. Research by CERID (2009) has shown that the transformation of training into the classroom is around 50%. This miserable and tragic situation of existing professional development courses shows that numerous aspects of TPD programs should be unveiled.

STEM: A Workforce Development Paradigm

Going back to the ideas of STEAM education, the credit for the inception of STEM ideas goes to National Science Foundation (NSF) of the USA. In 1959, NSF documented and discussed the needs of STEM disciplines by focusing its scope

and necessity in the present context (Chesky & Wolfmeyer, 2015). The major focus of STEM education, at that time, was on developing competent and skillful human resources who can contribute as per the needs of any organization. To develop highly competent human resources, the disciplines (i.e. Science, Technology, Engineering and Mathematics) were considered as foundations.

The STEM Education Act developed by the USA in 2015 states that "more support of STEM education is necessary to develop a STEM workforce for high-tech companies, and small businesses in all the sectors that struggle to find workers with necessary skills and knowledge to fill in-demand STEM jobs" (Guzdial & Morrison, 2016, p. 31). The primary concern of this act was to improve how the future workforce is prepared to fill in-demand STEM jobs in the market. The purpose of selecting those disciplines was the scopes of the disciplines they provide skills for the market-oriented workplaces. The discipline, Science, has been acknowledged for scientific inquiry that demands hypothetico-deductive reasoning (Kaplan, 2017) which is very essential to promote economic rationality. Another discipline, Technology, as a cross-cutting skill for every job, helps to develop skills that are essential to maximize the individual's performances in their workplaces (Jang, 2016). The discipline, Engineering, aims at developing design thinking skills among workforces who can develop a prototype of market-oriented products, test them, and finalize them for establishing high-rated products in the market (English, 2016).

For serving the conventional purpose of teaching mathematics and developing mathematical reasoning, the discipline mathematics was integrated as a part of STEM disciplines. As stated earlier, the major goal for introducing STEM discipline was to develop skillful human resources in the job market. This seems well in the industrial era where the use of technology in machine-based manufacturing companies was the major focus to increase the production for the economic growth in the USA (Hoeg & Bencze, 2017).

The political discourse on education in the USA is, at its foundation, about competitiveness and economic dominance; this is the education for workforce development paradigm (Martinez, 2017). This paradigm of education is necessary at one level, and has many advantages in the industrial era. But, this lacks many dimensions in school education. It delimits various perspectives that a human has to develop as a responsible citizen (Taylor, 2018). The strong glue that has made different discipline as STEM was the workforce development paradigm. We, as a researcher, acknowledge the initial attempt for bringing different disciplines under the umbrella of STEM, which is itself a rewarding. But, we believe that this view is very narrow, and needs to explore the other dimensions of STEAM education.

Technology in STEAM Education

The rapid growth of technology and the technological tools have contributed significantly to the ways we live and think in all the sectors. The long-rooted beliefs towards education and ways of educating people have been challenged due to the presence of technologically-rich societies. Here, we have discussed the presence of technology in education in general, and in school education in particular. While doing so, the needs, advantages, and also limitations of technology with different initiations need to be discussed. Also, we have asserted our position as a researcher in terms of using technology as a pedagogical tool, and as a process or as an approach of TPD.

The focus of school education, and the ways of dealing with school children have been drastically changed over the past decades. The different learning theories (such as cognitive, constructivist, cooperative, transformative) have assumed the roles of teachers, and students differently, and hence, proposed different modalities for teaching and learning approaches. On the other hand, the rapid growth of technology in the last few decades has drastically changed the views of education and pedagogy. UNESCO (2018) has argued that the 2030 Agenda for Sustainable Development recognizes that the prevalence of Information and Communication Technologies (ICTs) has a significant potential to accelerate progress, to bridge the digital divide and support the development of inclusive knowledge societies. The ideas of incorporating techno-pedagogy (Mishra & Koehler, 2006) is gaining popularity in education where teachers use different tools for maintaining the records, attendance, and grading of the students, and apply different skills in classroom teaching. Showing the important of technology in the STEAM field, Milner-Bolotin (2015) has mentioned, "Technology is viewed as a vehicle for exploration of science and mathematics ideas permeating the world we live in, a tool for engineering design, artistic expression, as well as a field of inquiry within itself" (p. 142).

