
Impacts of Formative Rubrics on Secondary Mathematics Self-efficacy: A Quasi-experimental Study in Zambia

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ABSTRACT

Rubrics have the potential to support student learning through transparency of learning outcomes and formative feedback. However, their value in improving mathematics self-efficacy is contradictory and is significantly biased towards higher education students. Therefore, this study investigated the impacts of using rubrics for formative assessment on mathematics self-efficacy of secondary students when learning quadratic equations in one rural district, Zambia. Using a quasi-experimental design, six grade eleven classes (n=149) from three secondary schools were selected at random, along with their teachers. Students from three classes were randomly assigned to experimental groups (n = 78) and used rubrics to obtain formative feedback that encouraged self-assessments for six weeks in the second term of 2024. The other three comparison groups (n = 71) implemented the same formative assessment practices without rubrics. The teachers used the formative feedback to differentiate effective teaching and learning approaches and to revise ineffective ones to promote students' learning. Self-efficacy questionnaires were used to collect the data from students, and mixed model ANOVA with repeated measures was performed using SPSS v.25. The results showed that secondary students who used rubrics for formative assessment significantly improved their self-efficacy in quadratic equations over time more than those who did not use rubrics, $F(1,147) = 18.24, p < .05$. Therefore, by providing transparent learning outcomes, timely feedback on strengths and weaknesses and supporting self-assessment, using rubrics as assessment tools is especially beneficial for improving secondary students' self-efficacy in mathematics. Effective training of students in formative rubrics remains equally crucial.

1. Introduction

Mathematics self-efficacy is a self-belief system derived from a person's confidence of his/her own ability to carry out mathematics actions required to achieve specific types of performances (Bandura, 1997). Self-efficacy is widely viewed as an influential predictor of student learning behaviors in mathematics (Mues *et al.*, 2025; Smit *et al.*, 2023), and plays a crucial role in the learning process (Blondeel *et al.*, 2024). Students levels of mathematics self-efficacy determine how they cope with mathematics tasks and how much efforts they put in to pursue academic activities

(Schimmelpfennig, 2025). Literature extensively agrees on the positive relationship between formative assessment practices and students' self-efficacy (Pancorbo *et al.*, 2021), where students are told what is expected, areas of strengths and improvements, as well as how the students should go about moving forward on their own (Blondeel *et al.*, 2024; Karaman, 2021; Yan & King, 2023). On the other hand, lower levels of mathematics self-efficacy have unfavorable far-reaching consequences on mathematics learning such as inability to complete assignments (Schimmelpfennig, 2025), and high levels of performance-avoidance self-regulations (Blondeel *et al.*, 2024; Myyry *et al.*, 2022; Panadero *et al.*, 2023; Panadero & Jönsson, 2013). Having said that, the challenge the teachers face in mathematics is to improve students' self-efficacy for a sustainable learning (Smit *et al.*, 2023). A need for this study was identified, by transforming principles of formative assessments (Ministry of Education, 2013a), into assessment guidelines to support secondary teacher's pedagogical practices through clear learning outcomes and formative feedback that promote self-assessment by means of rubric criteria.

As defined by Brookhart (2018), rubrics are assessment tools that list what students should include in their work to achieve specific levels of performance from excellent to poor. The use of rubrics by the students in higher education has shown to contribute to improved mathematics learning outcomes (Fitriyani & Evendi, 2024; Hattori *et al.*, 2025; Tashtoush *et al.*, 2023), and motivation to learn among the students (Fraile *et al.*, 2023; Panadero *et al.*, 2023). For example, higher education mathematics students who used rubrics as a guide when completing assignments achieved higher performance, higher self-efficacy, and greater accuracy compared to students who did not use rubrics (Auxtero & Callaman, 2021; Fraile *et al.*, 2023; Ling, 2024; Richiteanu-Nastase & Mihaila, 2023; Shirawia *et al.*, 2024; Smit *et al.*, 2023; Suryanti & Nurhuda, 2021). According to these studies, the use of rubrics provided students with clear guidelines for reflections, supported a common understanding of learning outcomes between the teachers and the students, and a fair and transparent assessment. Similarly, secondary mathematics students who used rubrics to obtain timely feedback and guiding self-assessment significantly performed better than students who did not use rubrics (Gallego-Arrufat & Dandis, 2014; Mwamba *et al.*, 2025)

