ISBN: 978-81-941567-9-6
January 3-6, 2020

INCORPORATING STEAM PEDAGOGY IN TEACHING MATHEMATICS

Binod Prasad Pant, Bal Chandra Luitel and Indra Mani Shrestha
Department of STEAM Education, Kathmandu University School of Education, Nepal
binod@kusoed.edu.np

Mathematics has been considered as an important discipline since ancient era. Teaching mathematics was taken as a prestigious job. Mathematics was considered as a source for creative and critical human resource. Over the period of time, teaching and learning Mathematics, mostly in school levels, is confined to transferring "official knowledge" from teachers' head to students' head. The overemphasis on procedural mathematical knowledge and major focus on routine problems have served the narrow interest of limited people who have been viewing mathematics as the subject of deposition of pre-defined knowledge and skills. There could be various reasons behind such scenarios. One of the reasons is inadequate teachers' knowledge and skills in the Nepali context on using innovative pedagogical practices. In this regard, this research was conducted to help teachers prepare and implement the various STEAM projects (inquiry-based projects, stories and poems, technology-enhanced teaching and so on) in mathematics teaching. The Participatory Action Research (PAR) was used in two different schools of Kavre district in the rural parts of Nepal. The specific problems were collectively explored after a series of consultative meetings, and the intervention plans (making projects) were developed together and implemented in the classroom. Through a series of reflections on/in the process, it was found that the motivation of students towards mathematics learning increased, and the engagement of the students in mathematics classroom was meaningful. This paper aims at sharing the needs of the research, methodology, and major findings and conclusions.

MATHEMATICS TEACHING IN THE NEPALI CONTEXT

Elsewhere, Nepali educators, Luitel (2013, 2019), Shrestha (2018), and Pant (2015, 2019) have illuminated the state of mathematics teaching in the Nepali context which is more decontextualized and disengaged in nature. Going back to the needs of subjects like mathematics, the Ministry of Education, Science and Technology (MoEST) has repeatedly mentioned that mathematics is the foundation for other subjects. The school level mathematics curriculum is largely aligned with the notion of 'curriculum as subject matter' (Schubert, 1986). The purpose of such a notion of curriculum is to prepare children having mastery in subject matter with very limited skills in dealing with real-world complex problems. The present mathematics textbooks provide a series of mathematical problems that normally do not represent the actual problematic context of life that can create rich learning experiences among school students. The students are forced to memorize the knowledge and demonstrate the limited skills in a discrete setting, thereby producing procedural understanding of subject matter (Baker, Czarnocha, & Prabhu, 2004). Over the period of time, such practices created disciplinary egocentrism (Connor, Karmokar, & Whittington, 2015) among students and teachers that

normally does not allow them to think outside their disciplines. The disciplinary egocentrism is a state of thinking and performing certain tasks where a person is hegemonized with the particular disciplinary knowledge system and ways of developing such knowledge. Such a situation does not welcome multidisciplinary and alternative ways of knowing and performing.

On the one hand, the school education envisages producing empowered citizens who can solve complex real-world problems. On the other hand, the majority of school teachers still take different subjects (such as Mathematics, Science, Computer, Social Studies, etc.) as completely separate entities. We forget that all the subjects at school level are to prepare children to deal with their daily life problems and develop the foundations for higher studies. For this, children should be at the centre, and different subjects should be considered as a means of achieving the goals of education. An influential educator, Palmer (2017), has stated that instructors who refuse or are unable to see students as whole persons, with intellectual capacities and emotional vulnerabilities, may lack an ability to "see" their own strengths. His thoughts also align with the ideas of integrated approach of teaching and learning where the children are viewed as whole and capable social beings. A recent study of Education Review Office, a government body, has found unsatisfactory results in Mathematics nationwide (ERO, 2017). Out of various reasons, the overemphasis on fragmented teaching and learning activities was noted.

