CASE STUDY

Procedures for online peer assessment: Assessing algorithm problems in school mathematics for future teachers

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Abstract: This action research study explored how peer assessment can help students and teachers evaluate algorithm problem-solving skills in mathematics. The study used a self- and peer-assessment activity in Moodle to assess 18 out of 40 Grade X students (10 boys and eight girls) from a school at Kathmandu Valley, Nepal. The students solved algorithm problems in arithmetic, algebra, statistics, and geometry. The study followed the action research methodology of planning, implementing, assessing, and discussing the interventions and outcomes. The results show that workshop activity can engage students in solving algorithm problems in mathematics. The study also discusses how cognitive and constructivist theories can explain some of this activity's unique aspects and potential uses. Moreover, the study highlights the benefits and challenges of self- and peer-assessment in mathematics for enhancing students' interest and abilities in the classroom. The study suggests students can develop analytical and evaluative skills using evaluation criteria to assess their peers' work. The study also implies that students are proactive, critical, and collaborative learners who can use self-and peer assessment to improve their mathematical abilities to solve algorithm problems in the classroom.

Keywords: assessment abilities, school mathematics, action research

1 Introduction

School education in general and mathematics education, in particular, have integrated various digital learning platforms and tools (Dahal & Pangeni, 2019; Dahal et al., 2020; Dahal et al., 2022c; Karakose & Malkoc, 2021; Mamolo, 2022). Web-based course delivery has been widely used in developing countries like Nepal during and after the pandemic. Standard practices submission includes uploading files (*e.g.*, .doc, .docx, .ppt, .pptx) to Moodle or other LMS and conducting quizzes. "The assessment tasks get students' attention, but once students submit their work, they typically become disengaged with the assessment process" (Thomas et al., 2011, p. 53). Evaluation is a fundamental aspect of the wide range of processes that occur in teaching and learning contexts. It allows students to assess their learning progress and helps teachers make decisions about teaching processes (Silver & Mills, 2018). This is our attempt to implement a self-and peer-assessment activity for Secondary Education Examination (SEE)-appearing students in school mathematics. The goal of implementing the tool is to make quality self- and peer-assessment among students in mathematics while assessing algorithm problems. We believe that the student's ability to evaluate peers' work, feedback, and interact with mathematics teachers or friends will improve their interactions and engagements in mathematics learning (Dimitrić, 2018; Freire, 1970; Marciniak, 2017).

On the contrary, "engaging students to gain a greater understanding of marking or evaluation criteria so that students may improve their comprehension of, and solutions to, future mathematical tasks. The study shall provide evidence of a positive impact on student learning and improvement observation, emulation, self-control, and self-regulation" (Brignell et al., 2019, p. 46). However, some of the unanswered questions, namely, is it true that how we use technology to teach and learn is not working well enough to evaluate students' work in mathematics? Which ICT tools in mathematics, especially those built into learning management systems or easy to use, are the best for making teaching and learning interactive?

In order to improve the self- and peer-assessment of students when evaluating algorithm problems, we utilized the self- and peer-assessment tools available in Moodle (Yirci et al., 2016). This tool is easily accessible in the add activity section and allows various student interaction, reflection, evaluation, and skill development opportunities. While self- and peer-assessment can typically be used for evaluating term papers, this method for assessing algorithm problems in mathematics may be a new experience for students. This study aimed to enhance students' self- and peer-assessment skills and prepare them for future teaching practicum and career development. We also explored how the chosen tool could be used to teach and learn mathematics. Before final grades were given, the study aimed to improve the quality of assessors and grades based on the quality of work (*e.g.*, Dahal et al., 2022b; Kearney, 2013; Ratminingsih et al., 2017; Ayalon & Wilkie, 2021; David & Debra, 2016).