Rubrics may be holistic which evaluates student's work as a whole or analytic which evaluates student's work by breaking it down into separate criteria (Morton *et al.*, 2021). Previous studies report that rubrics have the potential to improve mathematics learning outcomes particularly when they are analytic, and on the other hand, have limited impacts when they are holistic (Ling, 2024; Panadero & Jönsson, 2013). For example, Tashtoush *et al.* (2023) investigated the impact of using scoring rubrics on assessing the performance of students enrolled in a Calculus course. The results showed that students whose performance in Calculus was assessed using analytic rubrics was higher than students who were assessed using holistic rubric. In this study thereof, the term formative rubrics is used to imply the existence of an analytic scoring scale based on the SOLO (structure of observed learning outcomes) taxonomy. The SOLO taxonomy was developed by Biggs and Collis to describe the quality of learning through five levels of understanding from pre-structural level to extended abstract level (Adeniji *et al.*, 2022). The prototypical levels of the SOLO taxonomy are described as follows:

Pre-structural level: The task is inappropriately attempted. The student requires help.

Uni-structural level: One aspect of the task is achieved, and the student's understanding as a whole is not fully realized.

Multi-structural level: Several aspects of the task are achieved, but their relationships as a whole are disconnected and limited.

Relational level: Several aspects of the task are integrated and are attributed to a deeper understanding as a whole.

Extended Abstract level: A new understanding at the previous relational level is rethought at another conceptual level and in a new way, and is the basis for prediction, generalization, reflection, or creation of a new understanding.

While other frameworks such as Bloom's cognitive taxonomy (Anderson & Krathwohl, 2001) focuses largely on the cognitive processes such as applying and analyzing, the SOLO taxonomy focuses on the structure of the student's response, showing the quality and complexity of understanding and how well the students applied or analyzed

mathematical concepts (Adeniji *et al.*, 2022; Claudia *et al.*, 2020). Using the SOLO taxonomy in mathematics teaching and learning matters because it clearly shows if a student is just listing facts (uni-structural) or connecting concepts (relational), to highlighting why the students struggle, not just if they struggle (Mwamba *et al.*, 2025; Weeda *et al.*, 2020). By providing clear success criteria say from pre-structural level to extended abstract level, the SOLO taxonomy supports teachers in creating specific activities for each level, ensuring mathematics tasks challenge students at their current cognitive stage from simple formula application (multi-structural) to abstract thinking (Mukuka *et al.*, 2020a; Valenzuela-Gonzalez *et al.*, 2021). Thus, pushing students beyond surface-level knowledge (remembering facts) towards higher-order skills like creativity, critical thinking, and applying mathematics concept in new contexts (extended abstract) (Ghunaimat & Alawneh, 2024; Mukuka *et al.*, 2021; Parameswari *et al.*, 2023). By understanding a student's SOLO level, Mukuka *et al.*, (2020a) reported that secondary school teachers can decide the best remedial work in responding to student's mathematical learning difficulties or the next challenging problem, leading to effective pedagogical changes.

Rubrics can be used for formative or summative purposes (Panadero & Jönsson, 2013). Summative rubrics are usually used to evaluate students' performance at the end of the learning process (Ling, 2024), whereas formative rubrics are used primarily to assess students' learning during the learning process, to provide feedback, and to monitor learning to improve performance (Ling, 2024; Panadero *et al.*, 2024). The formative feedback inform students on the mastery of their mathematical concepts (Blondeel *et al.*, 2024), help students to identify their strengths and weaknesses, encourage students to improve their mathematical knowledge, promote deep learning, and motivate them to study more (Auxtero & Callaman, 2021). With the overall benefits of good design and classroom discussions with students, formative rubrics are associated with an increase in students' mathematics self-efficacy through transparency of learning outcomes (Karaman, 2021; Myyry *et al.*, 2022; Panadero & Jönsson, 2013), enabling students to understand the requirements of the task and improve the performance on their own through self-assessment and formative feedback (Fraile *et al.*, 2023; Liu *et al.*, 2016; Rakoczy *et al.*, 2019).