In case of Nepal, the government and non-government sectors have made a significant initiative in terms of promoting ICT in Education, and ICT-integrated pedagogy. National Planning Commission (2007) focused on ICT skilled human resource development and management by establishing ICT in all aspects of education and infrastructure development. In the same spirit, Ministry of Education (2009) stated ICT assisted teaching and learning as a core program in all schools in School Sector Reform Plan (SSRP) (2009-2016). The groundbreaking document in terms of ICT initiatives, in Nepal, is a comprehensive ICT in Education Master Plan (MOE, 2013). The plan has envisaged using ICT as an enabler for all students to reduce the digital gap, and ICT as a teaching and learning tool, as part of a subject and as a subject by itself. This provision has made a significant contribution in school education to promote ICT-integrated pedagogy. Another important plan in school education sector, SSDP 2016-2023, has focused ICT as an important tool to improve classroom instruction, increase access to learning materials, and improve the effectiveness and efficiency of educational governance and management (MOE, 2016).

UNESCO (2018) prepared ICT competency framework for teachers with a high priority on ICT-integration in teaching and learning. In this document, UNESCO has proposed three levels of knowledge (acquisition, deepening, and creation) with five different aspects (understanding ICT in education policy, curriculum and assessment, pedagogy, application of digital skills, organization and administration, teacher professional learning). Nepal government has also developed a framework for teachers' competencies. Out of eight domains under teachers' competencies standards, one is related with the use of ICT in their professional life (MOE, 2016).

In this paper, using ICT in pedagogy is a part of teachers' professional development. As a researcher in the field of STEAM Education, our entry point would be using some ICT tools (such a geogebra, mathematica) for visualizing mathematical ideas. This will, in turn help to move ahead for developing STEAM projects by incorporating the components of technology. The dynamic mathematical software opens doors to using mathematical modeling in order to explore the relationships between art (e.g. paintings, patterns, architecture) and mathematics (Milner-Bolotin, 2015). ICT has multi-purposes in educational field, broadly categorized as tools and as process/approaches. Our purpose of using ICT-integrated pedagogy in TPD is aligned with the ideas of Bidarian and Davoudi (2011), who proposed the application of ICT in three forms: a) it may involve all learners in learning process; b) it may increase the interests of learners, and c) it may provide variety in presenting manner of learning in a pleasant and non-boring situation.

An Integration of Arts in STEM Disciplines

The major idea raised in this paper is to incorporate arts in STEM disciplines. In this section, we have discussed arts integration as a construct, the scholars' view on this idea, and our position in using different facets of arts in TPD.

Generally, in all subjects of school education in Nepal, and mostly in Science and Mathematics, it is widely discussed that the roles of arts (i. e. using poem, stories, painting) in teaching and learning are not well acknowledged (Pant, 2015). This could be one of the reasons behind students' low motivation, and low performance in school mathematics and science. In the recent years, many educators (Dietiker, 2015; Eisner, 2002; Goldberg, 2016) around the globe have strongly advocated the needs of arts integration in school education. The fundamental reason behind the integration of arts is to create, "aesthetically-rich learning environments as those that enable children to wonder, to notice, to imagine alternatives, to appreciate contingencies and to experience pleasure and pride" (Sinclair, 2001, p. 26). For that, to begin with, the incorporation of paintings, poems and stories in different subjects such as Science and Mathematics, could be an effective point of department. Hunter-Doniger (2018) has defined an empowering model for arts infusion in education by employing three strategies: (a) all disciplines are regarded equally in pedagogy, content, and assessment; (b) collaboration exists between art and generalist educators; and (c) students are encouraged to delve deeper into subjects through art. The most important aspect for me/us is to the third strategy that makes students explore different subjects deeply through the integration of various forms of arts. Arts infusion allows students to do more than just memorizing the content and process of solving particular problems. It encourages learners to search alternative ways of viewing the problems, make their own meaning out of it, and apply this to update their knowledge and skills.

The important feature of school education in Nepal, mainly in mathematics, is developing procedural knowing where students memorize the steps to be followed to get the correct solutions (Manandhar, 2018). More specifically, the overemphasis on procedural knowing, knowing the steps required to attain the goals, has been given rather than on conceptual knowing in school mathematics, which is also known as a relational knowing (Rittle-Johnson & Schneider, 2015). This would turn students into machines rather than critical human beings. We are very much impressed with the idea of Eisner (2002), who declares his preference for aesthetic ways of knowing and learning. Eisner (2002) has drawn the idea of aesthetic from John Dewey, who describes aesthetics as an individual's response to an experience rather than an attribute of an object. Dewey notes that aesthetics is not an object's attribute but the individual's perception and interaction that is the path of aesthetics.

