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Developing 21st Century Skills while teaching Mathematics at School

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Abstract: *This paper aims to explain the ways of supporting to develop 21st century skills through classroom pedagogy by school teachers while teaching mathematics. I used case study research approach and selected seven case respondents (teachers) by using non-probability sampling techniques. I used observation note and interview guidelines to collect the information and analyzed them by using general inductive approach. The findings show that the teachers at institutional schools are using their classroom pedagogies to enhance 21st century skills such as critical thinking, creativity, communication, and collaboration while teaching and learning mathematics to some extent. However, there is rare uses of ICT tool to support their classroom pedagogy. Thus, it is suggested that the educators, policy makers and other stakeholders like local government need to reframe their school mathematics curriculum from the perspective to support to enhance 21st century skills among the students.*

Keywords: *Critical thinking, creativity, communication, collaboration*

Introduction

The rapid development and growth of digital technology has opened new door of each and every sector of the 21st century society in the world including in the sector of education. The development of such information and communication technology (ICT) in this digital era of 21st century demands new skills development for both teachers and students. These new skills sets are the 21st century skills. Central Board of Secondary Education (2020) has defined that 21st century skills are the skills that are required by an individual for his/her holistic development in this 21st century world (p.12). Also, preparing individual by cultivating 21st century skills together with his/her core subject specific knowledge, for example, the mathematics education, is essential for success in this era. These skills set includes critical thinking, problem-solving, creativity, communication, collaboration, information literacy, media literacy, technology literacy,

flexibility, leadership, productivity, initiative, and social skills (Trilling & Fadel, 2009; Central Board of Secondary Education, 2020).

On the other hand, mathematics is one of the important subjects from school to university level. It is also blamed that mathematics includes very dry and abstract concepts and thus becoming difficult for almost all learner of the world. So, the mathematics education, often criticized for being abstract and disconnected from real-life application, is uniquely positioned to promote the 21st century skills among students. In this context, this paper intends to explore the ways of developing 21st century learning skills by school teachers through the pedagogical intervention while teaching mathematics.

Objectives

The objective of this paper was to explore of how the mathematics teachers support to develop 21st century skills among their students at school.

Literature Review

There are lots of literature which describe the 21st century skills and 21st century learning framework. Central Board of Secondary Education (2020) states the meaning of 21st century skills as a broad set of knowledge, skills, work habits, and character traits that are believed by educators, employers and others required to success in the 21st century world (p.14). These skills are now considered essentials to success in this very competitive world market of 21st century.

There is no uniformity in the definition and framework of 21st century skills. However, most of the frameworks of 21st century skills have some common skills that are essential for the work force of the 21st century work place including mathematics teachers of the schools. Salas-Pilco (2013) explained the initial framework of 21st century skills is UNESCO's Delors (1996) which emphasizes on learning to know, learning to do, learning to live together and learning to be. Likewise, other framework of 21st century skills are OECD (1997 - 2003) which divides key competencies of learning into three categories: using tools interactively, interaction in heterogeneous group and acting autonomously (OECD, 2010, pp. 5-12). Salas-Pilco (2013) also stated more frameworks that describes twenty first century skills are European community (2006), P21 or Partnership for 21st century skills (2009), and ATCS (2010). This final framework categorized 21st century skills into four categories. They are ways of working (creativity and innovation, critical thinking, problem solving, decision making, learning to learn, metacognition), ways of working (communication and collaboration), tools for working (information literacy, ICT literacy), and living in the world (citizenship, life and career, personal and social responsibility). P21 (2009) explained 21st century skills into four broad categories which are learning and innovation skills; information, media, and technology skills; life and career skills; and core subjects and 21st century themes. However, most of the frameworks stated that the 21st century skills are: critical thinking, creativity, communication, collaboration, information literacy, media literacy, technology

literacy, flexibility, leadership, initiative, productivity, and social skills. Among these skills 4cs (critical thinking, creativity, communication, collaboration) are categorized into learning skills.