Peer assessment has multiple benefits, such as setting performance expectations and reducing evaluation efforts for mathematics teachers (Boud, 1995). However, students may find it challenging to conduct self and peer assessments initially, leading to stress and confusion (Dahal, 2022; Dahal & Pangeni, 2019; Dahal et al., 2022b; Ratminingsih et al., 2017). Regular practice can help students become comfortable with assessing algorithm problems. Tousignant and DesMarchais note that students' self-perceptions may not always be accurate (Tousignant & DesMarchais, 2002), so peer and self-assessment should be used alongside other methods. Students can benefit from a better understanding their strengths and weaknesses through self-assessment (Handayani et al., 2019). This strategy can promote intrinsic motivation, self-imposed effort, a mastery goal orientation, and deeper learning through higher-order thinking (McMillan & Hearn, 2008). Encouraging students to participate in the learning process can increase the effectiveness of assessment (Khonbi & Sadeghi, 2012). In mathematics, self- and peer evaluations help students take responsibility for their learning and performance (Baiduri, 2022; Pantiwati & Husamah, 2017) and improve their critical thinking ability (Anderson & Krathwohl, 2001). Web-enhanced teaching/learning tools, such as the workshop tool in Moodle (Alcarria et al., 2018), can facilitate peer assessment in MOOCs, while an e-portfolio system can improve the process (Welsh, 2012). Peer assessment is a formative evaluation model that involves students of the same level reviewing each other's work to determine quality (Karakose et al., 2022; Topping, 2009). It makes students responsible for learning and can positively impact mathematical learning (Black & Wiliam, 2009). In summary, this article explores the benefits of using the Workshop activity in Moodle for learning and assessment in the digital age (Kalogiannakis & Papadakis, 2022). It suggests ways to improve the design and implementation of future web-based peer assessment tasks in various courses (Dominguez et al., 2014).

In order to conduct a systematic investigation into the interactive learning/teaching, Workshop as a tool for potential applications, this study is guided by the questions – what are the challenges and opportunities that we encountered while integrating Workshop as a self- and peer-assessment tool to evaluate mathematics contents in school mathematics? Furthermore, how can we engage our students to use the self- and peer-assessment tools in solving algorithm mathematics-problem skills to improve interactive learning? The theoretical framework, methodology, discussion of the key findings, conclusion, possible ways out, and the researchers' reflections are all covered in this article.

2 Cognitive and constructivism as theoretical referents

Theories of cognitive and constructivism guide this study. The cognitive theory focuses on how individuals transform their thoughts during self- and peer-review processes, recognizing and acting upon what they learn (Freire, 1970; Belbase & Sanzenbacher, 2016). Students learn new things by applying what they have learned in real-world situations, adapting to changes, and evaluating their and their peers' work. Information is received, processed, stored, retrieved, and acted upon in context (Tzagaraki, Papadakis & Kalogiannakis, 2022). Educational software tools like Workshop can aid in the review process. Constructivism encourages students to build and deconstruct their knowledge through peer analysis, experimentation, and self-analysis (Ratminingsih et al., 2017; Conway, 2022). Writing from various angles and conducting research are necessary to critique others' work and improve their own. Radical constructivism emphasizes "learning by doing" and peer reviews according to predetermined criteria, with the teacher acting as a facilitator (Wasson, 2022; Thomas et al., 2011). Students express their opinions freely and learn from their mistakes, becoming creators and assessors of information rather than passive recipients (Gözüm, Papadakis & Kalogiannakis, 2022). The goal is to put students at the centre of the evaluation process.

3 Methodology

We briefly explain the peer assessment tool workshop on Moodle and how we collected and analyzed the data in this section. The research followed an action research approach with different phases (Petousi & Sifaki, 2020). The study explored the intrinsic characteristics of each case to understand the evaluation processes involved in this research. It was not an instrumental case because we did not intend to get a general understanding. This method is suitable to address the proposed research problems since it allows us to answer the questions from a qualitative perspective, offering detailed information about the processes observed in each case studied (Creswell, 2012). The researchers did action research as part of their research teaching practices (Dahal & Pangeni, 2019; Dahal et al., 2022b; Mertler, 2009), focusing on mathematics. They studied action interventions and how well students worked in one of the tasks of 24 questions (See appendix 1) of SEE appearing students of 2021. They completed the study after implementing the action research cycles in various phases. In the first part of the study, they focused on integrating the self- and peer-assessment tools. This helped them figure out what kind of intervention students needed. During the middle phase, they trained selected students (18 out of 40) on how to assess their peers' work in the Workshop activity. In the last phase, they analyzed the results by interviewing the participants and analyzing how they reflected and assessed friends' work on Moodle. Table 1 shows the total number of students who participated in the study based on the availability of a personal computer to accomplish the peer review task.

Table 1 Participants in each phase of the study

Subject	Grade	Boys	Girls	Total
Mathematics	X	10	8	18

Table S1 (See in the appendices) has been used to evaluate the peer submission by students. The peer assessments assigned at random to the assessors are shown in Table 2.

