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RESEARCH ARTICLE

Supporting teachers in implementing project-based learning in teaching secondary mathematics: An action research

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Abstract: In the context of Nepal, most mathematics teachers at the secondary level are still using conventional teacher-centred pedagogy. It is assumed that teachers' pedagogy might enhance learners' engagement in learning mathematics and build conceptual understanding. Project-based learning (PBL) is a student-centred pedagogy that can remove misconceptions about content knowledge, enhance engaged learning, and support teachers in developing pedagogical skills. The study tried to reform the pedagogical practice of teachers using conventional teacher-centred pedagogy in teaching mathematics. The action research was conducted in four secondary schools in Nepal by five secondary mathematics teachers in two cycles, each seven days. The study focused on the implementation of PBL in secondary-level schools, the impact of PBL on students' activities, and professional development. The seven-day project was prepared based on a 3-day workshop for teachers on the surface area of prism and pyramid of grade ten mathematics. The action research was conducted in four different school settings, and students' activities were observed. The study collected qualitative data through interviews (baseline and post), observation, and teacher reflection notes. Text data were analyzed thematically for meaning-making and finding. The study's significant findings were engaged learning, inclusive education, and contextualization of mathematics. Likewise, students' creativity was observed during the action research, and teachers were supported in reforming their pedagogy with new experiences through PBL. The study might support other teachers in implementing PBL for student-centred pedagogy and teachers' professional development.

Keywords: PBL, action research, prism and pyramid, engaged learning, inclusive education

1 Background of the study

In Nepal, most mathematics teaching is generally limited to classroom activities of school, which is a barrier to the environment for thinking beyond the box (Dahal et al., 2023). Teachers are using the traditional teacher-centred pedagogy of teaching mathematics, which is "transmitting teachers' knowledge to students' minds" with some fixed techniques and fixed algorithms; the classroom culture suppressed student ideas in the name of definitions, theorems, formulas, and 'depositing the teacher's ideas into students' heads' (Luitel & Taylor, 2005; Verawati et al., 2023). In the context of Nepal, the traditional education system and old teacher-centred pedagogy promote conventional disciplinary values, mindset, and content memorization, which have created a narrow and disempowering space in education (Pant et al., 2020). Some things could be improved in teachers' pedagogy and must be improved by transforming teachers' pedagogy in the mathematics classroom. On the other hand, The Education Review Office shows that (ERO, 2018) of Nepal shows that 32% fall below the basic level, has 5% of the tested curriculum, and 70% of students are under the 28% achievement of grade five in mathematics. Similarly, The Education Review Office (ERO, 2019) shows that 32% of students at the primary level and 59% of grade 10 students are at a low achievement level. Furthermore, it was found that there needed to be a higher achievement in grade 5, grade 8, and secondary education examination (SEE, 2023) examination results. Based on the student's achievements and the nature of the curriculum up to grade ten in Nepal, mathematics is considered a complex subject (Luitel & Pant, 2019). So, mathematics teachers have to transform their pedagogy to improve the achievement and interest of learners.

There is a misconception about understanding mathematics (Karakose at el., 2023), especially the surface area of the prism and pyramid of grade ten mathematics. Aziza and Juandi

(2021) pointed out three misconceptions in understanding the prism's surface area:y, ontogenic, epistemological, and didactical. Ontogenic obstacle shows the difficulties in finding names and elements of the prism, an epistemological obstacle indicates that students tended to memorize the definitions and formulas without a more profound understanding of the concept, and didactical obstacle indicates the lack of experience in constructing geometric shape models in surface area of a prism (Aziiza, & Juandi, 2021). Alternative ways of teaching mathematics are needed better to understand the surface area of prisms and pyramids (Zourmpakis et al., 2023a; Parissi et al., 2023). This study would be helpful for teachers and educators, as it would help them develop PBL skills and solve learners' misconceptions. As a teacher and an educator, I must address these challenges teachers and students face in teaching-learning. Almost all mathematics teachers use traditional teacher-centred pedagogy in their classes in Nepal. The study also supports this fact; ineffective pedagogy of mathematics teachers is also the cause of low learning achievement in mathematics (Pokhrel, 2023). Furthermore, the teacher's pedagogical factor significantly influences students' misconceptions and learning achievement (Tiwari, 2023). Teaching and learning activities are bounded and conducted within four walls of the classroom, which becomes a barrier to experiential and holistic learning (Susilawati & Supriyatno, 2023). Learners at the secondary level need to be more motivated, show less motivation, and be frustrated with mathematics (Tyata, 2018). On the other hand, Hasanah and Yalianti (2020) reported that students needed help understanding the representation of the prism and pyramid, making errors in using a formula and in calculations, and had several misconceptions. Furthermore, the research shows that difficulty in reading the information, the concept of the prism and pyramid, carelessness during calculation, hesitation in questions answering, and lack of effort of the students are the leading causes of the problems (Hasanah & Yalianti, 2020). This indicates that in traditional pedagogy, there might be a misconception of the understanding of the surface area of a prism and pyramid, which might cause students to be unable to solve the problems regarding the surface area of a prism and pyramid.