Methodology

I adopted qualitative case study research design (Gillham, 2000) to conduct this research which is descriptive in nature. I selected seven mathematics teachers of institutional schools of Kathmandu district by using non-probability sampling techniques. The teachers chosen here were the mathematics teachers to whom I regularly observed their classes once a month during a last year and provided them mathematics training. I used observation and interview guidelines to collect the information of this research. The classroom observation guidelines were used to observe the teachers' strategies that were applied to develop 21st century skills for their students while teaching mathematics. The in-depth interviews were taken by using guidelines prepared to explore teachers experiences and understanding of 21st century skills while teaching mathematics at school. I analyzed the data and interpreted its results by applying the methods explained by general inductive approach (Thomas, 2006).

Results and Discussion

The results were presented and discussed under separate heading as below. The headings are coined for the elaboration of 4c's (Critical thinking, creativity, communication, and collaboration) among several 21st century skills.

Critical Thinking

Critical thinking is one of the crucial 21st century thinking and learning skills required for the acquisition of new knowledge, in particular in mathematics. Bassham et al. (2011) explains in more general form that critical thinking involves several cognitive skills and intellectual dispositions essential to effectively identify, analyze and evaluate arguments and truth claims; to discover and overcome personal preconceptions and biases; to formulate and present convincing reasons in support of conclusion; and to make reasonable, intelligent decisions about what to be believe and what to do (p.1). It means that seeing something differently in support of logic is the critical thinking. Trilling & Fade (2009) explains that critical thinking is the ability to analyse, interpret, evaluate, summarize, and synthesize information to solve problems using various types of reasoning. It is the capability of objective analysis of information (Central Board of Secondary Education, 2020).

Critical thinking is governed by clear intellectual standards like clarity, precision, accuracy, relevance, consistency, logical correctness, completeness and fairness (Bassham et al., 2011, p.2).

For such understanding of critical thinking, I asked the selected teachers about the concepts of critical thinking, they had different level of understandings on it. The sample explanations are:

"*I do not understand the details of the critical thinking skills, but it is a logical thinking and arguing skills which helps our students to solve mathematics problems with the justification of each step with valid reasons*".

"*It is just judging the work effectively and viewing something differently*".

"*It is a capacity of objective analysis of the mathematical arguments and it focuses to raise question to every stage of problem-solving strategies*".

"*Students having critical thinking can solve mathematical problems very quickly*"

These responses show that the secondary school mathematics teachers have the concepts of critical thinking to some extent. However, they are not well familiar with the activities required to develop critical thinking skills among the students while learning mathematics at school.

The following was the classroom observation experiences of one mathematics teacher in the institutional school.

> "*One day the mathematics teacher entered the class nine and told good morning to all students. Students replied good morning to the students and sit on their seat by welcoming their teacher. The teacher opened the mathematics book and asked students to find highest common factors* (*HCF*) *of the algebraic expressions*: $x^4 - 16$, $x^2 - 8x + 16$, and $x^3 - 64$. *The teacher solved it by using factorization techniques to find the highest common factors among the factors of these expressions which was* $x - 4$. *The teacher also asked some question to the whole group to make participation and interactions. But students checked the answer from the answer sheet of the book and teacher gave similar types of problem to the students in the class. At that time teacher moved to whole class to check students work for this class task and asked them for correct answer. The*

same process repeated during the class and finished the teacher's presentation for that day".

These experiences of classroom presentation of mathematics teacher indicate that the traditional teacher dominant teaching and learning strategies are practicing to teach mathematics at school even today. Students just listen to teacher and copied to teachers' solutions from the white board. This teaching strategy was not supportive for the development of critical thinking. It was also found that almost all the selected mathematics teachers at that level had been focusing traditional ways of teaching mathematics which are not supportive for the development of 21st century skills and encourage to develop rote memorization. However, asking question before completing the teacher presentation, regular practices of formative assessment, provision of giving project work and provision of teacher training at the end of each month are some strategies supports to design critical thinking skills in the classroom.