Arts have been discussed as tools for critical pedagogy, more than that as a social pedagogical process (Peters, 2016). More specifically, the visual arts are central to public attentions and critique, and have the power to illuminate social injustices and inequalities, which is the main aim of critical pedagogy. The critical pedagogy puts efforts to understand the world through different subjects such as mathematics, science, technology, language. It aims to develop critical consciousness (Freire, 1970). Arts has also been viewed as a public pedagogy, as discussed by Giroux (2004), which focuses on the study of media, popular culture assuming society as an educative force for learners. The projects school teachers design can be borrowed from the media, cultural and local traditions that can possibly make strong connections between school-subjects and out-of-school practices. Those projects are always public, and have the power to create rich discussion in the learning process. Schuermans, Loopmans, and Vandenabeele (2012) have viewed "public pedagogy that scrutinizes the educational processes involved when issues and interests are made 'public' for social interactions and to promote the notions of living together in the society (p. 3)".

STEAM approach for TPD

The conventional approaches of teachers' professional development are guided by the notion of providing knowledge and skills by the trainers. This, in turn made our students good in lower level of cognitive abilities such as knowledge and comprehension. On the other hand, students were found losing cognitive abilities of higher strata such as transforming the

knowledge in solving real life problems. "National Assessment of Student Achievement (NASA), 2012 suggests, noticeably a higher number of students were able to solve only 15% or less of the practical problems (15% of the students in Mathematics, 11% in Nepali, and 5% in Science)" (NASA, 2012, p. 170). In mathematics, the open-ended questions that seek higher cognitive abilities were a far cry for students. Students tend to perform only basic calculations whereas task demanding use of higher cognitive faculties such as reasoning, problem solving, or in constructing figures are really doomed. "A similar situation is for science where students are good in recognizing the correct answer and in very fundamental knowledge such as choosing the facts and numbers, and writing the definitions, and also in language discipline such as Nepali, students performed well in the task requiring the recognition of the correct answer, recalling simple facts from the texts, fundamental thinking, and the basic interpretation of the paragraphs (DOE, 2018). Nonetheless, they are less strong in exhibiting verbal-linguistic intelligence such as writing essays or abstracts from a text. The present notion of curriculum as a set of tasks to be mastered or to lead students to a pre specified ends is failing badly. Research carried by NASA reveals that average score of students' learning achievement varies across the subjects ranging from 35% in Mathematics, 41% in Science to 48% in Nepali (NASA, 2012). Using only the disciplinary skills and knowledge of teacher as an approach of TPD proved to be insufficient to solve real world problems which appeared to be multidisciplinary and complex in origin.

A fundamental question before us is why our educational system not aware of the reasons behind schools,' consistently failing to foster desired higher cognitive skills in students. However, schools rarely teach cognitive skills but if we could focus more in developing interest in language, mathematics and science by using activity-based learning along with use of basic learning kit, then advancement in cognitive faculties of mind could be established. Now, this is the high time for curriculum planners, teacher educators and training modules designers to take a shared responsibility to address the issues of low performance level in higher ability tasks and for this, we must initiate discussion on how to incorporate skills and competencies in teachers in order solve the real world problems such as poor exhibition of creativity and critical thinking skill. In the Nepali context, elsewhere, Luitel (2009, 2013, & 2019) consistently argued that mathematics and science curriculum, and pedagogy are decontextualized, and disengaged. So, to keep students and teachers engaged in task demanding higher mental ability, we have initiated discussion on STEAM (Science, Technology, Engineering, Arts and Mathematics) as a multidisciplinary approach of professional development undertaking.

As we frequently indicated in almost all the previous sections of our writing, the STEAM Education in a broad sense, and STEAM pedagogy particularly have different focuses, and intentions (such as focused on technology, workforce development, arts integration). The major intention of this paper, which is to transform pedagogical practices towards more human-centric from content-centric teaching through inquiry-based approach could be achieved from the transformative dimensions of STEAM Education. Normally, school level mathematics teachers are interested for ready-made tips, tricks and techniques for solving various mathematical problems (Pant, 2017) which are easy to apply in the classroom teaching. We believe that effective teaching is much more than compilation of skills and techniques. For us, inviting teachers to reflect on their own practices is a great beginning towards transformation. The next ladder of self-reflection is critical reflection where two concepts of critical inquiry and self-reflection are considered as foundations for reflective practitioners (Larrivee, 2000). The pioneer in the areas of critical reflection, Stephen Brookfield, has argued that critical reflection is a matter of stance and dance. The notion of stance was discussed as one of the inquiry which is always open for further investigation whereas the idea of dance, here, was taken in terms of experimentation and risks that always looks for modifying the practices (Brookfield, 1995).