STEAM PERSPECTIVES IN SCHOOL EDUCATION

One of the problems of school education in Nepal is the overemphasis on the content that is presented in a more segregated manner in each subject. Teaching Mathematics, Science, Technology and Arts with different approaches keeps the subjects in isolation, and they are treated differently as they exist separately without any kinds of interconnections. The real-world problems require knowledge and skills from multiple disciplines. If we are asked to solve our personal, social and professional problems (such as building a model of a house, fixing the carpet at home, painting the walls, etc.), the ideas should be drawn from different areas (Mathematics, Science, Technology, Engineering, etc.) in many cases. For example, if a student is asked to develop a model of a house, she/he has to use various knowledge and skills from different subject areas; designing ideas from engineering perspectives, calculation from mathematics, use of different available materials from the perspectives of contemporary society, scientific perspectives from Newtonian science perspectives, and more than that creativity from artistic perspectives.

Working in the field of teacher education for more than a decade, we experienced that the connections among different subjects and within the contents of the same subject are not well covered and recognized. Such practices could not promote the holistic way of knowing. In this regard, treating a child as a whole and integrating more than one concept from different disciplines in a more critical and creative manner are urgent in our education system. To address such problems in school education, STEAM (Science, Technology, Engineering, Arts and Mathematics) education is gaining popularity these days around the globe. STEAM is an integrated and interdisciplinary approach to learning that encourages students to think more broadly and critically about the real-world problems. In this approach, the real-world problems are solved by incorporating the scientific, mathematical, engineering and technological knowledge in a creative way. It does not mean that

every problem needs all the dimensions to address but it normally requires more than one area to explore the better solutions. For that, our traditional "subject-centric" approach of teaching and learning is unhelpful and disempowering.

The idea of STEAM education has been proposed to promote productive engagement among the learners in issues and problems associated with science, mathematics and related curricular areas (Stroud & Baines, 2019). STEAM education puts primacy on integrated curriculum and pedagogy so as to use knowledge and skills in creative and imaginative (i.e. artistic) ways. The 'A' in STEAM education is helpful to address the unaccounted approaches to integration. For example, arts-based methods (painting, building models, story-telling, singing, etc.) help teachers and students connect various disciplinary skills of science and mathematics. Another important feature of STEAM education is to practice the idea that school is a place for the "production" of knowledge. Here, the notion of production is political and for the betterment of society. This helps to replace the conventional lecture-based pedagogy through a series of carefully designed sessions in which students actively engage in exploring, analysing, evaluating, and creating something useful and related to their academics. By enabling learners to create something new, it may increase the engagement of learners in the educational processes.

STEAM education engages students in transformative learning that promotes the interconnected ways of knowing such as cultural self-knowing, relational knowing, critical knowing, visionary and ethical knowing, and knowing in action (Taylor, 2015). Keeping the notion of STEAM related skills (science process skills, manipulative skills, computational thinking skills, reasoning skills, engineering design thinking skills and ICT skills) at the centre, the courses in the school level can be designed accordingly, which can be taught using an inquiry-based approach, project-based learning and digital learning. Inquiry-based approach promotes STEAM disciplines to enable students to engage in authentic and meaningful activities that help to improve reasoning skills. The project-based learning enables students to develop 21st century competencies including resilience, coping with uncertainty, self-reliance, and creativity by interacting with the real-world activities. The digital learning is a modern learning environment that enables students to develop their technological literacy and critical thinking skills throughout their daily learning activities. English (2016) also argues that a greater focus on STEM integration is needed with a more balanced focus on each of the disciplines.

PURPOSE OF THE STUDY

The purpose of this study was to explore the innovative pedagogy that contributes to the enhancement of the performance of teachers and students. More specifically, the researchers were interested in collaborating with school leaders and mathematics teachers to develop and implement the STEAM pedagogy from the perspectives of integrated learning approach as per the needs of the context.

THEORETICAL POSITION

As teacher educators, after a long journey in identifying well-known theories of our field, we came to realize that there is no "royal road" to pedagogy, and grand theories of teaching and researching may not be

appropriate in developing ourselves (and teachers) as change agents. Hence, we believe in home-grown theory (i.e. theory which is locally developed to serve the needs of the local context) in pedagogical worldviews. In this context, Transformative Learning Theory which is rooted in the work of Mezirow (1991) and Living Theory Methodology (Whitehead, 2008) were very much helpful for us in this study.

