Enhancing Mathematics Learning through Self-Directed Pedagogy: Strategies and Evaluation Techniques for Effective Student Engagement

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ABSTRACT
Mathematics is taken as a challenging subject. It is the major concern of education all over the world. It is abstract by nature and its study necessitates engaged learning with tenacity, discipline, and persistence in learning. In context of Nepal, school math students are facing problems in comprehending, examining, and generalizing the mathematical situation. These conditions are not considered in teaching of mathematics at present. So this study attempts to explore learning strategy and student's evaluation in self-directed learning pedagogy in mathematics teaching with its objective to introduce learning strategy and student's evaluation in self-directed learning pedagogy. To meet the objective SDL pedagogy is analyzed in terms of engaged learning with self-motivation, self-monitoring and self-management for metacognitive skills.This is obtained by using document analysis design through teaching learning strategy such as inquiry based learning, project base learning, flipped classroom strategy, collaborative strategy, reflective and KWL strategy, goal setting & self-assessment strategy, problem base strategy, think pair shared strategy, reciprocal strategy, Socratic questioning strategy and brain storming strategy. Each teaching strategy mentioned above supports Self-Directed Learning (SDL) by fostering autonomy, critical thinking, self-management self-motivation andself-monitoring. Through this research, it is found that these strategiesem power students to ask questions and seek answers independently, with evaluations focusing on their-self assessment, rubric,portfolio,meta cognitive skills and critical abilities.

Keywords: Mathematics Education, Student Evaluation, Learning Strategy, Self-Directed Pedagogy

INTRODUCTION

Mathematics is a principal discipline that contributes on the evolution and acceleration in the development of technology. It's origin can be traced from the beginning of the human civilization (Poudel et al, 2023). It is essential for everyday life and also for higher study in every field (Poudel, 2020).Thus it is considered as the queen of science (Burton, 2003). Therefore, it is given a major position in school education all over the world. Despite its value in school education, many students find it to be a challenging subject (Yadav, 2017). Students' indifference towards learning mathematics from school level to university level (Pandit, 2007) is the major concern of education all over the world. Furthermore, mathematics by nature is a highly abstract subject and its study necessitates engaged learning with tenacity, discipline, and persistence in studying (Kleden, 2015). In context of Nepal, Khanal (2015) and Panthi and Belbase (2017) concluded that secondary school math students in Nepal facing difficulty in comprehending, examining, and overviewing the situation of mathematics learning. As a result, large number of students fail in mathematics exams. Moreover, report of ERO (2019) mentions that less than 32% of students meet competency in mathematics while studying in class 8, and one-third perform below the national average in the same. Students finds it difficult to gain basic knowledge and are unable to tackleadvanceanalytical problems. Concerning this fact, new learning pedagogy and student's evaluation system should be used in teaching learning process(Luitel, 2024). Learning is meaningful if it is by self-initiation, learning in a scheduled time, identifying learning necessities, exploring learning goals, identifying resource for learning, selecting, employing suitable learning strategy and evaluating learning outcomes are important aspect in learning mathematics (Kleden, 2015). Those above things are related

to SDL. SDL is a process where individuals take the initiative to identify their learning needs, goals, resources, strategies, and outcomes (Knowles, 1975). Borich (2011) defines self-directed learning as an approach that actively engages students in the learning process, fostering higher order thinking skills. It encourages creative and intuitive potentials, while Hamlet (2006) asserts that self-directed learning is meaningful when students engage in self-planned, self-initiated, and autonomous learning The above-mentioned condition does not apply to the teaching of mathematics at present. Consequently, learning math is by rote. Concerning this issue, this study tries to explore learning strategy and student's evaluation system in self-directed learning pedagogy in mathematics teaching.

Objective of the Study

The objective of this research article is to introduce learning strategy and student's evaluation in self-directed pedagogy in mathematics teaching.

METHODOLOGY

This study is based on document analysis method. This method is a systematic procedure for reviewing or evaluating both the printed and electronic materials. It requires data be examined and interpreted to elicit meaning, gain understanding, and develop the empirical knowledge (Bowen, 2009, p. 27). To meet our objectives, we have collected and analyzed books, journal articles, research papers, forum, dissertation and online documents. We have used key words such as Self-directed learning, SDL strategy, SDL evaluation, student's evaluation. Sources of research are Google Scholars, digital library of Tribhuvan University, Central Library in digital resources and published books and journals. From those sources, we have prepared different themes and accumulated them to prepare conceptual and theoretical categories. While writing these arguments are build up.Based on theseanalysis and interpretation with necessary citations. The research work was completed.

Reviews and Discussion

Concept of self-directed learning

Self-directed learning is a process for meaningful learning. It is a process for the studentsto make the major decision on planning, continuation, and evaluation of their educational experience (Merrian et al., 2007). There are different perspectives of SDL. "Self-directed learning is a process in which individual take the initiative, with or without the help of other, in diagnosing their learning needs, formulating learning goals, identifying human and materials resources for learning, choosing and implementing appropriate learning strategies, and evaluating learning outcomes" (Knowles, 1975, p. 18). To achieve the desired results, self-directed learning motivates the students to assume responsibility for their own learning (Pham, 2011). It is possible to determine that self-directed learners establish their own methods for action, identify the resources necessary for learning and success, and assess the degree to which they have met their own learning objectives.(Pokhrel and Poudel, 2024) It assumes a learner is fully autonomous in his learning. But this level of autonomy may not be fully applicable for junior's students, however their own- action for learning is essential. With the same spirit, Hamlet (2006) argued that Self-directed learning involves students setting individual learning goals, selecting strategies, and evaluating their achievement and success. Moreover, Huda (2014) suggests that self-directed learning (SDL) is a learning model that promotes learner autonomy and lifelong learning skills. Therefore, SDL can boost students' self-confidence and learning abilities (Taylor, 2001). Hence self-directed learning is a process of meaningful learning and can be utilized as a pedagogy in mathematics learning. But its empirical justification is necessary and may need to develop different pedagogical models utilizing these conceptualizations, for it is not a prescriptive entity, but a growing entity.