One form of enabling pedagogy is project-based learning (PBL), in which learners engage in various projects for experiential learning and develop critical thinking, collaboration, and communication skills (Zourmpakis et al., 2023b). The PBL is an instructional approach that can create learning activities and tasks through which learners can challenge themselves to solve their daily problems (Goodman, 2010). Furthermore, the PBL is a student-centred approach to learning in which students simultaneously learn soft and hard skills through an inquiry approach (Bell, 2010). The teacher's role is transferred into facilitator from a transmitter in PBL (Papadakis et al., 2021); students are exposed to natural and meaningful problematic situations or tasks which allow them to practice basic scientific skills (Krajcik & Blumenfeld, 2006). According to Krajcik and Blumenfeld (2006), PBL is an overall approach to learning which can design a learning environment and has five key features: driving questions, situated inquiry, collaboration, use of technology tools to support learning and creation of artefacts are critical features of PBL.

Based on the above scenario, to resolve conceptual understanding with hands-on mathematics activities, collaborate with other teachers, and improve teachers' pedagogical practice, we selected project-based learning (PBL) and action research in secondary mathematics, especially in grade ten. During the action research, we collaborated with our co-researcher to integrate project-based learning in the mathematics teaching-learning process for the secondary level.

Teachers, educators, and researchers should reformreform their pedagogy to support mathematical understanding (Papadakis & Kalogiannakis, 2019). The main challenge for researchers and educators is to reform teachers' pedagogy. The study aims to develop teachers' skills for implementing Project-based learning (PBL) in mathematics for the surface area of a prism and pyramid. Based on the above context, we set research questions: How do teachers implement PBL to reform their pedagogical practices in teaching the surface area of prism and pyramid?

1.1 The rationale of the study

As I mentioned in the previous section, PBL is essential in the teaching-learning process, and it might help transform the pedagogy of mathematics teachers. Furthermore, there is a massive gap between the education policy, expectation of curriculum, and practice of teaching mathematics, which makes it challenging to manage students-centred pedagogies in practice. Although there is an explicit provision for incorporating PBL in teaching-learning activities, as indicated by the policy and curriculum of mathematics at all levels, most teachers need to start using PBL in their practice. The action research findings might help develop or enhance pedagogical skills about PBL in mathematics and solve the misconception of the surface area of the prism and pyramid of grade ten mathematics.

In summary, this action research study intended to explore the ideas by which teachers can develop and enhance their skills in implementing PBL in secondary mathematics teaching, which can create a better learning environment in the classroom. So, the study will contribute to the student's and novice teachers' fulfilment of the expectation of curriculum and policy for a better learning environment in the classroom.

1.2 Delimitation of the study

This study intended to motivate and support secondary-level mathematics teachers to apply PBL in their workplace in a chapter on the mensuration of grade ten mathematics in Nepal. A topic can only represent part of the course of grade ten mathematics, and projects for the chapter might not be used in other chapters of mathematics. So, the study is limited to the pedagogical knowledge of the participant-teachers, which does not focus on the whole mathematics course, and choosing a single chapter, "Mensuration", of grade ten mathematics as content knowledge. The study's findings are delimited based on the data collection of selected teachers from selected schools in the Kailali district of Nepal.