1.1 The current study

Extensive research reports that rubrics have the potential to support mathematics learning outcomes through transparency of learning outcomes, improving the use of formative feedback on strengths and weaknesses, and encouraging students to assess their own work (Auxtero & Callaman, 2021; Blondeel *et al.*, 2024; Fitriyani & Evendi, 2024; Malespina & Singh, 2022; Myyry *et al.*, 2022; Tashtoush *et al.*, 2023; Toalongo *et al.*, 2022). However, their value in improving students' self-efficacy is contradictory and significantly biased towards students in higher education (Brookhart & Chen, 2015; Panadero *et al.*, 2023; Panadero & Jönsson, 2013; Reddy & Andrade, 2010). The contradictory findings are also reported with regard to whether or not rubrics were shared with students (Ling, 2024). Although students agree that rubrics help them to focus their efforts, produce quality work, earn better grades, and feel less anxious (Andrade *et al.*, 2009), Panadero and Jönsson (2013) noticed that some secondary school students exhibited more actions which were detrimental to mathematics learning and higher stress levels than higher education students after using rubrics. Other students also perceived rubrics as tools for satisfying the teacher's demands rather than as representations of the criteria to be achieved (Estaji, 2012; Reddy & Andrade, 2010). These contradicting perspectives provide opportunities to design better studies and ultimately strengthening rubric's potential to support student learning. Therefore, this study investigated how the use of formative rubrics, which include transparent learning outcome, detailed feedback, and supporting student self-assessment impacts secondary school students' mathematics self-efficacy regarding their ability to learn quadratic equations. One research question was formulated to guide the investigation; What are the impacts of rubrics on secondary school students' self-efficacy about themselves as learners of quadratic equations?

1.2 Development and validation of rubrics to assess quadratic equations learning outcomes

Quadratic equations form fundamental topics in the Zambian education, where students are expected to acquire mathematical reasoning skills and graphical fluency in order to approximate solutions using graphs (Ministry of Education, 2013a, 2024). However, previous studies report that secondary students face challenges such as not being able to correctly use and apply the formula (Examinations Council of Zambia, 2022, 2023), had little understanding of the zero-product law (Mukuka *et al.*, 2020b), and completing the squares method (Lopez *et al.*, 2015). Graphs of quadratic equations were characterized by no clear labelling of the axes, wrong scales, curves not being smooth and mathematically incorrect (Examinations Council of Zambia, 2023). These challenges in quadratic equations are ascribed to the way teachers taught and assessed student's work, which was mostly based on the use of closed-ended assessment tests and quizzes (Guat Poh *et al.*, 2015; Ministry of Education, 2013a; Mukuka *et al.*, 2020b). Nevertheless, prior research suggests that the use of rubrics can improve the way teachers teach and assess students' learning outcomes

in mathematics (Hattori *et al.*, 2025; Tashtoush *et al.*, 2023). Therefore, the authors analyzed learning outcomes associated with quadratic equations in the Zambian secondary schools namely, solution by graph, factorization, completing squares and quadratic formula methods (Ministry of Education, 2013b, 2024), and developed four questions for assessing students' understanding of quadratic equations with respect to each of the criteria. With those questions, a rubric as well as a scoring strategy based on the SOLO taxonomy (Mukuka *et al.*, 2020a), was developed (see Table 1A in Appendix 1). The guidelines advanced in previous literature (Brookhart, 2024; Ling, 2024; Morton *et al.*, 2021) for designing effective classroom rubrics such as defining desired learning outcomes and assessment criteria, determining levels of performance and deciding on the scoring scale were adopted.