Asking questions to the students while teaching mathematics is important activity of teachers to enhance critical thinking (Zabit, 2010). By asking questions, the teacher can check the readiness of the students to learn new concepts. That is, the teachers can evaluate students' prerequisites in learning mathematics. For example, while defining highest common factors and lowest common multiple, the students need to have sufficient ideas of factoring algebraic expression. But there was practice of asking of group questions rather than in-depth questioning within the implementation of improved traditional teaching and learning approach in mathematics classrooms.

However, it was found that while solving and proving the geometric theorems which were not in text books, students have been applied critical thinking strategies as explained by mathematics teachers. For, one selected teacher replied as:

"*We give some geometrical theorems from the practice books and question banks to the students. Students try to solve it by linking the learned concepts of geometry with these new concepts and give logical reasons of proving. Students will ask us (teachers) if they are unable to solve it*".

These responses of teachers indicate that in solving the open-ended questions of geometry, the teachers of mathematics at school have focused some of the intellectual standards of critical thinking as explained by Bassham et al. (2011).

After observing the classes of mathematics teachers of school, I explained some teaching and learning strategies to enhance critical thinking of students. These strategies were related to develop thinking skills by following general rules of teaching such as: ask questions to students to check prerequisites (for example concept of factorization in above classroom episode), help students to generate their own ideas, give task to solve in groups, ask students to present their ideas, help students to generate their own logic while solving mathematical problem, provide multiple answer open questions for their students, use think-pair-share strategies while solving problem, use technology and concrete materials as much as possible, praise students works and guide students for the correctness of the mathematical logic.

Supporting to above arguments, the selected teachers reported that:

"*We learnt the above strategies for developing critical thinking while teaching mathematics, but we cannot apply it in the classroom effectively. We learned ideas to make student centered pedagogy, team work strategies and critical thinking strategies from the training*".

These statements depict that mathematics teachers of selected institutional schools are learning critical thinking strategies. However, they explained that:

"*If we use more child centered strategies, then it is very difficult to finish the course in stipulated time. So, we emphasis more practice to solve the mathematics problem rather than discussion. But there is provision of project work for which students try critical thinking strategies to solve the assigned problem of mathematics*".

These opinions display that mathematics teachers in institutional schools have knowledge of critical learning strategies, but they are not practicing in day-to-day class of mathematics teaching effectively because of time constraints to complete the course. So, it is suggested that the curriculum of mathematics should design from the perspective to develop critical thinking strategies in school mathematics.

Creativity

Creativity can be nurtured by learning environments that foster questioning, patience, openness to fresh ideas, high level of trust, and learning from mistakes and failures (Trilling & Fadel, 2009, p.58). Creativity is the skill to explore and create fresh ways of thinking that refers to new way of seeing or doing things (Central Board of Secondary

Education, 2020). Assisting students to use wide range of idea creation techniques like brainstorming; to create novel ideas; and to evaluate own ideas are essential for creative thinking (Piirto, 2011, p.1; Trilling & Fadel, 2009, p.58). Creativity includes four components: fluency (generating new ideas), flexibility (shifting perspective easily), originality (conceiving of something new), and elaboration (building on other's ideas) (Central Board of Secondary Education, 2020).

Within these understanding of concepts of creativity, how the selected teachers enhance creativity among their students while teaching and learning mathematics. One of the examples of classroom observation stated as:

> "*It was a class of teaching equations and identities at class eight of institutional school; the teacher had been expected different examples of equations and identities from students. The students provided several examples of equations such as* $x - 2 = 0$, $x^2 - 5x + 6 = 0$, $2x^2 - 4 = 5$ *etc. and the identities such as* $(a + b)^2 = a^2 + 2ab + b^2$, $a^2 - b^2 = (a - b)(a + b)$ *etc. But they were unable to define the differences between them. The teacher again asked them to construct different example of identity which is not an equation, students gave* $a^2 - b^2 = (a - b)(a + b)$. T*hen teacher moved the classroom discussion with the definition and example of equation which is not identities. Students did mistake several times, but finally teacher helped them to reach the correct definition and examples, so students learned these concepts that every identity is an equation but the converse may not be true*"

The above activities of teacher and student show that students can learn by doing mistakes and from failure in several times. The teacher role is important to develop students' creativity to learn new concepts by linking the learned concepts.