1.3 Social constructivism as a theoretical support

For the study, the leading theory was Vygotsky's social constructivist theory (1978), which focuses on social interaction in the knowledge construction process based on the learners' prior knowledge. According to the social constructivist theory, the learner initially performs the learning task based on the prior knowledge, then performs with the help of the other, and finally performs self without help from the other (Vygotsky, 1978). Along with the purpose of the study, social constructivism believes that knowledge cannot be deposited in the mind of learners separately as the banking concept of Freire (2005); it can be constructed through the active participation of the learner in social interaction with different social groups, and participation in various activities (Taylor, 2018). In this study, the teacher designed various projects with some learning objectives, created a learning group of the students, allowed them to do some specific task, discussed in a group for meaning-making, facilitated them and evaluated the project at every stage. In this way, the social constructivist theory supports and guides my action research.

1.4 Supporting literature

An empirical review has been done to identify related studies on PBL and its effect leading to it and to identify the knowledge gap. Holmes and Hwang (2016) found that the students at risk and the minority benefited greatly, and the academic performance gap and width diminished significantly, which was the main finding of the investigation. Furthermore, it was found that PBL students had developed higher critical thinking and peer learning skills and were intrinsically motivated. Bastola (2021) argued that there should be a balance between the curriculum, the teacher qualification, students' enthusiasm, and the prior assessment procedure of the education system for better learning through PBL. Likewise, Herawaty et al. (2018) conducted preliminary research by interviewing six students from a Junior high school in Indonesia. The study aimed to describe students' metacognition in problem-solving in Rejana Lebong ethnomathematics. The study's primary finding was that students could combine information about traditional houses with properties similar to those of prisms, pyramids, and cubes.

Chiphambo and Mtsi (2021) conducted a qualitative case study to find students' errors during the calculation of the surface area of the prism by taking 18 students from grade eight in South Africa. The study's primary finding was the failure of students to connect between 2D and 3D figures, using a formula, and misunderstanding the mathematical terminology. The study suggested that teachers find those errors and use activity-based tools to remedy them. Toyota et al. l. (2021) conducted action research on project-based learning in grade nine in an institutional school in Nepal. The study on PBL helped engage the learners through questioning, pair/group discussion, discovery learning, and concept mapping. Likewise, Irdani and Santia (2023) conducted action research on project-based learning to improve the competencies of student learning outcomes of grade one at SD Negeri. The significant finding of the study project-based learning model can be used to improve the completeness of students' numeracy learning outcomes.

Rati and Rediani (2021) conducted descriptive qualitative research to identify the obstacles teachers and parents face in implementing a project-based learning model in the network during the COVID-19 pandemic. The main constraints found were making learning plans, availability of learning tools, and participation in the learning process. Setemen et al. l. (2023) conducted a quasi-experimental design study on PBL to analyze its effectiveness and explore, implement, and analyze the model on conceptual understanding and agility. It was found that PBL was beneficial in improving students' understanding of concepts and agility as learners. Gao and Zhang (2023) conducted a study on project-based learning in primary-level mathematics in China. The study was designed as project initiation, exploration, and optimization, so students were encouraged to think like mathematical experts. Also, students integrated various resources and personal experiences during problem identification, formulation, analysis, and resolution. The study focused on integrating real-world practical examples into the curriculum, which can bridge the gap between abstract mathematical concepts and real-life connections.

However, the research shows the error and its cause. However, the study should have informed how teachers used PBL in secondary mathematics, especially in problems related to the surface area of prisms and pyramids. So, there is a need for further use of PBL to solve these problems during teaching-learning activities of prisms and pyramids.

1.5 Research gap

Though there is some research and literature on PBL in mathematics and students' misconceptions, I still need to find literature regarding the solution to misconceptions about the surface area of prisms and pyramids. My study is unique because such a study has yet to be conducted in my context and secondary-level mathematics, especially in the mensuration chapter of grade ten mathematics. On the other hand, the study was conducted collaboratively with six teachers from different schools as project-based learning for action research on secondary mathematics. So, I observe the knowledge, theoretical, and methodological gaps. Likewise, the study will contribute to pedagogical reformation and enhance the skills of teachers in my context.