Role of SDL Learners and Teacherin Self -directed Learning Pedagogy.

Self-directed learners are interested, confidence, and responsible with metacognitive skill in learning process to make autonomous learning. (O, Shela, 2003; Oswalt, 2003; Askin and Denirel ;2018). Similarly, Self-directed teachers are motivator, facilitators, counselor and not coach. (Hamlet, 2006 & Brandt ,2020).

Learning strategyand student's evaluation in SDL pedagogy

Self-directed (engaging) teaching and learning method focuses on fostering student engagement, autonomy, responsibility and active involvement in there one learning process (Pokhrel et al, 2024). Those methods encourage students to take responsibility, set learning goals and making learning agreements.

Student's evaluation is a genius part of learning process for meaningful learning and key to success in learning, training and certification processes (Sheremetov, et al. (2006). Students are evaluated into four

types: placement, formative, diagnostic, and summative. Placement evaluation is conducted to assign students to appropriate groups or classes based on their abilities, often using pretests or aptitude tests to assess their entry behavior, which helps teachers to adjust their lesson plans. Formative evaluation is aimed at identifying areas where students may be struggling, providing feedback to both students and teachers to improve learning and teaching effectiveness, often through weekly tests or terminal exams. Diagnostic evaluation follows formative evaluation when persistent learning difficulties are identified, seeking to uncover the underlying causes of these challenges through diagnostic tests, interviews, or observations, allowing for targeted interventions. Finally, summative evaluation is carried out at the end of a course or program to assess the overall achievement of objectives. It is used for certification and offers a comprehensive judgment on the effectiveness of the teacher, students, curriculum, and the educational system as a whole (Sheremetov, et al.,2006). Moreover, student's evaluation in education aims to assess cognitive, affective, and psychomotor learning by evaluating both the process and the final product, with results reflecting behavioral changes in the learner. Formative assessment involves ongoing, formal and informal evaluations during the learning process, providing detailed feedback to help teachers adjust their methods and improve student outcomes. Summative evaluation focuses on assessing the outcomes of a program, measuring student learning, skills, and achievement at the end of a specific instructional period, such as a course or school year. This paper examines how formative and summative evaluation techniques influence student behavior and teacher effectiveness, aiming to identify strengths and weaknesses in the current evaluation system and suggest areas for improvement (Bhat, B. A., & Bhat, G. J. (2019).

In context of Nepal, lack of creativity, lack of critical thinking & collaboration, rote learning, dropout rates, and difficulties with learning achievement are the main pitfalls of evaluation system. Evaluation system ismainly guided by theories and book-based instructions, written examination-oriented evaluation, and assessment of learning rather than assessment for learning (Gyawali,2021). Hence student evaluation system is does SDL pedagogy. In self-directed learning pedagogy, mostly formative evaluation system should be used.Formative Evaluation occurs during the learning process and is used to monitor student's progress and provide ongoing feedback. Examples in formative evaluation include quizzes, homework assignments, and class discussions.Moreover, in the context of Self-Directed Learning (SDL) pedagogy, diagnostic evaluation plays a crucial role in understanding and addressing the specific learning needs of students. Closely related to formative evaluation, diagnostic evaluation is often conducted alongside in the classroom to identify the underlying causes of learning difficulties. This type of evaluation is essential not only during the learning process but also prior to instruction, as it helps place students at the appropriate level based on their current achievements. By pinpointing specific areas of weakness, diagnostic evaluation provides a foundation for tailored instructional strategies, enabling students in an SDL environment to focus on areas that require improvement and thereby take greater ownership of their learning journey. The summative evaluations can serve a diagnostic purpose, offering insights that guide future learning paths in SDL by revealing long-term trends in student performance (Gafoor, K. A.,2013). Furthermore, Self-Directed Learning (SDL) pedagogy, various student evaluation methods foster self-regulation, responsibility, and real-world application. Self-assessment empowers students to evaluate their own work, promoting self-reflection and accountability in their learning process. Peer assessment encourages students to assess each other's work, offering diverse perspectives and fostering collaborative learning, which is essential in SDL environments. Portfolio assessment allows students to compile a collection of their work over time, providing a comprehensive view of their growth and learning achievements, which supports the continuous and reflective nature of SDL. The authentic assessment evaluates students' ability to apply their knowledge and skills in real-world or simulated scenarios, such as through case studies, project-based assignments, or internships, aligning with SDL's focus on practical, real-life learning experiences (Sullivan & Hall ,1997; Andrade & Brown. ,2016). In Self-Directed Learning (SDL) pedagogy, student evaluation systems, particularly formative and diagnostic assessments, are crucial for fostering autonomy, responsibility, and active engagement, ensuring meaningful learning and guiding students toward continuous improvement and real-world application of knowledge.I had enclosedhere some teaching and learning strategy and evaluation system in SDL pedagogy.