For the development of innovative ideas among students in mathematics, the selected teacher explained that:

"*I regularly give project work to construct mathematics materials for the students. The students prepare materials by demonstrating their own idea and techniques in the chart paper very beautifully, and some times makes paper materials like kite, boat, plane and they can interpret the geometric concepts in the concepts*"

These responses show that giving project work and connecting mathematics with the real-world application enhance the student's creativity while learning mathematics at school.

The selected teachers also experienced as:

"*When I used ICT for example GeoGebra in teaching mathematics and sometime I displayed YouTube video related to algebraic tiles that represent algebraic expression, then students motivated highly and they made different algebraic tiles. These activities helped me to explain algebraic concepts to the students*"

These experiences reveal that the use of ICT in teaching and learning mathematics at school enhance creativity among students. Likewise, one respondent expressed his idea as:

"*Sometime I give group project in the classroom, for example to construct cube, pyramid, prism and other solid figures, then ask the areas of each surface of them for the students of grade nine. Then all the members of group brainstorm/discussion to generate ideas of give solid*"

The statements show that the process of generating ideas through brainstorming and group discussion. The group members add all the ideas in group to find the required surface area of the face of solid after discussion which is the application of creativity skills. Likewise, the process of elaborating, analyzing and evaluating their original ideas in the group enhance their creativity as indicated by:

"*In the construction of solid material like prism and determine the technique of finding surface area, students develop, implement, and communicate new ideas to others*".

However, not all the selected teachers of this study are not familiar with the ways of developing creativity while teaching mathematics at school. They are mainly using lecture cum practice method which is an improved traditional method of teaching mathematics. These teachers are also unaware of using ICT tools in teaching and learning mathematics.

Communication

Communication is an essential 21st century skills for teaching and learning mathematics at school level. Communication refers to the ability to express one's opinions, desires,

needs, apprehensions etc. to oneself appropriately, verbally and no-verbally (Central Board of Secondary Education, 2020, p.21). So, the person who has good communication skills can articulate thoughts and ideas effectively, listen effectively, use multiple means of communication, and understand purpose of communication (Trilling & Fadel, 2009, p.55).

For the development of communication skills, the selected mathematics teachers claimed that:

"*We use teamwork strategies of member 3 to 5 sometimes while teaching and learning mathematics where all students work together to solve the assign problem of mathematics. The students take leadership, share ideas, and other students look carefully the group ideas*".

"*In our schools, every Wednesday is for extra activities. So, we organize mathematics quiz competition among students' level wise. In this competition, students work in small teams and work for team. They analyse the mathematical problem of quiz in group, share ideas and reach the conclusion of the asked question within stipulated time and group leader explain the answer*".

These activities promoted by mathematics teachers and school help to enhance communication skills while doing work with mathematics. The teamwork activities help individual students to share ideas, to take part in the discussion, and to build confident on their logic and solution in mathematics. Thus, students can easily interact with teachers and friends which increase the classroom participation/interaction while learning mathematics.

Another strategy that was used by selected mathematics teachers to enhance communication and social skills are related to individual project work as reflected follows.

"*The individual project work assign for grade nine students are related to find profit and loss, bills of electricity, commission and taxation, simple and compound interest. In this project work, individual students need to go in society, collect information by asking the people in the society/office and solve the give problem*".

This statement explained here help to develop talk /interviews and interact people of the community respectfully to collect information. The students understand the policy of tax

and other relevant information of their nation including tax. Such types of project work not only develop good communication skills among students while teaching mathematics, but also develop positive attitude towards learning mathematics and help to find the application of the mathematics in the society.

Moreover, language is the medium of communication skills. There is good practice of English language to make communication with friends and teachers while learning mathematics. For the selected teachers expressed as:

"*In our schools, students and teacher need to speak by using English language in the class and for other activities that help us to develop language proficiency as well as communication skills*"

The statement reflects that the compulsory to speak English language in institutional school while teaching and learning with mathematics plays a vital role to increase English speaking and writing capacity among teachers and students. However, it has some demerits while explaining the meaningfully the concepts of mathematics in the classroom because for the teacher and student of non-English background cannot demonstrate and explain very simple words for communication while giving application of mathematics and others.