2 Methodology

2.1 Paradigm and philosophical orientation

In this study, I have selected an interpretive paradigm concerned with understanding and investigating the meaning of social events (Luitel, 2009). This paradigm will help understand the PBL phenomena deep inside by standing in participants' shoes, looking through their eyes, and feeling their pleasure or pain by creating rapport between participants during the study (Tayler & Medina, 2011). I will interpret the participant's voice for meaning-making in their context and situation. As an interpretive researcher, my study was guided by a set of beliefs that can create a clear roadmap for conducting research, called a paradigm (Guba, 1990). In this study, Ontology is a multiple reality, epistemology is subjective, and the value of participants and the researcher will influence the study to be value laden. In this studt all international standards regarding which was followed (Petousi, & Sifaki, 2020).

2.2 Action research as a research method

Nowadays, practitioners conduct action research in a natural setting to improve their practice and find solutions to real-life problems in an organizational, personal, or professional field (Papadakis & Kalogiannakis, 2019b; Tyata, 2016). Among various models and a cycle of action research, we used the spiral process mentioned by Kemmis et al. (1988), which includes three stages: 'Plan', 'Act and Observe', and finally 'Reflect'. (see in Figure 1)

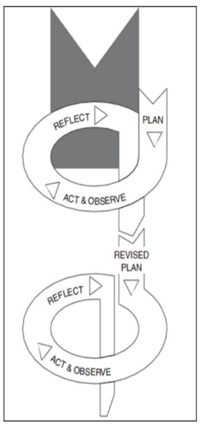

Figure 1 The Action Research Spiral (Kemmis & McTaggart, 1988, p.29)

In the planning phase, I conducted a 3-day face-to-face workshop for some participants and a 3-day online discussion for those who did not participate in a face-to-face workshop in which we worked together in a workshop to prepare the framework of the project work. We prepared for the following question during the preparation of a plan. Likewise, in the act and observe phase of the action research, our main aim was to implement the plan and observe the action. Furthermore, they took photos and videos of memorable moments and wrote daily reflection journals.

In the reflection stage, each teacher shared their experience, reflection on the whole project in their context, challenges faced during the project, and solutions to the problems. In this stage, I collected data through interviews with participant teachers and teachers and my self-observation during a project, reflective journals of participant teachers, photos, and videos.

2.3 Description of the school setting

Four secondary-level schools in the Kailali district and the neighbouring Kailali, Nepal, were selected as the research sites for this action research. I selected two communities and two institutional schools for the study. Two of these four schools were in rural areas, and the remaining two were in urban areas. For the study, we (participant teachers) selected ten students aged 14 to 18 from the school for purposive project implementation.

2.4 Design of the intervention

For the intervention, I planned and conducted a 3-day workshop for teachers. Participants constructed a seven-day mathematical project plan for the first action research cycle on the surface area of prism and pyramids based on the curriculum of grade ten mathematics. In the project, the teacher or school managed low-cost materials. It facilitated students to construct various solid materials and use them in the group to construct knowledge of the surface area of prisms and pyramids. Finally, students presented their tasks to the whole mathematics class. During the process, teachers had to facilitate the task, observe students' activities, guide them, and use techniques to improve the classroom activities.

2.5 Sampling framework and sampling

For the participant selection, I informed ten neighbouring secondary schools' mathematics teachers to invite them to the meeting on 17th July 2022 through means of communication such as telephone, messenger group, WhatsApp, and telegram. After that, I conducted a 3-day face-to-face workshop and selected four schools based on the interest of teachers who participated in the teachers' workshop.

Out of the selected schools, I selected 5 participants from four schools purposively depending on the suitability of time, context, interest, and dedication of the teacher's working experience teaching mathematics. There were selected five male teachers (there were no female secondary-level mathematics teachers in the study area) of age 25 to 40 years who had an experience of at least five years of experience in teaching mathematics at the secondary level. All selected teachers had qualification masters in mathematics from Tribhuvan University, Nepal.

2.6 Working with teachers

For the study, I conducted an introductory meeting among possible participants to discuss all the projects. After the brief discussion, I conducted a 3-day workshop (conducted face-to-face and virtual mode in six days at a suitable time) on introducing the MATPD project, mentoring, reflective writing, and project-based learning. We constructed an action plan for the research study and selected five participants from four schools based on the problems, interests, activeness, time managing capacity, and other factors of teachers. Two teachers were from my school, and the remaining three were from a neighbouring school. During the workshop, I took the experience and practice of teachers regarding pedagogy and PBL in mathematics.