On the one hand, Transformative Learning Theory provided us as researchers with a new epistemological ground in research that advocates research as a means for transformative learning. It helped us, as citizens of non-Western societies, to assess our false consciousness on the so-called dominant theories of education and learning, where the influence of the neocolonial thinking is increasing day by day (Pant, 2019). Moving forward to what Mezirow (1991) proposed as Transformative Theory, we used the ideas of Dirkx (2012), which values the integrated approach to transformative learning grounded in a concept of multiple 'selves' that recognizes the importance of both the rational and affective, and the personal and the social dimensions in fostering self-understanding. On the other hand, Living Theory Methodology always reminded us of the most important question raised by Whitehead (2008), "How do I improve what am I doing?" Whitehead (2008) explained that a living theory is an explanation produced by individuals for their educational influence in their own learning, in the learning of others and in the learning of the social formation in which they live and work. For us, these theories were supporting to have deeper view of the world of our research and practice.

RESEARCH METHODOLOGY

We, researchers, claim that we conduct research for the betterment of the society. But, it is hardly seen that the researchers involve research participants to share their voices in all stages of the research process. However, as PAR (Participatory Action Research) researchers, we believe that young and adult people should be able to articulate their views on issues that matter to them, and their views should be valued in accordance with their age and maturity (Lansdown, Jimerson & Shahroozi, 2014). Moreover, PAR model provides such opportunities where a researcher acts as an activist-scholar (Mirra, Garcia & Morrell, 2016), and ordinary people are enabled to play an active and influential role in decisions which affect their lives, meaning that their voices are not only heard but also addressed throughout the research process. Rather than the objective interpretation of an outsider, PAR demands insider participation that illuminates the problem under the study (Padilla, 2014) and is conducted under a collaborative research team that utilizes dialogue and reflection during all phases of the research process. The PAR research design creates a set of interconnected opportunities where conversations about teaching and learning take place with a lot of innovations in curriculum, pedagogy and assessment. In this regard, we adopted the PAR approach so as to engage the teachers, students and community members in the development of innovative strategies to improve the performances of both the teachers and schools.

Most importantly, PAR aims to develop critical consciousness about the research agenda and research process to improve the lives of those who involve in the research process, and to transform fundamental societal structures and relationships. Park (2001) calls PAR the research of the people, by the people, and for the people. In our research context, 'people' are students, teachers, teacher educators and community people. In

this regard, we also felt that PAR could be an appropriate research methodology to serve our interest to bring some notable shifts in the present pedagogical approach. There are various steps to be followed in PAR methodology. The principles behind such steps are democratic, equitable, liberating, and life-enhancing qualitative inquiry that make it distinct from other qualitative methodologies as noted by MacDonald (2012). We chose two different schools and worked with four teachers who teach mathematics till grade eight. During the phase of needs identification and sharing, we also invited head teachers and the community members. The first step was to identify the needs of the school teachers.

Based on our experiences as teacher educators, we felt that incorporating STEAM pedagogy in school mathematics is one of the needs of the school education at present. But the needs of the teachers in the research site could differ from our assumptions. That's why, the "real" needs were identified after conducting one workshop, two interviews and one participant observation with school teachers, leaders and community members. This was a collective task in PAR. After conducting workshops, we developed a plan of actions. The school teachers shared that students were demotivated in mathematics class, and the problems of textbooks were not contextual. The head teachers were expecting supports for school teachers to prepare rich tasks in mathematics. The community people shared that their kids found mathematics very difficult.

BEING IN THE FIELD

The capacity building of teachers on the chosen strategy was the most important aspect in this study. Both the capacity building of the teachers and the implementation of the skills they developed during the workshop sessions, went together. We planned for three cycles – each cycle of one month. Our intent was to improve our plan after the completion of the first cycle as per the spirit of PAR. The first cycle aimed at reflecting teachers' practices and helping them to develop inquiry-driven mathematical tasks, which was the foundation for STEAM pedagogy. The second cycle aimed at preparing and implementing STEAM projects, and the third phase was for updating the projects based on the feedbacks and reflection of the first and second cycles, and reflecting the entire process and the outcomes at the end. In doing so, a two-day workshop was conducted at the beginning of each cycle and teachers were asked to implement the tasks/projects prepared in the workshop for the rest of the days. We, as researchers, provided ample support to implement the projects in the class, and we all collaboratively (with school teachers) explored the solutions to the problems that arose during the implementation. Regular follow-up and feedback sessions were also organised in the schools.