In the present context, teachers are trapped into the reflexive circle in different mental models that are influenced by the popular belief and make choices-based the personal assumption in the classroom. This guides their teaching practices and classroom reflection. For most teachers in Nepal, due to their authoritarian nature, appear to be ignorant of the influence of such unaware behaviors in the teaching and learning process (Pant & Luitel, 2016). The teachers, hence, need to practice critical reflection in their professional career, which is highlighted as being a personal awareness discovery process. The teachers can engage themselves in the reflective process by making it an integral part of daily practice. One of the strategies discussed by Larrivee (2000) is maintaining a "reflective journal", which allows them to reflect their daily activities and analyze the impact of their activities on the students.

The ways of inviting teachers for reflective practice is not an easy task, and always the same approach. However, we found the approach suggested by Larrivee (2000) for examining the core belief for making the strategies or moves for action. The very first step is examining the core belief which is based on the meaning of life, religious beliefs, ethics, and values, etc. The next step is to organize the framework for beliefs and includes the theories teachers are attached with. The third level is linking teachers' beliefs with the general plan of action. Based on the core belief and underlying principle, teachers develop a plan of action or daily practices. Finally, teachers make strategies and moves to implement their plan of actions. This idea is very much closed with the idea of Transformative Learning that was discussed by Mezirow (1991).

Thus, to envisage the better teaching and learning approaches as pedagogical innovations and to transform the existing teaching and learning practices, the transformative lens of STEAM education could be one of the major hallmarks in the Nepali context. And, as a citizen of non-Western societies and the nation where neocolonial thinking is gaining popularity day by day, the transformative learning has created spaces to assess the alternative ways of knowing, and researching, being critical with the so called dominant theories of education and learning.

Conclusions

The examination of the content of the experience by the process of professional development is a long-term, collaborative process where teacher is envisaged as reflective practioner. Since long time, NESP has substantiated training as an engraving of TPD, but transformation of training into classroom is around 50% (CERID, 2009). Thus, exploration of numerous aspects of TPD is a must to get rid of such real, ongoing tragic. While referring STEAM education from its inception to today, it has undergone various modification and integration.

Quinnell (2019) conducted a study to illuminate his shift from STEM to STEAM by reflecting on academic identity and scholarship. The researcher has reflected on his select moments in his career where his scholarly work was informed by his home discipline of Biology and extended into other discipline spaces, specifically the Arts. He reflected on the importance of working across disciplines as fields of practice and of connecting with others within science, and across and outside of science. The most important realization he made was the Science-Art moments that made a remarkable shift in his professional life.

Similarly, Lajoie and Poitras (2017) conducted a study on crossing disciplinary boundaries to improve technology-rich learning environments by reviewing several technology-rich learning environments in different areas. The adaptive capabilities of different contexts are discussed in terms of the metaphors of using computers as cognitive, metacognitive, and affective tools. The data were collected through multiple modalities to gain a better understanding of what learners know, feel, and understand. It was found that these investigations have significant implications for the metaphor of using technology as a tool to the thinking of the learners. The major challenges were to consider social and emotional perspectives of learning, and to adopt the ever-changing technology.

Bundsgaard (2019) has argued the need of technology to scaffold the progressive learning. The researcher used a scaffolding interactive platform, a tool informed by practice, a transformation of resources from tacit structures to explicit structures. In this research, computers have been used in various ways to support more complex teaching practices. The result showed that these practices improved the students' competencies both in the STEM areas, and the arts field in the authentic context.

Kang (2019) has examined the STEAM education initiative in South Korea and investigated its effects on learning and teaching. Studies in South Korea found that teacher professional development courses increased teachers' recognition of the initiative as well as their confidence in teaching STEAM. The interviews conducted with teachers showed that coaching in classroom practices within teachers' professional development was very much helpful. The study has clearly stated that many science teachers adopted STEAM in science teaching. But, there was a lack of research on how teachers taught STEAM lessons. As for STEAM effects on students' learning, a number of meta-analyses showed that students' experiences with STEAM were effective in both cognitive and affective learning. In the case of Korea, the Ministry of Education has issued a nation-wide policy agenda in 2011, which included the promotion of integrating science, technology, engineering, arts, and mathematics education. The STEAM education in South Korea is an approach to preparing a quality STEM workforce and literate citizens for highly technology-based society by integrating science, technology, engineering, arts and mathematics in education (Kang, 2019, p. 2).