The first cycle of AR implemented a 7-day plan from the first week of September to the second week of October, and the second cycle from the 1st to the second week of December of 2022 at a suitable time for teachers in their schools. During the first cycle, teachers conducted a workshop for students/assigned students to construct Prism and Pyramid using low-cost materials. Likewise, students used Solid materials to find the concept of surfaces, the area of parts of prism, and pyramids in their groups. During the second cycle of the AR, teachers were trying to engage all students to improve their learning. During the implementation process, classes were observed and interacted with teachers to collect data and improve practice during the implementation phase of AR.

During the implementation, we (participant teachers and I) were connected virtually through mobile calls, messenger, telegram, and other means of communication to share our experiences and challenges with PBL and obtain appropriate solutions or techniques. We also shared our challenges and experiences with other participants, field mentors, and academic mentors. (see in Figure 2)

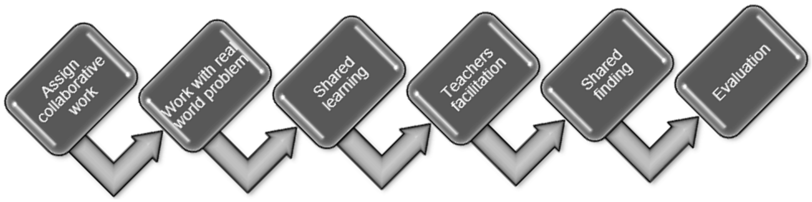

Figure 2 Process for Implementation of PBL in mathematics class

Figure 2 shows the process of PBL, which participant teachers follow during the implementation of action research in mathematics classes. Before the beginning of the project work, teachers prepared the action plan for the project to find the surface area of the prism and pyramids in the workshop collaboratively. In implementing PBL, teachers initially orient their students regarding project work; students construct solid objects (models of prism and pyramid) and are assigned group tasks. During the group task, students were allowed to discuss surfaces and types of surfaces in solid objects, the relation between 2D and 3D figures, the difference and relation between prism and pyramid, the formula and calculation of the area of surfaces, and the total surface area of solid objects. Finally, students shared their understanding of the group work with the whole class. During the process of PBL, teachers facilitated, supported their students, and evaluated students' performance in every stage of learning through action research.

After completing the action research on the selected school, I prepared a report. I shared the report, learning, and experiences with the co-researchers and other teachers. Likewise, I conducted a one-day workshop on creating an STEAM project for schools for primary and secondary teachers in a reputed institutional school, Dhangadhi. Kailali, Nepal. There were 25 school teachers as participants, and the Karkhana project and Kathmandu University supported the program. In that workshop, I shared the 5E model of a project and my experience on the project.

2.7 Data collection and findings

For the data collection, I used Semi-structured interviews, class observation, and teacher reflection journals. I also used thematic Analysis techniques in action research to find, interpret, and make meaning from the data (Saldaña, 2016).

After finalizing a plan for the project, we discussed the classroom support process from the mentor and the reflective journal writing process for TPD. Furthermore, we fixed the timeline for implementing the first and second cycles, each of seven days of AR, the data collection process, and ways of connection among the group. Due to the various constraints, implementing the AR took over a month. While implementing the AR cycle, I observed four classes of four teachers in the first cycle and three classes in the second cycle of different teachers using semi-structured observation guidelines. Likewise, teachers wrote reflection notes for each class. I collected reflection notes from all participant teachers, as well as photos and videos. After the implementation of the second cycle of action research, an in-depth interview was conducted with all five participant teachers. And after collecting data from interviews, observation, and reflection notes from all participant teachers, I analyzed qualitative data using thematic analysis for qualitative research. In this process, I transcribed interview data and observational data, conducted coding by using the Nvivo coding method and categorized and found themes from the data (Saldaña, 2016). During the data analysis, I found engaged learning, the base of inclusive education, contextualization of mathematics, the creativity of students, and reformation of teachers' pedagogy to be significant themes.