1. Inquiry-Based Learning strategy

Inquiry-based learning is growing in higher education in recent years. Inquiry-based learning has gained prominence in recent years as a didactic approach in higher education. Because of this, inquiry-based learning is also seen as a link between the more recent demands of a pluralistic world where learning is a lifelong skill and a willingness to do so, and the more traditional demands for theunification of teaching.Students use inquiry and research to examine problems, scenarios, or questions. While they

don't offer direct solutions, teachers facilitate the process. Students then present their findings in a mathematically-related real-world issue, like budget optimization or statistical data analysis (Schoenfeld & Kilpatrick, 2013). Moreover, Inquiry-based learning is a personal discovery process where learners generate questions and answer them through critical thinking. It teaches students about knowledge generation, transmission, and contributions of various parties, including experts, teachers, parents, and society. Inquiry learning teaches respect for one's own interests and others'. Teachers should understand the methodology's roots and essence, including its respective disciplines and learning theories. Constructivist learning theory is the foundation of inquiry learning, which emphasizes learning through inquiry and problem-solving through critical and creative thinking. This method offers a valid alternative to traditional classroom methods. To fully understand inquiry, learners must experience it directly, gaining a deep understanding of its characteristics. Successful inquiry learners can become productive lifelong mind seekers (Ismail, et al 2006). Similarly, Dreyøe et al., (2018) argued that Inquiry-based teaching in mathematics emphasizes engaging students in problem-solving, problem-posing, and modeling activities, which enhance their mathematical creativity. This approach encourages students to explore concepts through open-ended questions, investigation, and collaboration, fostering a deeper understanding of mathematical content. As a form of self-directed learning, inquiry-based learning (IBL) empowers students to take ownership of their learning through self-assessment and peer feedback, with educators providing guidance to support their exploration and engagement with mathematical concepts. In inquiry-based learning (IBL), student evaluation is centered on both the learning process and outcomes. Rather than focusing solely on final answers, assessments include students' abilities to ask questions, design experiments, analyze data, and make evidence-based conclusions. This approach, which integrates self and peer assessments, supports deeper learning by emphasizing critical thinking and ongoing feedback (Anderson & Krathwohl, 2001; Schwartz & Bransford, 1998). Hence, Inquiry-based learning in mathematics teaching strongly emphasizes student-driven inquiry, critical thinking, and practical problem-solving. It uses a constructivist approach reinforced by continuous feedback and self-evaluation to foster deeper understanding and lifelong learning skills.

2. Project-Based Learning (PBL)

Project Based Learning (PBL) is a teaching method that motivates the students in participating in real-world problem. Project-Based Learning and collaborative work is becoming more commonplace in teaching practice. Pinero (2017) added that Project-based learning (PBL) directs itself to the use of technologyof the present times. With PBL, students'use internet resources in research, investigate, and work collaboratively. Additionally, technology allows for both autonomous and collaborative work, enabling students to succeed at their own pace and potentially avoid conflicts of perspective while researching varying contexts, and finally providing them with a medium to connect their material with other students. Project base learning premise SDL focus by self-monitoring his or her own progress and attending to his or her own metacognitive skills involved in the learning process.Similarly, Fisher, et al., (2020) argued that project-based learning is based on SDL pedagogy. NCTM (2000) added that it has the characteristics that students can choose topics fo project presentations/products, produce final products such as presentations, recommendations for solving problems related to the real world, involving various disciplines, varying in duration of time. Project-based learning involves integrating new knowledge through real-life experiences, starting with problem-solving and guiding students through collaborative projects that integrate various subjects into the curriculum. Similarly, Project-Based Learning is an instructional approach designed to give students the opportunity to develop knowledge and skills through engaging projects set around challenges and problems they may face in the real world (Schuetz, 2018&Pusztai,2021). Moreover, in project-based learning (PBL), student evaluation is a comprehensive process that extends beyond traditional methods, focusing on both the learning process and the final product. Evaluation typically includes formative assessments where students receive ongoing feedback throughout the project, allowing them to reflect and make adjustments. Summative assessments are also important, evaluating the final product and the presentation skills students demonstrate. The peer and self-assessment play crucial rolesbecause students evaluate each other's contributions and reflect on their own learning, which fosters self-directed learning.

3. Flipped Classroom learning strategy

The flipped classroom is a blended learning strategy that uses online content to deliver instruction outside the classroom, transforming traditional learning environments. This approach encourages a learner-centered approach, allowing students to explore topics in depth and create meaningful learning opportunities. Content delivery can take various forms, including video lessons, online discussions, digital research, and text readings. The flipped classroom model promotes equal learning opportunities and

allows students to revisit and review topics, enhancing their understanding of fundamental concepts(Rayees,2018). Anjomshoaa, et al., (2022) added that the flipped classroom is an educational approach that is supported by technology and consists of two components; individual and direct computer-based training outside the classroom through video lectures and interactive group activities within the classroom. This definition emphasizes the use of instructional videos in extracurricular learning. Hence, the flipped classroom approach improves learning, cognitive load reduction, engagement, accuracy, motivation, attitude, satisfaction with the course, and self-efficacy in learners. Students are assessed on their ability to independently understand and engage with material before class, often through quizzes, reflections, or assignments. This approach encourages active learning and critical thinking, fostering a deeper understanding of the subject matter (Kurt, 2017).