Collaboration

Collaboration depicts a way of working with others while teaching and learning mathematics. Collaboration in mathematics classroom will take several forms such as small group discussions, peer teaching and other group projects. Good collaboration with others demonstrates the ability to work effectively and respectfully with diverse teams, exercise flexibility and willingness to be helpful in making necessary compromises to finish the common goal, and value the individual contribution in the team (Trilling & Fadel, 2009, p.55; Central Board of Secondary Education, 2020, p.21).

It is a most valuable skills among 4c's category of 21st century skills. Mathematics teachers can work collaboratively with other in various forms such as collaboration in small group discussion with students, collaboration to make questions, instructional plans and project works with the teachers of mathematics of different institutional schools. This paper is prepared on the basis of research and training to mathematics teachers of institutional schools.

The selected teachers of this study experienced as:

"*We involve in the mathematics teachers training organized by our school at the end of every month where we as teachers share our ideas of teaching and learning with others including training experts, we work collaboratively in small groups in workshop models, and we take leadership in the presentation of groups. We discuss the issues associated to teaching, learning, and accessing mathematics during the mathematics. Our group is heterogenous and thus our expert form small group of teachers from grade one to three, grade four to seven, and grade eight to ten for discussion*".

These statements of selected teachers' experiences show that the mathematics teachers of the selected teachers are familiar with the ways of working and collaborations in small teams. Within these collaborative teams of training, teachers can share their difficulties with others and solve it with the discussion of peers and subject experts of training.

> "*It is an observed class that mathematics teachers of grade nine formed small groups of three to five students in such a way that the students sitting in a bench is a group. The teacher gave different problem questions from the contents of the geometry and facilitate them to work collaboratively such that each students need to explain their contribution in the group. Accordingly, each small group did break down the assigned questions and solve it individually at first then present to the small groups. Each small group finished the assigned tasks and ready for the presentation. The group leader presented the solved problem of geometry in the white board and ask the validity for it to the class and to their teacher. The teacher and students discussed the solution in details and finished the class for that day*".

This classroom observation displays that mathematics teachers of selected institutional schools work collaboratively and help to enhance collaborative skills while teaching and learning mathematics. The observed classroom activities and the teacher's explanation of their works justified that there is as much as practice to develop 21st century skills including communication and collaboration through teamwork activities to learn mathematics concepts.

One selected teacher reported that:

"*I used blooms taxonomy to make objectives of planning and to construct assessment questions. I prepare exam questions with the discussion others teachers and subject*

experts of mathematics in a team and finalize it after the inputs and suggestions given by friends. I include questions of test papers to measure both lower order thinking skills and higher order thinking skills".

Another selected teacher also explained that:

"*I give individual as well as group project work to my students where students work creatively by communicating ideas collaboratively in their own groups and present in in the groups. Sometime, I use ICT tools for teaching and learning mathematics where students actively participate in the discussion*".

These explanations indicate that the selected school has awareness to measure the higher order thinking while using formative assessment tools. The school has managed training for the meaningful teaching and learning of mathematics. However, the teachers are not able to use ICT tools because of their technical limitation. That is the teacher and school both did not have sufficient fund for the management of it.

Conclusion

The mathematics teachers of institutional schools are trying to transcends boundaries of traditional approaches of teaching mathematics and practicing some strategies like questioning, teamwork, project work, and other activities like quiz competition within the periphery of 21st century pedagogical approaches like problem-based learning and inquiry-based learning. These teachers are working for developing and enhancing 21st century skills including critical thinking, creativity, communication and collaboration skills among students while implementing pedagogy for teaching mathematics at schools. However, there is very rare uses of ICT tools for teaching mathematics at this level. Thus, it is suggested that the educators, policy makers and other stakeholders like local government need to reframe their school mathematics curriculum from the perspective to support to enhance 21st century skills among the students.

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