2.8 Engaged learning

Before the study, it was expressed by all participant teachers, and from my experience, students' mathematics activities were minimal or almost passive. In the study, we (Here, we refer to the participant teachers and myself.) observed the students' involvement in learning activities and interaction with teachers and students as engagement. Students' engagement is active involvement based on attention, curiosity, interest, participation, and passion during learning activities (Poondej & Lerdpornkulrat, 2016). During the implementation of PBL in every school, I observed that most students actively participated in their group work and interacted with and supported each other in a joyful environment. All participant teachers observed the same facts during the implementation of PBL in their mathematics classes. Supporting the fact, Mr. Bajgain said, "*I found that students were more engaged in learning activities than the usual mathematics classes*". Likewise, Mr. Bista said, "*I found that students were engaged in constructing an object, working in groups, interacting for the best solution, and they were motivated, experienced a new and joyful learning environment in project-based learning*". Supporting the fact, Mr. Chalaune said,

"I never found such types of engagement of students in my teaching career. Initially, it was challenging for all students to participate in groups. However, after dividing responsibilities into groups, all students were equally engaged in several activities such as managing materials, measuring sides, finding an appropriate formula, calculation, discussion, presentation, and incorporating feedback from other groups of students and teachers.... I found a new and interesting environment and felt student-centred activities in my mathematics class". (see in Figure 3)

Figure 3 Students engaging in learning activities during PBL

From the above statements, it is clear that most participant teachers' views were aligned with learners' engagement during PBL. Several studies supported students' engagement through PBL (Holmes & Hwang, 2016). Based on the above arguments, I concluded that teachers developed their ability to enhance students' engagement through PBL in mathematics classes.

2.9 The base of inclusive education

In the study, inclusive education refers to how teachers incorporated and supported PBL in all students in the mathematics classroom (Finkelstein et al., 2019). During the implementation process, teachers implemented flexibility in time, focused on learning activities and abilities of students that include a diverse range of learners and brought about improved social development, academic outcomes, and development of social skills and interaction for all learners. In the general context of Nepal, the inclusive education system was not applicable due to the single conventional pedagogical practice of teachers and various constraints. In PBL, most teachers tried to incorporate all students from various diverse societies and abilities in every learning activity of the project. Although there were various diversities in culture, language, economic classes, and physical disabilities in grade ten of our selected schools, participant teachers were trying to include all students in every role in group work. Most teachers shared their experience in dividing duties and responsibilities for each student in group tasks during the project implementation. Based on the interaction and interview with participant teachers, most teachers tried incorporating all students into various learning activities in the project work.

Supporting the fact of inclusive education, Mr Khanal said, "*I distributed all possible roles such as a collection of materials, measurement, calculation, presentation, and answering the questions from others for each student during the group work so that each student gets equal opportunities of learning*". Likewise, Mr Bista said, "*I supported mostly those students who need special help in the classroom*", and Mr Bajagain said, "*Students were changing their roles each day in group work, and I support by talking with the students in their mother languages*". Likewise, Mr Chalaune said, "*I observed during the implementation of both phase of action research that there was collaboration and teamwork spirit among the students to complete the task given in the group*". (see in Figure 4)

The statements above from the participant teachers indicated that they were trying to work within groups, support each other, and learn from each other, which indicates the inclusive

Figure 4 Students were engaging in their group work

environment during PBL. This fact was supported by Finkelstein et al. (2019), who said that instructional support, collaboration and teamwork are tools for inclusive education. The finding shows the opportunities for all children in various PBL activities, so the study provides the base for inclusive education (Schuelka, 2018). These facts indicate that with the help of PBL, teachers promoted an inclusive school environment.

3 Contextualization of mathematics

Before the PBL, most teachers used conventional ways of teaching, in which they practised rote memorization of mathematical contents without relating and using their knowledge to students' situations. During the PBL, I observed teachers trying to connect mathematical knowledge with students' life experiences, situations, and activities. Other participant teachers also observed these facts. Supporting the contextualization of mathematics, Mr. Chalaune said, "*I found that most students were able to recognize and calculate the surface area of prism and pyramids around the class*". Likewise, Mr. Bajgain said, "*Students were able to find the surface area of given prism and pyramids, write, interpret, and present the finding in their language. This indicates the contextualization of knowledge*". Other participant teachers indicate similar facts about contextualization. (see in Figure 5)