4. Collaborative Learning strategy

A collaborative learning is a learning strategy that involves more than two students working together to complete activities, share resources at specific times, and require varying abilities and skills from each other in order to meet learning objectives. These interactions, experience exchanges, and role changes within the group all have an impact on the students' performance (Siller & Ahmad,2024). Collaborative learning strategy is SDL pedagogy where students are working in groups and makes students responsible for each other's learning, and each accountable for their own learning. Collaborative learning fosters a deep understanding of content, leading to improved academic performance compared to competitive or individual learning approaches. It helps students develop essential social skills, civic values, and higher-order critical thinking abilities. Additionally, collaborative learning encourages personal growth and nurtures a positive attitude toward self-directed learning. The students learn most effectively through interaction and the exchange of ideas, this approach aligns with SDL pedagogy by promoting autonomy, responsibility, and active engagement in the learning process. (Hsu & Shiue, 2018; Shi et al., 2020). Furthermore, Hossain & Tarmizi, 2013 found that Collaborative learning establishes a community in which students can get help and support from other group members immediately in a noncompetitive learning environment, just raising their hands and waiting for the right answers to be given. Collaborative learning is an educational approach that involves students and teachers working together in groups to explore and solve problems. It encourages conversation, debate, and relationship-building, and is most effective in teaching mathematics courses. It is recommended for late students to engage in heterogeneous groups to share experience and problem-solving skills (GebreYohannes,2017). Hence, in collaborative learning in mathematics teaching, students work together in groups to achieve common learning goals, share knowledge, and provide mutual support. Teachers facilitate group interactions and provide guidance as needed. Collaborative learning, as a strategy within SDL pedagogy, promotes autonomy and responsibility by encouraging students to work in groups, share knowledge, and support each other's learning, which enhances their engagement and performance while aligning with a holistic student evaluation system that values both process and outcomes. Similarly, Crawford et al., (2005) argued that Cooperative learning techniques enable students to participate actively while organizing activities simultaneously, resulting in productive and organized learning. These techniques offer academic and social benefits, and are not just a quick way to encourage participation in large classes. They also added that Cooperative learning offers several key benefits, including the development of higher-order thinking as students engage with ideas, concepts, and problem-solving tasks. It also boosts motivation and morale, leading to increased attachment to the school and class, which can improve attendance and retention rates.

Jigsaw is a cooperative learning method that encourages students to help each other learn by working in both home groups and expert groups. This method is suitable for classes of nine to ninety students, with home groups typically consisting of four members and expert groups of four or five members. The teacher must prepare task sheets in advance of the lesson to ensure a balanced learning environment. The Jigsaw technique promotes active learning, encourages collaboration, and allows students to take responsibility for their own learning while benefiting from the expertise of their peers. It is effective in fostering a deeper understanding of complex subjects and developing communication skills. To evaluate students in the Jigsaw method, it is essential to assess both their individual contributions and their collaboration within the jigsaw groups. In summary, Jigsaw is a cooperative learning strategy that encourages active learning, collaboration, and the development of communication skills among students. It is effective in fostering a deeper understanding of complex subjects and enhancing students' understanding through collaboration(Crawford et al., (2005).Hence, Collaborative learning strategies in SDL pedagogy promote student autonomy, responsibility, and engagement by fostering deep understanding, social skills, and higher-order thinking through group interaction and mutual support. Ross, et al., (1998) argued that Collaborative teaching and learning involves a balanced approach to student evaluation, assessing

individual and group contributions. Individual assessments include peer evaluations and self-assessments, while group assessments focus on the quality of the group's final product and collaborative process. Clear rubrics and criteria ensure fairness and transparency. Continuous feedback from peers, self, and instructors helps students to adjust and improve.

5. Reflective Learning and KWL strategy

Dewey emphasizes on reflective learning through problem solving and critical thinking skills instead of memorizing of the content matter. Reflective and KWL strategy are learning strategy of SDL pedagogy. In reflective learning students regularly reflect on their learning experiences, set personal goals, and assess their progress. Teachers encourage reflection and provide feedback to help students improve (Hatton & Smith, 1995). Reflection is a vital tool for self-assessment and learning. It involves critically evaluating one's performance to improve the quality and depth of learning. By reflecting on their experiences, students understand that learning extends beyond the classroom and encompasses life experiences. Reflection help the students to think about what and how they learn, which in turn influences their academic success. It encourages a structured approach to personal development and enables learning from both direct experiences and observation of others. For mathematics teacher, reflective teaching goes beyond mere thoughtful instruction; it involves examining professional practices to transform them into learning opportunities, fostering continuous growth and development (Gupta, et al.,2019). Lee &Mori (2021) added that refection learning strategy is the reflective practices of collaboration, self-reflection, and peer feedback are the most significant predictor of SDL competencies. Since both emphasize on active, independent engagement in the learning process, reflective learning strategies and self-directed learning (SDL) pedagogy are closely related. Reflective learning is based on students regularly evaluating their experiences, creating goals for themselves, and asking for feedback. This is in line with SDL's guiding principles, which emphasize that students take ownership of their own learning.Similarly, KWL strategy is a collaborative and reflective learning process. This strategy is conducted by the teacher throughcreative discussion about the topic of the lesson.It is implemented by the use educational materials to record student information about what they know (K), want to learn (W) and finally what they have learned (L).(Figure given below.) The KWL chart is a workflow that consists of three main columns, namely: K – What I Know; Second W – What I Want to Know; and the third L – What I Have Learned. KWL strategy help to student as; the opportunity to expand their ideas and their understanding through brainstorming.Students activate their previous knowledge on the subject of the lesson, increasing their interest and motivating them to understand. The students can limit theirdesire to study and the questions about the topic. It increases their reading and hence their understanding, students' self-learning by monitoring their understanding and development ability and finally evaluate their learning outcomes. Hence, KWL strategy is effective in education, especially in the primary stage(Neslihan&Muamber,2020)