The rubric was assessed for content and criterion validity (Mohajan, 2017). Five subject matter experts independently examined the content validity and item validity evidence of both the rubric and test items respectively (Bhatnagar *et al.*, 2021; Brookhart & Chen, 2015). The experts also examined the clarity of behavioral descriptors at each level of the rubric to ensure they provided enough evidence to assess different levels of performance of quadratic equations from pre-structural level to extended abstract level, called criterion validity evidence (Brookhart & Chen, 2015). Experts' differing opinions were debated until a consensus was established. Additionally, wording was changed to incorporate observable skills and desired competences into the rubric.

Thereafter, ten students completed the quadratic equations pilot test and their answer scripts and a rubric were photocopied and shared among the four experts. Each student's response to test items was analyzed by experts independently using the rubric and the inter-rater agreement was determined by computing the Fleiss' kappa statistic using Statistical Packages for the Social Sciences (SPSS) version 25. Fleiss' kappa coefficients have been widely used to evaluate inter-rater reliability for multiple raters (Hattori *et al.*, 2025). The Fleiss kappa showed that there was a significant agreement among the raters with kappa values $\kappa = 0.831$, $p < 0.5$, suggesting that the raters used the rubric to grade student's responses to quadratic tasks consistently (Brookhart & Chen, 2015).

2. Methods

2.1 Research design and sampling procedures

This study employed a quasi-experiment, non-equivalent comparison group design (Ishtiaq, 2019). This design was more suitable to investigate the impact of rubrics in real-time classroom contexts, where randomization may not be possible (Mukuka *et al.*, 2021). Mafinga district was conveniently selected because it was cost effective and convenient to the researchers compared to other sampling techniques (Chittaranjan, 2021). Then, multiple-stage sampling procedures were followed to select schools and students (Creswell, 2009). Using simple random procedures (Singh & Masuku, 2011), three secondary schools were randomly selected from nine schools. Then, two intact grade 11 classes from each school were randomly selected and were allocated into experimental or comparison groups at random. Eventually, three classes and their teachers formed experimental groups ($n = 78$, 40 males and 38 females) and the other three classes formed comparison groups ($n = 71$, 38 males and 33 females).

2.2 Experimental procedure

The use of rubrics was integrated into three assessment practices; think-pair-share, group activities, and individual activities. In each lesson, the teachers introduced quadratic concepts through think-pair-share activities that encouraged students to discuss, share ideas, and learn from each other in order to improve understanding of quadratic equations. Thereafter, the students in small groups worked on the same task for 15–25 minutes, discussing the strengths and weaknesses of their own work. Upon completion, the teachers asked pairs of groups to exchange solutions and assessed the other group's work without assigning scores (peer assessment). This group assessment took an extra 10–15 minutes and enabled students to provide oral feedback on the other group's work, debating on the strengths and areas to improve (peer feedback). Following that, the teachers provided feedback to each group on the needy areas with nuanced information on how to improve in future assignments (teacher feedback). Here, the teachers from experimental groups used rubrics as a basis for communicating their objective feedback to students.

Finally, students completed the same classwork individually. Upon submission, the teachers checked the correctness of the completed work and provided feedback to students on areas that needed improvement. The teachers also used

feedback from the analysis of students' work and from face-to-face conversations to align instructions with assessment activities and the desired learning outcomes to improve student learning. While completing the tasks, the students from experimental groups used rubrics to score their own work from pre-structural level (0) to extended abstract label (4) and recorded the score at the end of each task. The self-score was used exclusively to guide studying, revisions, and monitoring the learning progress. Unlike the feedback without rubrics, teachers from experimental groups provided rubric-based feedback by indicating the level of performance achieved by the student from 0 to 4 and encouraged the students to practice the algebraic skills where they scored low marks (0–2).

To ensure the research measured the impacts of the intervention while minimizing teacher effects, the researchers provided in-service support to individual teachers through collaborative lesson planning. Fidelity of the intervention was achieved by ensuring that the teachers taught quadratic equations three times a week, covered the same quadratic equations content and conducted a total of fifteen lessons across a six-week period in the second term of 2024. The duration of each lesson was 80 minutes.