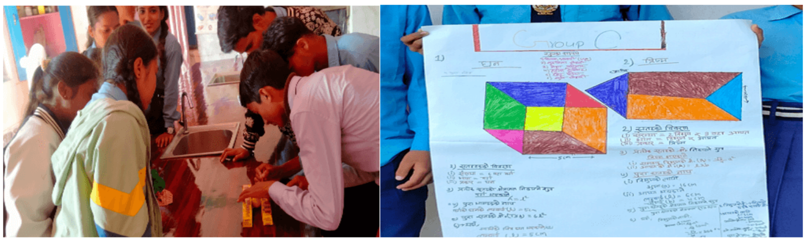

Figure 5 Students using local resources and language in activities

During the PBL, teachers and students used materials and instruction methods to link mathematical knowledge with experience and environment (Reyes et al., 2019). Likewise, the contextualization of mathematics fosters students to know, understand, and appreciate the cultural heritage of learners (Bringas, 2014). This indicates that teachers and students were contextualizing mathematical knowledge.

4 Creativity of students

In our experience (here, our experience refers to the experience of participant teachers and myself.), the general or conventional ways of teaching mathematics must provide an appropriate environment to develop students' creativity in mathematics classes. There was a monotonous environment in which students could solve similar textbook problems in the mathematics classroom; there needed to be more creativity in writing, finding a solution, and presenting a solution in the classroom. Creativity is using imagination and students' original ideas in activities and learning presentations. Students' creativity was observed during the classic 3P approach (person, process, and product) (Cropley, 2011). During the study, we observed how students showed their creativity during group work, presentations, and interactions. Likewise, we observed the work process in groups and the types of prepared models and charts. During the study, we observed the students' activities, the learning process, and the findings of the activities during the presentation as the students' creativity.

During the PBL, I observed students' creative ideas in writing, presenting, and calculating surface areas of solid materials. Every group had different and unique styles of writing and presentation of learning. All participant teachers observed and expressed the facts during an interaction and interview. During the interview, Mr. Chalaune said, "*In PBL, students showed their creativity in presenting their findings, working within a group, and distributing responsibilities*". Similar statements were from other teachers. Mr. Bajgain said, *"I never expected and seen such types of creativity from students"*. Mr. Bista made a similar supporting statement. He said, "*During the classes, I realized that students get opportunities to show creativity in constructing solid materials, drawing, calculating, and presenting the task in the classroom*". These statements of the participant teachers indicate some aspect of the creativity of all students in PBL learning activities. (see in Figure 6)

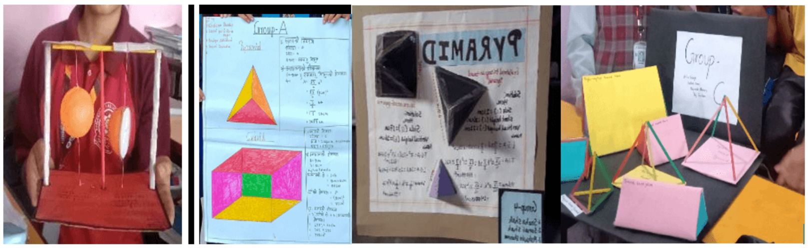

Figure 6 Creativity of students

During the study, students presented their opinions, searched for new ideas, and showed the uniqueness of their performance in several ways, which might indicate creativity. The above statement aligned with Cropley's (2011) finding that learning in novel ways is learners' creativity. Creativity is not unique, and correct solutions to any problem should offer multiple solutions that emphasize the process rather than the result (Suastika, 2017). The multiple ways of presenting their learning during the study indicate that PBL provides the space for creativity for all students.

5 Professional development of teachers

The term professional development of teachers refers not only to learning content but also to developing various skills for teaching, such as communication, collaboration, problem-solving, and critical ways of thinking and doing (Chu et al., 2016). For the professional development of teachers, I conducted a three-day workshop in which we discussed the experience of mathematics teachers, challenges of mathematics teachers, PBL, mentoring process, and reflection. During the workshop and implementation of PBL, I observed that experience sharing, mentoring process, and reflective writing were new steps in professional development for mathematics teachers. In the study, we used the mentoring process to work together, share experiences, and support teachers. Likewise, reflection is remembering past events and analyzing our past events for better future practice.