In the workshop of the first cycle, the teachers were asked to reflect on their practices. The researchers used the principle of transformative learning to make them realize their assets and limitations as mathematics teachers. The 'asset' was about eagerness to learn new things and the 'limitation' was about the deeply-rooted beliefs and practices in traditional ways of teaching mathematics (i.e. lecturing the ideas, solving the problems on the whiteboard, and giving routine-based problems as homework). The inquiry approach in mathematics lessons was discussed and some inquiry-driven tasks were developed in the workshop. When mathematics teachers implemented those tasks in the class, they were asked to share their experiences. The good part was that almost all the teachers shared that the tasks helped to develop conceptual knowledge and understanding of mathematics. For example, in one of the tasks, a teacher asked students of grades six to prepare a budget

of their family. This particular task provided rich environment to learn about the family income, expenditures and the expense headings. One of the students shared that the majority of expenses had to be allocated in health and education. This cycle created a good foundation for us to move forward to preparing STEAM projects.

Moreover, we have taken STEAM more than an acronym for Science, Technology, Engineering, Arts and Mathematics. STEAM is an innovative pedagogical approach in which scientific thinking is derived from science, logical thinking from mathematics, design thinking from engineering, arts-based pedagogy from arts, and technology-enhanced pedagogy from technological perspective. So, in the second cycle, the teachers were asked to develop projects by using those various perspectives (one or more) in teaching mathematics. In this cycle, one teacher prepared a project named as *mathematics in the kitchen* where he tried to teach basic operations of mathematics (addition, subtraction, multiplication and division) with the examples of stuffs which are used in the kitchen. Another school teacher prepared a project named as *mathematics of the carpenter* where he taught measurement related ideas by connecting with the practices of carpenter. The purpose of such activities was to improve teachers' own practices as Whitehead (2008) suggested asking the question to oneself: "How do I improve what I am doing?" Finally, the teachers implemented their plans accordingly and shared their insights.

In the third cycle, the teachers were updated with their projects based on the insights received from the first and second cycles. Some teachers were guided by scientific inquiry model while updating the projects while the others had their focus on technology, different forms of arts (stories and cases) and design thinking. In this cycle, the teachers gradually prepared few stories to capture the past events of the community. One teacher started to use mobile set to demonstrate the various geometrical objects. Another teacher asked students to draw their dream house with the appropriate measurement. These activities provided rich experiences for students. At last, the community people also shared the changes they observed in the students and teachers and the practices.

REFLECTION AND LESSON LEARNT

Reflection and lessons learnt were iterative and bi-directional throughout this research study. The reflection part was an ongoing process since the time we started interacting with school teachers, students and other stakeholders. During the process, we always emphasized the critical reflections on our deeply-seated beliefs, practices and ideologies. We observed that the overemphasis on disciplinary approach of school education was unhelpful to develop students as a holistic human being with enough human and social values and integrities. If we prepare rich teachers' professional plan that supports teachers in their workplace, it will be much beneficial to all the stakeholders (students, teachers, school and community). The study successfully demonstrated that teachers were able to develop and implement the projects. The performances of the students also improved, and more than that they were found motivated in learning mathematics meaningfully. The performances of the students were measured through a rubric developed by school teachers. In the rubric, the scores of class tests, interaction with teachers and students, attentiveness, and timely completion of the projects were mentioned. During the research study, we found the ideas of Spivak (2003), who has been

ignoring the standardized "rules" of the academy and advocating moving forward from the disciplinary boundaries, much empowering and helpful in our context. Based on our research study and experiences, the conventional disciplinary values and such mind-set have been creating a narrow and disempowering space in school education. That's why we conclude that the innovative STEAM pedagogy should be incorporated in teaching mathematics through STEAM education in Nepal.

Note: This paper is based on the research conducted by the first author. The second author is the supervisor of the first author. The third author is the "critical friend" of the researcher who offered critical suggestions during the field work, and writing phase.

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