Topic:

K	W	L

Figure 1: KWL Table

The KWL strategy, rooted in metacognitive thinking, is an essential teaching method in science education that activates prior knowledge, sets learning goals, and fosters reflection on what students have taught (Crawford et al., 2005). The KWL strategy is deeply connected to SDL pedagogy in mathematics teaching, is a collaborative and reflective learning process that uses metacognitive thinking to activate prior

knowledge, set learning goals, and foster reflection, thereby enhancing students' understanding, motivation, self-monitoring, and evaluation of their learning through creative discussions and structured KWL charts, making it particularly effective in primary education when integrated with face-to-face classroom interactions. Evaluating students in the KWL strategy involves assessing their initial knowledge, learning goals, and outcomes, encouraging reflection and self-assessment, providing peer and teacher feedback, and using follow-up activities to comprehensively gauge their progress and support their learning needs.

6. Goal Setting and Self-Assessment strategy

Goal setting and self-assessment is essential part of SDL pedagogy for student autonomy in mathematic teaching and learning. Goal setting and self-assessment is necessary for integration of self-monitoring, self-management and self-motivation in SDL process. When Students set their own learning objectives and assess their progress toward achieving these goals. Teachers support this process by providing tools and frameworks for self-assessment as well as Students set goals for mastering a particular math skill and use rubrics or checklists to evaluate their progress and adjust their learning strategies. Self-assessment practices in the 21st century need to be revised and redesigned to promote self-directed learning and assessment literacy. Assessment literacy includes the development of self-assessment skills (Lubbe et al., 2021).It is an important component of self-directed learning, which was originally developed in the field of adult education and is an important skill for successful independent learning (Papanthymou &Darra,2023). Student self-assessment is a reflective and monitoring process where students evaluate their work and its quality, including aspects such as how well they've performed and the value of their work. This process helps students self-regulate their learning by setting goals, selecting strategies and resources, and responding to feedback to improve their outcomes. Self-assessment is a crucial aspect of Assessment for Learning, involving students evaluating their learning processes and products. It is a powerful learning strategy that enhances motivation, engagement, and adaptability. Assessment-capable students show higher achievement. However, successful self-assessment requires significant teacher input, sustained direct teaching, and follow-up support. In the long term, self-assessment facilitates self-directed learning by students, but it requires sustained direct teaching and follow-up support(Harris &Brown,2018). Teachers should create the right conditions in the classroom to prevent students from feeling judged. To facilitate self-assessment, teachers can use eight tools: rubrics, scripts, journals, portfolios, traffic lights, exit cards, and paired marking. Rubrics help students compare their work against criteria and assess the standard they have reached. Scripts guide learners through a clear progression of steps, detailing self-talk and progress. Portfolios demonstrate students' learning and competence, helping them understand progress, document interests and strengths, and identify preferences. Exit cards are small pieces or post is given at the end of a lesson for students to write comments about their learning and areas they need more help with. Traffic lights indicate students' perceived understanding of work, labeling it green, yellow, or red. This helps determine groupings or activities for the next part of the lesson. Teachers can pair green students with yellow students or assign follow-up activities based on their traffic light color. Paired marking involves pairs of student's interchange and assess work using rubrics or success criteria. This allows students to practice assessment skills and open up dialogue about the purpose of assessment, useful feedback from an assessor, and reflection on success criteria. Discussions can take place between paired students or with the whole class after a session (Andrade& Brown, 2016). Moreover, Barana, et al., (2022) added that Self-assessment plays a vital role in helping students develop autonomous learning skills and self-regulation. It involves three key processes: self-observations, where students focus on specific aspects of their performance relative to their personal standards; self-judgments, where they evaluate how well they have achieved their general and specific goals; and self-reactions, where they assess their satisfaction with their progress and adjust their standards accordingly.

Through self-assessment, students enhance their metacognitive abilities by closely monitoring and reflecting on their work. This process not only improves their self-efficacy but also shifts their focus from merely performing well to genuinely understanding and mastering the content, ultimately supporting more effective and self-directed learning. Hence, Self-assessment is integral to Self-Directed Learning (SDL) as it fosters autonomous learning and self-regulation by enabling students to monitor, reflect on, and adjust their performance, thereby enhancing their metacognitive abilities and promoting deeper understanding and mastery of content. Ultimately, self-assessment is an active learning process that fosters control over thoughts, actions, emotions, and motivations to achieve goals. Moreover, Goal setting in mathematics teaching enhances self-directed learning (SDL) by fostering student autonomy, motivation, and engagement, allowing them to set clear, challenging goals, monitor progress, and improve academic achievement (Punnett, 2001; Panadero& Alonso, 2013).Moreover, madden (1997) argued that

students establish themselves to accomplish the goal-setting It is different from academic expectations in the classroom, which students must reach to satisfy the standard established by the teacher. In the same vein, Buzza, & Dol, (2015) argued that Student achievement goal setting, when integrated with self-directed learning (SDL), enables students to enhance their ability to set and achieve quality goals, despite fluctuating motivation and self-regulation. By setting clear learning objectives and monitoring progress, students take ownership of their educational journey, enhancing their ability to manage learning processes, adjust strategies, and reflect on progress. Incorporating student evaluation in a goal-setting teaching strategy involves engaging students in setting personalized, SMART goals, followed by regular self-assessment and peer reviews to track progress. Teachers provide formative assessments and reflective feedback, allowing students to adjust their goals as needed. The process concludes with a summative evaluation and self-reflection on achievements, fostering adaptability and self-directed learning while celebrating successes. Hence, In mathematics teaching, integrating goal setting and self-assessment with SDL pedagogy enhances student autonomy, motivation, and engagement by enabling students to set objectives, monitor progress, and adapt their strategies, ultimately fostering self-directed learning and reflective practice.