Most participant teachers expressed the fact of professional development from the PBL during an interview. Mr. Bista said, "*I got an opportunity to learn about project-based learning, mentoring process, and reflection... experience sharing about pedagogical practice, and ways of facing challenges was constructive for me*". Likewise, Mr. Bajgain said, "*PBL is helpful not only for students but also for the professional development of teachers. Teachers also learn new pedagogical skills, management skills, and planning skills from the PBL*". Likewise, Mr. Khanal said,

"*It was beneficial for me. Before the project, I was unfamiliar with PBL, but I have learned new pedagogical skills such as PBL, management skills, and incorporating all students into learning activities. It gave me a new experience that I had never experienced before in my teaching career. ... PBL helped me improve my teaching style, understand the nature of students, and ways of dealing in the group learned student-centred activities, and the 5E model of PBL.*"

Likewise, Mr Chalaune said, "*It was a new experience in my pedagogical practice.... On the other hand, I realized that every teacher could create project work in which students work in a group and construct knowledge by collaboration and interaction*". Likewise, Mr Dhamala said, "*I got more support from other teachers and my mentor during implementation, learned how to deal with a larger group, how to face challenges in mathematics classes, and how to reform my pedagogy from teacher-centred to the student-centred*". These statements indicated that teachers benefited from the PBL during the implementation of action research. (see in Figure 7)

Figure 7 Teachers learning from each other

Collaboration, learning, and dealing with groups of teachers and students were professional skills for teachers during the PBL. The involvement of teachers in teaching-learning activities, collaboration, and dealing with other groups of learners is one of the aspects of the professional development of teachers (Chu et al., 2016). During the study, it was found that co-researchers tried to reciprocate their ideas and experiences among them. The study also tried to connect teachers with their communities of practice, which improved their teaching and student learning (Levine, 2010). This indicates that the study provides learning space for teachers, which yields support for their professional development.

6 Challenges faced during the study

Besides the various advantages of PBL, we found some challenges during the study. Initially, most teachers were reluctant to change their conventional pedagogy, showing various circumstances, but a few teachers were interested in the PBL. I started with ten mathematics teachers, but at the end of the study, only five teachers completed the second action research cycle. Most teachers who did not complete the action research said they needed more time for the project, were overloaded in the workplace, needed more support from the school management and head teacher, and had some personal circumstances. Some teachers need more resources in their schools for project work.

Likewise, during the project, some co-researchers expressed some challenges during the action research. Most teachers (here, teachers refer to the co-researchers of the action research who completed both cycles) and said they faced challenges of equal participation of all students in a large group during group work. A few students regularly led the group in activities, but most were passive in group activities. After sharing such a challenge among the co-researchers, it was found that the participation of students can be increased by making small groups and dividing responsibilities among each student in the group.

Besides these challenges, time consumption was another challenge of project-based learning found during the study. Project-based learning is a flexible, student-centred pedagogical technique that takes more time during planning and implementation. Before the beginning of the project, every teacher should be aware of the time and planning of the study. At the end of the study, all co-researchers agreed that challenges are not problems but alternative and more exciting solutions to the problems.

7 Conclusion and implication of the study

The study was about supporting mathematics teachers in implementing PBL in their classes and developing skills for implementing action research. From the workshop, the interactions of teachers with other participant teachers, and implementation in their mathematics classes, teachers learned skills regarding the implementation of PBL and action research. It was found that PBL promotes engaged learning and provides the base for inclusive education, space for contextualization of mathematical knowledge, and space for creativity for students. Likewise, it provided space for the professional development of teachers by reforming their pedagogical skills through interaction with others and implementing PBL. The study provides the overall process of PBL for secondary-level mathematics and some aspects of the professional development of teachers.

The study supports participant teachers and provides a learning space for me as a mentor. During the study, I observed PBL classes, interacted with teachers, shared experiences, and discussed with other teachers for a better solution and implementation. This new experience supported me in developing mentoring skills during the project and helped me improve my practice. Besides the successful implementation of PBL by most teachers in their secondary mathematics classes and adequate support from most school administrations, I faced some challenges, such as the reluctant nature of some non-progressive teachers, time management for PBL, and lack of resources management in some schools. These challenges provide opportunities to think about an alternative solution for the challenges. There is a need for motivation and incentives for all teachers to reform their conventional pedagogy. And this study might provide learning space for novice teachers to reform their pedagogical practice through PBL and show the potential for improving the school learning environment.

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Conflicts of interest

The author declares that there is no conflict of interest.

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