2.3 Data Collection instrument and procedures

In this study, the researchers relied on the adapted self-efficacy questionnaire with eight items based upon the Shavelson and Bolus's (1982) model to measure mathematics self-efficacy from totally agree to totally disagree. The items asked students about how easy and challenging they perceived quadratic equations and about how they dealt with quadratic tasks in terms of avoiding or not avoiding. While aware of many self-efficacy questionnaires in literature (Stodolsky *et al.*, 1991; Szydlik, 2000; Tapasak, 1990), the adapted questionnaire was chosen because of its extensive use in different contexts and cultures (Balan, 2012; Mason, 2003; Schommer-Aikins *et al.*, 2005; Steiner, 2007). Leach *et al.* (2006) provided relatively strong evidence of the instrument's ability to yield reliable scores from 19 studies that applied it. In addition, Balan (2012) also used and administered the self-efficacy questionnaire to 45 first year university students to analyze students' responses using factor analysis. The students rated the items using a four-point response options for each item: totally agree, agree, disagree, or totally disagree and the calculated Cronbach's alpha reliability was, $\alpha = 0.77$, confirming the reliability of the scale. In this study, items were slightly revised to suit the focus of the study. For example, the item "Maths is easy for me to understand" was changed to "Quadratic equations are easy for me to understand". Five items were positively worded while other three were negatively worded and had a reliability index of, $\alpha = .75$, computed using data gathered from a pilot study involving 17 secondary school students. The full details about the questionnaire items are reported verbatim in the Results section. The use of questionnaires enabled researchers to capture data from relatively large sample size (Ishtiaq, 2019).

To collect the data, researchers administered the mathematics self-efficacy questionnaire to students both before and after the intervention. The students rated the items on a 5-point Likert-type scale ranging from totally agree to totally disagree. Students took about fifteen minutes to complete the questionnaire. Students' mathematics self-efficacy was measured through the following procedures;

- (1) For every item, a different value was assigned to possible answers; 5 = totally agree, 4 = agree, 3 = neutral, 2 = disagree and 1 = totally disagree. Negatively worded items were coded in reverse from totally agree (1) to totally disagree (5) so that high values indicated the same type of response on every item (Dodeen, 2023).
- (2) For each student, a mean value was obtained by adding the values corresponding to items on the scale divided by the number of items.
- (3) A positive self-efficacy was associated with item mean values equal to or greater than 3.51. Mean values between 2.51 and 3.5 represented that students were not sure. On the other hand, negative self-efficacy was associated with mean values equal to or less than 2.50 (Lindner & Lindner, 2024). The researchers compiled the results for analysis.

2.4 Data analysis

Descriptive statistics (mean and standard deviation) were used to summarize the results. A mixed model analysis of variance (ANOVA) with repeated measures was used to assess the impact of time on students mathematics self-efficacy (Hagos & Andargie, 2022). The independent variable, gender of the student, was added as a covariable. Statistical assumptions behind the use of the mixed model ANOVA were checked and satisfied (Blanca *et al.*, 2023). The test of within-subject factor was performed using pre-test and post-test measurements while the test of between-subject factor was performed to compare self-efficacy between comparison groups and experimental groups. Paired samples t-test was performed to investigate whether there was a significant improvement within each group. SPSS

version 25 was used for this investigation. All statistical tests were run for significance at the 0.05 level (Rudas, 2018).

3. Results

Descriptive statistics for pre-test and post-test measurements are presented in Table 1.