7. Problem Based learning strategy

Problem based learning strategy is another learning strategy of SDL pedagogy. It describes a learning environment that drives the way of learning through problems. The learning begins from a problem to be solved.The problem is driven such that students need to acquire new knowledge before they can solve the problem. It is a classroom strategy that organizes mathematics instruction around problem solving activities and affords students more opportunities to think critically, present their own creative ideas, and communicate with peers mathematically. Furthermore, Rezio, et al., (2022) argued that Problem-Based Learning (PBL) is an instructional approach that emphasizes practical, active learning through investigating and solving real-world problems. It is based on cognitive science principles, which suggest that prior knowledge influences how students process and integrate new information. In PBL, students tackle complex problems with no single solution, enhancing their ability to think critically, generate creative ideas, and engage in mathematical communication. The method involves three core elements: the tutor's role as a learning facilitator, students' responsibilities for self-directed and self-regulated learning, and the use of poorly structured problems to drive research and problem-solving. Similarly, the key component of PBL is that students work together collaboratively in small groups to analyses, research, and find solutions to ill-structured, open-ended, real-world problems which have many potential solutions and PBL focused to structuring of knowledge for use in clinical contexts, developing an effective clinical reasoning process, developing effective self-directed learning skills and an increased motivation for learning (Martin & Jamieson,2022). Hence, in mathematics teaching, Problem-Based Learning (PBL) aligns with Self-Directed Learning (SDL) pedagogy by centering instruction on real-world problems that drive the learning process. PBL fosters SDL by requiring students to engage in critical thinking, creative problem-solving, and collaborative work, thereby enhancing their ability to manage their own learning. This approach encourages students to integrate new knowledge independently and apply it to complex, ill-structured problems, aligning with SDL principles of self-regulation and autonomy. By working in small groups and tackling open-ended problems, students develop essential skills for self-directed learning and increase their motivation and engagement in mathematics.

8. Think-pair-share strategy

Think-Pair-Share (TPS) is a collaborative learning strategy that encourages students to generate opinions individually and share them with others. It differs from traditional methods, which involve a teacher asking a question and one student responding. TPS is learner-centered and is widely used in higher education. The model consists of three stages: think, pair, and share. Students think independently about the question, then pair with a partner in class to discuss their opinions. The final stage is to share their debates with the class. TPS not only improves student learning but also encourages participation from all students, including those who may be more reserved. The model is widely used in higher education and is considered to be effective in engaging students in discussions (Tanujaya & Mumu,2019). Similarly, Asfaroh & Hidayati (2014) added that Think-Pair-Share is a learning model that helps teachers with cooperative learning in pairs, where each pair of learners is given the opportunity to discuss with partner learning and this learning model requires students to work with each other in small groups and more characterized by cooperative awards rather than individual rewards. Crawford et al., (2005) added that TPS fosters critical thinking, enhances communication skills, and encourages active participation. It's particularly effective in mathematics education to explore problem-solving strategies or conceptual understanding. In the Think-Pair-Share (TPS) strategy, student evaluation focuses on collaborative learning and critical thinking. Students first reflect individually on a question or problem (Think), then discuss their thoughts with a partner (Pair), and finally share their insights with the larger group (Share).

This method allows for a deeper understanding of the material as students articulate and refine their ideas through discussion. Evaluation in TPS can include assessing individual contributions, the quality of peer interactions, and the ability to synthesize and communicate ideas effectively, promoting both individual accountability and cooperative learning. Hence, The Think-Pair-Share (TPS) strategy integrates well with Self-Directed Learning (SDL) pedagogy in mathematics teaching by fostering independent thinking, collaboration, and critical reflection. TPS encourages students to think individually, collaborate in pairs, and share ideas with the class, which enhances their understanding and participation. In mathematics, TPS is particularly effective for exploring problem-solving strategies and conceptual understanding. The student evaluation within TPS focuses on individual contributions, quality of peer interactions, and the ability to synthesize and communicate ideas. This approach supports both individual accountability and cooperative learning, reinforcing key SDL skills in mathematics education.