Table 2 Random allocation of assessors and assessed

S.N.	Assessors	Assessed
1	Student 18 and Student 1	Student 2
2	Student 17 and Student 18	Student 1
3	Student 16 and Student 17	Student 3
4	Student 15 and Student 16	Student 4
5	Student 14 and Student 15	Student 5
6	Student 13 and Student 14	Student 6
7	Student 12 and Student 13	Student 7
8	Student 11 and Student 12	Student 8
9	Student 10 and Student 11	Student 9
10	Student 9 and Student 10	Student 10
11	Student 8 and Student 9	Student 11
12	Student 7 and Student 8	Student 12
13	Student 6 and Student 7	Student 13
14	Student 5 and Student 6	Student 14
15	Student 4 and Student 5	Student 15
16	Student 3 and Student 4	Student 16
17	Student 2 and Student 3	Student 17
18	Student 1 and Student 2	Student 18

We applied three categories of analysis to systematize this study: general process, representations used, and solutions found (de-Armas-González et al., 2023). To address the research questions with in-depth discussions, we collected data using various methods, such as a survey, an interview, phone calls, and informal discussions. We documented and reported all the processes in this paper. However, we did not have a fixed plan for data collection in this study. Instead, we used an iterative action process during problem finding, problem exploration, and problem evaluation (Dahal et al., 2022b).

4 Findings and discussions

This section analyzes the descriptive statistics of the responses of students' evaluations based on three categories of analysis: general process (followed as "✔" and not followed as "✘" on average), representations used (used as "✔" and not used "✘" on average), and solutions found (found as "✔" and not found as "✘" on average) on average marks evaluated by two peers with extended discussions on the later section of the each-stages of the research cycle's results. Table 3 shows the result of descriptive statistics.

Table 3 shows the result on average of the students assessed by two peers. The average marks secured by the students are relatively satisfactory, as the average mark is 41.85 out of 50 of 18 students. All the students (N = 18) followed the general processes while solving the algorithm mathematics problem, and representations for the solutions were used wisely by 12 students

Table 3 Analysis of the solutions

Students	Assessors	Average marks secured	General processes followed on average	Representations used for the solutions in average	Solutions found on average
2	Student 18 and Student 1	44	✔	✔	✔
1	Student 17 and Student 18	45	✔	✔	✔
3	Student 16 and Student 17	40	✔	✔	✔
4	Student 15 and Student 16	44	✔	✘	✔
5	Student 14 and Student 15	46	✔	✔	✔
6	Student 13 and Student 14	38	✔	✘	✘
7	Student 12 and Student 13	48	✔	✔	✔
8	Student 11 and Student 12	47.5	✔	✘	✘
9	Student 10 and Student 11	48.8	✔	✔	✔
10	Student 9 and Student 10	49	✔	✔	✔
11	Student 8 and Student 9	48	✔	✔	✔
12	Student 7 and Student 8	47	✔	✔	✔
13	Student 6 and Student 7	45	✔	✔	✔
14	Student 5 and Student 6	34	✔	✘	✔
15	Student 4 and Student 5	33	✔	✘	✘
16	Student 3 and Student 4	30	✔	✔	✘
17	Student 2 and Student 3	25	✔	✘	✘
18	Student 1 and Student 2	41	✔	✔	✔

on average. Nevertheless, five students needed help finding the exact solutions to algorithmic mathematics problems while solving them.

The following section discusses and analyzes each stage of the research cycle's outcomes while solving an algorithm mathematics problem. Self- and peer-assessment tools can be used in online platforms for school mathematics in terms of interactivity, self-and peer-assessment, and reflective learning in both on-school or blended modes. The themes emerged for discussion and analyzing each stage of the research cycle's outcomes.

4.1 Opportunities and challenges students encounter

Students' feedback after assessing peers' work included the following comments:

> *Being able to grade two solutions gave a much better idea, such as* $\overline{X} = \frac{168+14k}{12+k} = \frac{14(12+k)}{12+k} = 14$, *of what kinds of math solutions get high marks and what kinds get low marks, helping about solutions in a better way.*
>
> *A chance to learn how to grade assignments and to see what makes a perfect solution such as* $\frac{1}{y+b}+\frac{1}{y+c}+\frac{1}{y+d}+\frac{by}{y^2(y+b)}+\frac{cy}{y^2(y+c)}+\frac{dy}{y^2(y+d)} = \frac{1}{y+b}+\frac{1}{y+c}+\frac{1}{y+d}+\frac{b}{y(y+b)}+\frac{c}{y(y+c)}+\frac{d}{y(y+d)} = \frac{1}{y+b}+\frac{b}{y(y+b)}+\frac{1}{y+c}+\frac{c}{y(y+c)}+\frac{1}{y+d}+\frac{d}{y(y+d)} = \frac{y+b}{y(y+b)}+\frac{y+c}{y(y+c)}+\frac{y+d}{y(y+d)} = \frac{1}{y}+\frac{1}{y}+\frac{1}{y} = \frac{3}{y}$. *It helps a lot to have detailed criteria for evaluating the peers' solutions.*
>
> *It is a good process because it is our first time, and we need to be educated and assisted peers' solutions.*
>
> *The peer review process could be more successful. This is because I have noticed that some friends do not know what they are evaluating as suggested in the marking scheme, so when marking other peers' tasks based on the marks scheme, they shall correct and mark the proper solutions wrong.*