Almost all research studies we reviewed have put the ideas of technology integration and art-integration at the center. The reasons behind such integration were making classroom more motivating and engaging. This is good to itself but those studies could not concentrate on the critical understanding of the contents and the processes. We could not find the research studies that focus on improving teachers' practices by exploring their strengths and limitations. After going through the several research studies done in the areas of STEAM education (more specifically, STEAM pedagogy) in school education, We realized that this is a new, and timely area in the Nepali context due to various reasons such as the government's initiatives on integrated curriculum, the present disengaged school pedagogy, the shift of education authority to the new establishment of local government.

Finally, we ascertain that besides teachers, we need to work collaboratively with policy makers and curriculum developers if we have appetency to advance STEAM education and measure adequacy of changes in our learners in solving real world problems. And for the change to take effect it takes effort in real time. We hope this paper serves to start the conversation on STEAM education towards that effort.

References

Bundsgaard, J. (2019). Using technology to scaffold progressive teaching. In Babaci-Wilhite Z. (Eds.). Promoting Language and STEAM as Human Rights in Education (pp. 109-124). Springer, Singapore.

Bhumi, A. L. & Suwal, R. (2014). Teacher management and development in federal system of Government in Nepal. Kathmandu: UNESCO Office Kathmandu.

Brookfield, S. (1995). Adult learning: An overview. International Encyclopedia of Education, 10, 375-380.

Bidarian, S., &Davoudi, A. M. (2011). A model for application of ICT in the process of teaching and learning. Procedia-Social and Behavioral Sciences, 29, 1032-1041.

CERID. (2009). Education for All (2004-2009) (Formative Research Report on Exploring the opportunities for professional development of primary school teachers in Nepal). Kathmandu: CERID, T.U.

Chesky, N. Z., &Wolfmeyer, M. R. (2015). Philosophy of STEM education: A critical investigation. New York, NY: Springer.

Department of Education (2018). A study on identifying ways for managing school level teachers in federal system (Final Report). Sanothimi, Bhaktapur. Retrieved from http://www.doe.gov.np/assets/uploads/files/c3d311abba5aa25f30b60d7cad5bbe0c.pdf

Dietiker, L. (2015). What mathematics education can learn from art: The assumptions, values, and vision of mathematics education? Journal of Education, 195(1), 1-10.

Eisner, E. W. (2002). What can education learn from the arts about the practice of education? Journal of Curriculum and Supervision, 18(1),
4-16.

English, L. D. (2016). STEM education K-12: Perspectives on integration. International Journal of STEM Education, 3(1), 3.

Freire, P. (1970). Pedagogy of the oppressed. New York, NY: Continuum.

Fielding, G.D, & Schalock, H.D. (1985). Promoting the professional development of teachers and administrators. Eugene, Oregon: ERIC clearing house on educational management.

Ganser, T. (2000). An ambitious vision of professional development for teachers. In NASSP Bulletin, 84(618), 6-12.

Giroux, H. A. (2004). Cultural studies, public pedagogy, and the responsibility of intellectuals. Communication and critical/cultural studies, 1(1), 59-79.

Glatthorn, A. (1995). Teacher Development. In: Aderson, A. (Ed.) International Encyclopedia of Teaching and Teacher Education (Second Edition), p.41, London: Pergamon Press, 1995.

Goldberg, M. (2016). Arts integration: Teaching subject matter through the arts in multicultural settings. New York, NY: Routledge.

Guzdial, M., & Morrison, B. (2016). Growing computer science education into a STEM education discipline. Commun. ACM, 59(11), 31-33.

Hoeg, D. G., & Bencze, J. L. (2017). Values underpinning STEM education in the USA: An analysis of the next generation science standards. Science Education, 101(2), 278-301.

Hunter-Doniger, T. (2018). Art Infusion: Ideal Conditions for STEAM. Art Education, 71(2), 22-27.

Jang, H. (2016). Identifying 21st century STEM competencies using workplace data. Journal of Science Education and Technology, 25(2), 284-301.

Kang, N. H. (2019). A review of the effect of integrated STEM or STEAM (science, technology, engineering, arts, and mathematics) education in South Korea. Asia-Pacific Science Education, 5(1), 2.