9. Reciprocal teaching strategy

Reciprocal teaching is a cooperative learning strategy that focuses on improving students' reading comprehension skills through four components: predicting, clarifying, questioning, and summarizing. This approach encourages active participation in class and improves lateral thinking abilities, thereby enhancing students' overall learning experience (Muanifah, et al. 2021).In the context of mathematics teaching within SDL pedagogy by reciprocal teaching, forming groups and assigning problems for collaborative practice can significantly enhance learning outcomes. Begin by organizing students into small groups to foster teamwork and peer learning. Assign each group a specific problem or set of problems that challenge their understanding and require critical thinking. Allow the groups to work together to solve these problems, encouraging them to discuss and explore various strategies. After solving the problems, have each group member take turns teaching the solution to their peers within the group. This process reinforces their grasp of the concepts and improves their explanatory skills. Finally, each group presents their solutions and teaching to the entire class, facilitating a broader discussion and enabling the exchange of different problem-solving approaches. This method supports SDL by promoting self-directed learning through active problem-solving, collaboration, and peer teaching, while also enhancing students' responsibility for their learning and their ability to communicate mathematical concepts effectively (Crawford et al., 2005). Similarly, Aslam, et al. (2021) argued that reciprocal teaching is an evidence-based, dialogical instructional approach that supports a collaborative process of teaching-learning between teachers and students to jointly construct the meaning. Reciprocal teaching for mathematics appears to be an essential strategy for nurturing a more in-depth understanding of the text of mathematical word problems at the elementary level. Students feel more relaxed and confident in posing questions and participating in productive and substantive conversations because they learn to have, and lead, discussions. Evaluating reciprocal teaching involves observing students' use of strategies like predicting, questioning, clarifying, and summarizing. Key methods include assessing skill application, gathering peer feedback, encouraging self-assessment, and using written reflections. Rubrics help standardize evaluations of strategy use, engagement, and contributions, ensuring comprehensive assessment of teaching and understanding. Hence, Reciprocal teaching in mathematics enhances SDL pedagogy by fostering active problem-solving, peer collaboration, and self-directed learning. Students work in groups to tackle problems, teaching each other and presenting solutions, which supports their critical thinking and communication skills. Evaluation methods, including peer feedback and self-assessment, ensure comprehensive understanding and effective use of teaching strategies.

10.Socratics questioning strategy

Greek philosopher Socrates, this approach encourages students to explore complex ideas, challenge assumptions, and engage in reflective dialogue. The goal is not to provide answers but to stimulate thoughtful inquiry and discussion. Socratic questioning is a teaching method used to promote critical thinking and deep understanding through a process of asking and answering questions. Socratic Questioning is a teaching technique that promotes independent thinking in students, allowing them to analyze content through their own and others' thinking. It is a disciplinary question that generates complex ideas, verifying their validity, and solving problems. Socratic thinking aims to distinguish between what they know and what they don't know, and can be applied in classrooms or spontaneous learning sessions. It helps students develop higher-level thinking skills and ownership of their learning(Yan,et al.,2005). Moreover , (Muhammad, & Niazi, 2022) argued that Socratic questioning is one of the approaches used by teacher in schools and universities to produce intelligent thoughts and give new recommendations to address incumbent issues that are related to philosophical and critical thinking skills. It is learning method that is used in class by debating with questions and having a meaningful conversation between two or more parties, specifically between students and teachers. Socratic questioning fosters deep learning by using open-ended questions that prompt students to think critically and articulate their ideas. This method encourages students to elaborate on their reasoning, provide

examples, and explore various perspectives, enhancing their understanding. Through facilitated dialogue, students engage in collaborative discussions where their ideas are examined and challenged. This process helps them refine their thinking and consider alternative viewpoints. Finally, students reflect on the discussion and synthesize their thoughts, leading to a more nuanced and comprehensive understanding of the topic (Crawford et al., 2005).The evaluation of students in Socratic Questioning involves assessing their participation, response quality, critical thinking, listening and reflection, self-assessment, and teacher feedback. This helps identify strengths and areas for improvement, enabling teachers to provide constructive feedback and support students' learning. hence,Socratic questioning supports SDL pedagogy in mathematics by encouraging students to think critically, reflect deeply, and independently explore complex ideas, thereby fostering self-directed learning and engagement.

11.Brainstorming strategy

Brainstorming is one strategy which is used in SDL pedagogy. Brainstorming is a teaching strategy designed to generate a wide range of ideas, solutions, or responses to a specific problem or question. This method encourages creativity, critical thinking, and collaborative problem-solving by allowing students to freely share and build upon each other's ideas in an open, non-judgmental environment (Crawford et al., 2005). The evaluation of students in brainstorming involves assessing their participation, creativity, collaboration, organization, and implementation skills. Teachers can evaluate their creativity, collaboration, problem-solving abilities, and their ability to organize and develop ideas. Students should also provide feedback on what worked well and what could be improved. This helps teachers gain insights into their students' creativity, collaboration, and problem-solving abilities, ultimately benefiting the overall learning experience. Hence,SDL pedagogy for mathematics teaching, brainstorming is a key strategy that promotes creativity, critical thinking, and collaborative problem-solving. It helps students generate diverse ideas, encourages flexible thinking, and strengthens their ability to approach mathematical problems from multiple perspectives, supporting their development as self-directed learners.