Listening to what students had shared about their experiences while assessing peers' algorithm mathematical problems solving skills was incredibly rewarding as assessors (Lavidas et al., 2022). All students agreed that peer assessment was an effective way to learn and evaluate their peers' tasks. Most found that peer reviewing provided the best opportunity to improve their work while helping their peers. Mathematics teachers can use the peer assessment feature to assign individual students a set number of submissions to grade and comment on, with each opinion receiving a score added to their grade for submitting work on time. The Workshop's primary goal is to create a collaborative learning environment that encourages students to provide feedback on their peers' submissions and learn from each other (Dahal, 2019; Dahal, 2022). Peer evaluation is an essential part of the learning process for students in mathematics, as it provides them with additional perspectives on their efforts and helps them identify areas for improvement (Dahal & Pangeni, 2019). While self-assessment focuses solely on individual activities, peer-assessment strategies consider both the individual and their classmates' work, promoting critical thinking skills and the development of different perspectives (Wang et al., 2014). The study found that peer review improved evaluation skills based on criteria, even in mathematical solutions, though it was challenging for students to defend the quality of their solutions. Some challenges included grading and marking, content-based analysis, time constraints, liberalism, and a lack of knowledge about evaluation criteria (Dahal & Pangeni, 2019). However, despite these challenges, peer review helped students develop new ideas and concepts (Lavidas, Apostolou & Papadakis, 2022), better understand different aspects of the same thing, and cultivate a culture of idea-sharing (Dahal & Pangeni, 2019). To participate in the Workshop, students must review at least two of their classmates' solutions, which helps them make sound decisions and thoroughly understand the solutions. The Workshop tool can play a role in changing the culture of learning in mathematics, as it aids students in learning while being graded (Dahal & Pangeni, 2019).

4.2 Students as reviewers

In response to the question, how can students be encouraged to assess and improve each other's work? One of the students comments on collaborative work on:

Collaboration often takes longer, so working this way means more work, but the ideas that come out of it give students more exciting and rewarding ways to learn, such as techniques and methods to find the solutions to mathematical algorithm problems. At first, it was hard, and it took much time to incorporate all the ideas into the practice.

Once the activity has been configured in their LMS course block, Workshop can accept student submissions. Before submitting their work, students can review the sample submission provided by the course facilitators to understand how the feature works. Most students submitted their work in .pdf format. After the submission phase, the student submissions undergo peer review during the assessment stage. Table 2 outlines the evaluation criteria used during the evaluation process. The first step is establishing how students will provide feedback, assign grades, and justify their evaluations. We discovered that some students used a rigid evaluation standard based on the provided criteria (Lavy & Shriki, 2014). Although comments and feedback can be valuable, some students needed to address all the evaluation components they were expected to, resulting in generic and misaligned feedback on mathematical solutions. Furthermore, students needed to show more concern for their peers' opinions on the feedback provided, resulting in excessively generic comments. We realized that the evaluation process should prioritize fairness in how students evaluate and provide feedback to one another.

4.3 Workshop tool for mathematics teachers

The mathematics teacher significantly impacted the planning and implementation of the activity. Mathematics teachers need to consider how they will evaluate the activity and how it will be implemented using both ideas and technology (Zourmpakis, Papadakis & Kalogiannakis, 2022). Once the activity is set up with all essential phases, such as instructions for submission, grading, and evaluation, mathematics teachers must still be available to help students with any issues, although their role becomes less important. The smooth running of this activity relies on the careful assignment of submissions to reviewers and transitions between phases, whether done manually or automatically. The first author commented that this alignment with what was going on in each class improved their school experience, and mathematics teachers saw the value in the methods of instruction and evaluation used. This activity makes it easier for mathematics teachers to keep track of grades and assign work for peer review, grading, and comments. The average of both submission and assessment grades is automatically calculated. Using this activity, course facilitators can do less manual work when teaching and grading small or large groups of students in mathematics (Habiyaremye et al., 2022). However, some mathematics teachers hesitated to use the Moodle-based Workshop activity due to needing more time to learn the new tool and being accustomed to communicating with students through email. The system's feature of adding grades to submissions and assessments is also enjoyable. Instead of grading, mathematics teachers can add their grades to each student's record or accept the ratings of their peers. They can also transfer tasks to be reviewed anonymously by peers. This ensures that students give honest ratings, as they cannot see the name of the author or reviewer. Nevertheless, mathematics teachers must ensure that they understand the setup of the activity well.