Kaplan, A. (2017). The conduct of inquiry: Methodology for behavioural science. New York, NY: Routledge.

Lajoie, S., & Poitras, E. (2017). Crossing disciplinary boundaries to improve technology-rich learning environments. Teachers College Record, 119(3).

Larrivee, B. (2000). Transforming teaching practice: Becoming the critically reflective teacher. Reflective Practice, 1(3), 293-307.

Luitel, B. C. (2009). Culture, worldview and transformative philosophy of mathematics education in Nepal: A cultural-philosophical inquiry (Unpublished doctoral thesis). Science and Mathematics Education Centre, Curtin University, Perth, Australia.

Luitel, B. C. (2013). Mathematics as an im/pure knowledge system: Symbiosis, (w) holism and synergy in mathematics education. International Journal of Science and Mathematics Education, 11(1), 65-87.

Luitel, B. C. (2019). Journeying towards a multi-paradigmatic transformative research program: An East-West symbiosis. In P. C. Taylor & B. C. Luitel (Eds.) Research as Transformative Learning for Sustainable Futures (pp. 19-37). Brill Sense.

Manandhar, N. (2018). Conceptual and procedural knowledge of students in mathematics: A mixed method study (Unpublished MEd thesis). Kathmandu University School of Education, Nepal.

Martinez, J. E. (2017). The search for method in STEAM education. Location: Springer International Publishing.

Mezirow, J. (1991). Transformative dimensions of adult learning. Thousand Oaks, CA: Jossey-Bass.

Milner-Bolotin, M. (2015). Technology-Enhanced Teacher Education for 21st Century: Challenges and Possibilities. In X. Ge., D. Ifenthaler, & J. M. Spector, (Eds.). Emerging technologies for STEAM education: Full STEAM ahead. Location: Springer.

Ministry of Education. (2009). School sector reform plan 2009-2015. Kathmandu, Nepal: Author.

Ministry of Education. (2013). Information & communication technology (ICT) in education master plan 2013-2017. Kathmandu, Nepal: Author.

Ministry of Education. (2016). School sector development plan 2016-2013. Kathmandu, Nepal: Author.

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge.Teachers College Record, 108(6), 1017- 1054.

National Assessment of Student Achievement (2012). Report. Sanothimi, Bhaktapur: Education Review Office.

National Center for Educational Development (NCED) (2066 BS). Teachers Professional Development (TPD) Handbook-2066. Sanothimi, Bhaktapur, Nepal: Author, p.1.

National Planning Commission. (2007). Three year interim plan. Kathmandu, Nepal: Author.

Pant, B. P. (2015). Pondering on my beliefs and practices on mathematics, pedagogy, curriculum and assessment (Unpublished MPhil dissertation). Kathmandu University School of Education, Lalitpur, Nepal.

Pant, B. P. (2017). Doing, teaching, learning and thinking about mathematics on becoming a transformative teacher. Journal of Education and Research, 7(1), 11-24. doi:http://dx.doi.org/10.3126/jer.v7i1.21237

Pant, B. P., & Luitel, B. C. (2016, July). Beliefs about the Nature of Mathematics and its Pedagogical Influences. Published in a conference proceeding at the International Congress of Mathematics Education (ICME-13, 2016) in Hamburg, Germany

Peters, C. (2016). Critical Pedagogy and Art. Encyclopedia of Educational Philosophy and Theory, 1-6.

Quinnell, R. (2019). Shifting from STEM to STEAM-reflecting on academic identity and scholarship. International Journal of Innovation in Science and Mathematics Education, 27(7), 1-9.

Rittle-Johnson, B., & Schneider, M. (2015). Developing conceptual and procedural knowledge of mathematics. Oxford handbook of numerical cognition, 1118-1134.

Schuermans, N., Loopmans, M. P., & Vandenabeele, J. (2012). Public space, public art and public pedagogy. Social & Cultural Geography, 13(7), 675-682.

Sinclair, N. (2001) .The aesthetic is relevant. For the Learning of Mathematics, 22(1), 25-32.

Taylor, P. C. (2015). Transformative science education. In R. Gunstone (Ed.), Encyclopedia of science education (pp. 1079-1082). Dordrecht, The Netherlands: Springer.

Taylor, P.C. (2018). Enriching STEM with the arts to better prepare 21st century citizens. AIP Conference Proceedings, 1923(1), 89-93. doi:10.1063/1.5019491

UNESCO. (2018). UNESCO ICT competency framework for teachers. Paris, France: Author.