SDL Components Focuses Effective Learning Strategies

Self-Directed Learning (SDL) pedagogy is integrating of self-monitoring, self-motivation, self-management, and the creation of a conducive learning environment forms the foundation for a transformative student evaluation system in mathematics learning (Pokhrel& Sharma, 2024). These elements work together to support students in taking ownership of their learning process, fostering independence, critical thinking, and deeper engagement with mathematical concepts (Knowles, 1975 & Garrison, 1997). Self-monitoring is at the heart of SDL pedagogy, encouraging students to assess their learning progress regularly. By setting personal goals and objectives for each lesson, students gain the ability to track their advancement through self-evaluation rubrics. These rubrics serve as tools for students to measure their understanding, identify gaps, and make necessary adjustments to their learning strategies. For instance, techniques such as KWL (Know, want to Know, Learned), reciprocal teaching, and brainstorming help students actively engage in the learning process, enhancing their ability to evaluate their performance. In this context, teachers play a crucial role in scaffolding these skills by incorporating collaborative learning techniques. Tools like the traffic light method, think-pair-share, and jigsaw puzzles further support self-monitoring, enabling students to reflect on their learning in a structured manner. Reflective practices, such as peer feedback, error analysis workshops, and Socratic questioning, are designed to develop students' metacognitive abilities, helping them think critically about their problem-solving processes. This constant self-assessment cultivates responsibility and encourages students to take charge of their progress, ensuring that they remain on track toward their learning goals(Fattah,2010). Furthermore, Self-motivation, another pillar of the, transitions students from external inducements like grades and rewards to intrinsic motivation driven by personal interest and goals. In mathematics teaching, this is essential for cultivating a mindset where students are motivated to learn not just for rewards but for the intrinsic satisfaction of solving problems and understanding concepts. This shift is facilitated by teachers through the creation of a stimulating learning environment where students are actively engaged in meaningful tasks (Garrison, 1997 & Grow,1991). To foster self-motivation, the SDL model encourages activities that involve real-world applications of mathematical concepts, interactive games, and collaborative projects. Teachers can also help students visualize their future success in mathematics, celebrate achievements, and reflect on their learning journey. As students begin to enjoy learning for its own sake, they develop the perseverance to tackle challenges, an essential skill for mastering mathematics. This intrinsic drive becomes a catalyst for sustained learning and creativity in problem-solving (Bosch et al., 2019). Self-management in the SDL model refers to the gradual shift from a teacher-managed learning environment to a student-centered one. Students learn to take responsibility for their similarly, learning tasks, including time management, problem-solving, and organizing their

work. Teachers guide this process by modeling strategies for planning, setting learning goals, and managing resources. In the mathematics classroom, this translates to students developing structured approaches to learning, such as breaking down complex problems, managing time constraints, and collaborating with peers to solve mathematical challenges (Pokhrel et al., 2023).By empowering students to manage their own learning, this SDL encourages autonomy. Students become more efficient at organizing their tasks, prioritizing their goals, and overcoming obstacles. This self-management skill is critical in mathematics, where students often need to independently apply concepts and work through problems systematically. Finally, creating a conducive SDL environment is essential for the success of SDL. This environment includes flexible learning spaces where students can choose their learning methods, manage resources, and engage with both technology and peers. Teachers transition into facilitators, offering guidance when needed but allowing students the freedom to explore mathematical concepts independently. Collaborative learning, group work, and the use of digital tools and self-assessment methods contribute to a supportive environment that fosters independent thinking and self-planning (Rashid, Haron & Din, 2016). Hence SDL pedagogy integrates self-monitoring, self-motivation, self-management, and a conducive environment to create a comprehensive system where students not only evaluate their progress but also take full ownership of their learning. This approach, grounded in SDL pedagogy, ensures that students engage deeply with mathematics, develop critical thinking skills, and become lifelong learners capable of directing their own educational journey.

CONCLUSION

Self-Directed Learning presents a powerful approach to mathematics education by emphasizing student autonomy, responsibility, and engagement. The challenges of teaching mathematics, particularly in Nepal, highlight the need for innovative pedagogies like SDL, which makes learning more meaningful and effective. SDL encourages students to take ownership of their learning, set personal goals, and evaluate their progress, thereby fostering higher-order thinking and lifelong learning skills. Project-Based Learning engages students in real-world problems, promoting self-direction and collaboration, with evaluations including both formative feedback throughout the project and summative assessments of the final product. The Flipped Classroom model enhances SDL by encouraging students to prepare independently and engage actively in class, with evaluations centered on preparation, participation, and application of concepts. Collaborative Learning supports SDL by facilitating teamwork and shared problem-solving, with evaluations assessing individual contributions and group dynamics. Reflective Practices encourage self-awareness and metacognition, with evaluations focusing on the depth of reflections and their application to learning. The KWL Strategy helps students organize their learning and track progress, with evaluations considering goal setting and the ability to reflect on acquired knowledge. Goal Setting promotes self-direction by helping students define and pursue learning objectives, with evaluations of goal clarity and progress. Self-Assessment fosters accountability and self-regulation, with evaluations focusing on the accuracy and impact of self-evaluations. Problem-Based Learning drives students to solve complex problems independently, with evaluations assessing problem-solving processes and real-world applications. Think-Pair-Share encourages independent thought and collaborative discussion, with evaluations based on individual and group contributions. Reciprocal Teaching supports SDL through peer teaching, with evaluations of students' leadership and understanding. Socratic Questioning enhances critical thinking and dialogue, with evaluations of questioning skills and engagement. Lastly, Brainstorming promotes creative thinking and idea generation, with evaluations focusing on the originality and relevance of ideas and collaboration during the process. Above discussed strategies facilitate a comprehensive SDL approach, making mathematics learning more interactive and student-driven while cultivating essential metacognitive abilities. Hence, Self-Directed Learning (SDL) in mathematics education enhances student autonomy, engagement, and metacognitive skills through innovative strategies like inquiry-based learning, project-based learning, and reflective practices, fostering meaningful and effective learning. Hence SDL pedagogy is integration of self-monitoring, self-motivation and self-management and empowers students to take full ownership of their learning, fostering critical thinking, autonomy, and lifelong engagement with mathematics.

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