4.4 Students' experiences

The students who participated in the activity were unfamiliar with the self-and peer assessment process but found it enjoyable. Evidence of their self-awareness was seen in their use of language, elaboration of arguments, fair judgment of their peers' work, and completion of their assignments promptly (Kalogiannakis & Papadakis, 2020). Some students found it challenging to be honest about their work and compare it to others, especially those who had never done peer review before or used the LMS Workshop feature. However, all students agreed that the

Workshop provided opportunities to learn from peers' solutions and improve their learning. One student remarked that after orientation from the mathematics teacher, the tool was easy to use for learning and evaluating peers' work in mathematics. Another student suggested that students have some experience marking their work before evaluating their peers' submissions. After submitting their work and receiving feedback from peers and mathematics teachers, the students reported that they could submit their work on time. However, some needed help with the peer review process, as they had to judge their peers' work and make connections between ideas and the learning process. Some found the evaluation criteria and items to be marked clearly, while others found it too much work to look over the work of two peers at once.

5 Conclusions and implications

We learned from this research that Workshop activity helps students learn mathematics concepts. Engaging students in the assessment process can help them become more engaged and invested in their learning, boosting the quality of their mathematics learning (Beltozar-Clemente et al., 2022). Even though it was short and only looked at one of the tasks of 20 questions and 50 full marks. This study helped us understand students' difficulties while assessing peers' solutions to mathematical algorithm problems. Based on the discussion, we offered some of our experiences for how others can use self- and peer-assessment to improve students' short- and long-term learning outcomes in school mathematics. Opportunities and challenges students face, students as a reviewer, workshop tools for mathematics teachers and participants' experiences are at the centre of the discussion of this paper.

In the same way, it would be helpful for this research to be done over a more extended period to cover how such as online assessment tool is used in mathematics courses. We also helped students to work together to learn using self- and peer-assessment skills. Workshop's technological tools are new and have the potential to change how mathematics teachers could use for assessing students' submissions, as the mathematics teachers have a hard time designing, making, and implementing the activity because they are struggling and do not know how to use such online peer evaluation technology tools (Campos-Pajuelo et al., 2022). Mathematics teachers must attend in-house mathematics training sessions to excel in Workshop activity. Workshops in the Moodle system offer both opportunities and challenges. The main challenge is that many mathematics teachers must learn about this important and valuable feature of the Workshop tool for self-and peer assessment in mathematics (Qureshi & Qureshi, 2021).

Likewise, high school students who participated in the activity learned to assess peers' submissions in blended and/or on-school. Even high school mathematics teachers can implement these essential evaluations tool in a school mathematics course for evaluation self and peer assessment tools. It helps us offer a new method for enticing students to learn mathematics as assessors of peers' submissions. We have introduced a new approach to learning and assessment in Nepal, which involves even-for-school mathematics. This tool allows students to keep track of peer reviews and assignments anonymously, and self-and peer assessment is a crucial resource for online and distance learning in mathematics. Students are allowed to offer constructive feedback to their peers through insightful comments. Peer-review activities can keep students engaged, primarily when the mathematics teachers are occupied with regular academic responsibilities (Can & Bardakci, 2022). Before setting up the Workshop and transitioning between phases, mathematics teachers must focus on thoroughly learning and implementing the tool. Whether the course is online, distant, or face-to-face, this activity can effectively evaluate students' work by assessing their peers' submissions.

Author contributions

Niroj Dahal conducted the research with the help of Indra Mani Shrestha, Netra Kumar Manandhar, and Laxman Luitel; Niroj Dahal, Binod Prasad Pant, and Bal Chandra Luitel analyzed the data; Niroj Dahal draft and address the concerns raised by reviewers with the help of all the authors; all authors had approved the final version.

Availability of data

Upon a reasonable request, the corresponding author will provide the information supporting the study's conclusions.

Conflicts of interest

The authors declare that there are no conflicts of interest.

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