Table 1. Descriptive statistics between comparison groups and experimental groups between measurements

Measurement	Comparison groups (<i>n</i> = 71)		Experimental groups (<i>n</i> = 78)		Grand mean (<i>n</i> = 149)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Pre-test	3.47	0.50	3.53	0.54	3.50	0.52
Post-test	3.14	0.66	3.81	0.58	3.49	0.71
Estimated marginal means	3.31	0.05	3.68	0.04	3.49	0.03

Results in Table 1 show that students from comparison groups changed the belief about their ability to learn quadratic equations after the intervention ($M = 3.14$, $SD = 0.66$) towards lower self-efficacy and lower confidence in their own abilities to cope with quadratic instructions than they were before the intervention ($M = 3.47$, $SD = 0.50$). The paired samples t-test for difference between means indicated that the negative change was significant, $t(70) = 3.04$, $p < .05$, 95% CI [0.11,0.54], Cohen's $d = 0.6$, indicating a moderate, noticeable effect (Cohen, 1988). This shows that the majority of students who did not use rubrics responded in a way that showed that they struggled to understand quadratic equations even after learning the topic in full [items, 1, 2, 4, and 5]. Additionally, students' responses also showed that they did not like doing quadratic equations and did not care whether or not they understood quadratic equations after the intervention (items 3, 6 and 8). Furthermore, these students responded that they were only studying quadratic equations because it was applied in other math topics (item 7).

On the other hand, students who used formative rubrics changed their answers about how they perceived themselves as learners of quadratic equations after the intervention ($M = 3.81$, $SD = 0.58$) in a way that indicated positive self-efficacy and higher confidence in their own abilities to cope with quadratic instructions than they were before the intervention ($M = 3.53$, $SD = 0.54$). A paired sample t-test showed that the positive change was significant, $t(77) = 3.04$, $p < .05$, 95% CI [-0.47,-0.10], Cohen's $d = 0.5$, indicating a moderate, noticeable effect (Cohen, 1988). This shows that the majority of students who used rubrics responded that they found quadratic equations interesting and easy to understand after the intervention (items, 1,2, 4, and 5), that they enjoyed doing quadratic equations with friends (items 3, 6 and 8) and that they studied quadratic equations because it was applied not only in other math topics but also in daily life (item 7). The item-mean distributions between students from comparison group and those from experimental group over two measurement times are shown in Table 2.

Table 2. *Distribution of means and standard deviations on items for each group before and after the intervention*

No.	Items	Measurement	Comparison group		Experimental group	
			<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
1	Quadratic equations are easy for me to understand.	Pre-test	3.25	1.16	3.10	1.14
		Post-test	3.68	1.15	3.65	1.20
2	I feel bad when I don't understand quadratic equation concepts	Pre-test	4.10	0.97	3.55	1.25
		Post-test	3.62	1.47	4.23	1.14
3	In class, my friends come to me for help in quadratic equations	Pre-test	3.30	1.15	2.90	1.27
		Post-test	3.44	1.15	3.50	1.29
4	I think that quadratic equation problems can be interesting and challenging.	Pre-test	3.32	1.12	3.03	1.21
		Post-test	3.51	1.16	3.87	1.22

5	I have difficulties understanding quadratic equations.	Pre-test	3.17	1.24	2.76	1.34
		Post-test	2.92	1.23	3.14	1.34
6	I avoid anything to do with quadratic equations.	Pre-test	3.70	1.03	2.76	1.31
		Post-test	3.41	1.36	3.65	1.39
7	I'm only studying quadratic equations because they are applied in other maths topics.	Pre-test	2.63	1.31	2.85	1.37
		Post-test	3.05	1.60	4.00	1.34
8	I've always done well in quadratic equations.	Pre-test	2.82	1.06	2.85	1.06
		Post-test	3.04	1.21	3.09	1.23

Furthermore, the results from the mixed model ANOVA are presented in Table 3 and Table 4 for the test of within-subject effect (pre-test and post-test) and test of between-subject effect (comparison groups and experimental groups) respectively.

Table 3. Test of within-subject effects between pre-test and post-test

Source	Type III Sum of Squares	<i>df1</i>	<i>df2</i>	<i>F</i>	Sig.	Partial Eta Squared
Time	Sphericity Assumed 0.40	1	147	1.07	.303	0.00
Time×Gender	Sphericity Assumed 0.54	1	147	1.42	.235	.01
Time×Group	Sphericity Assumed 6.88	1	147	18.24*	.000	0.11

Note. Asterisk (*) means effect is significant at $p < .05$

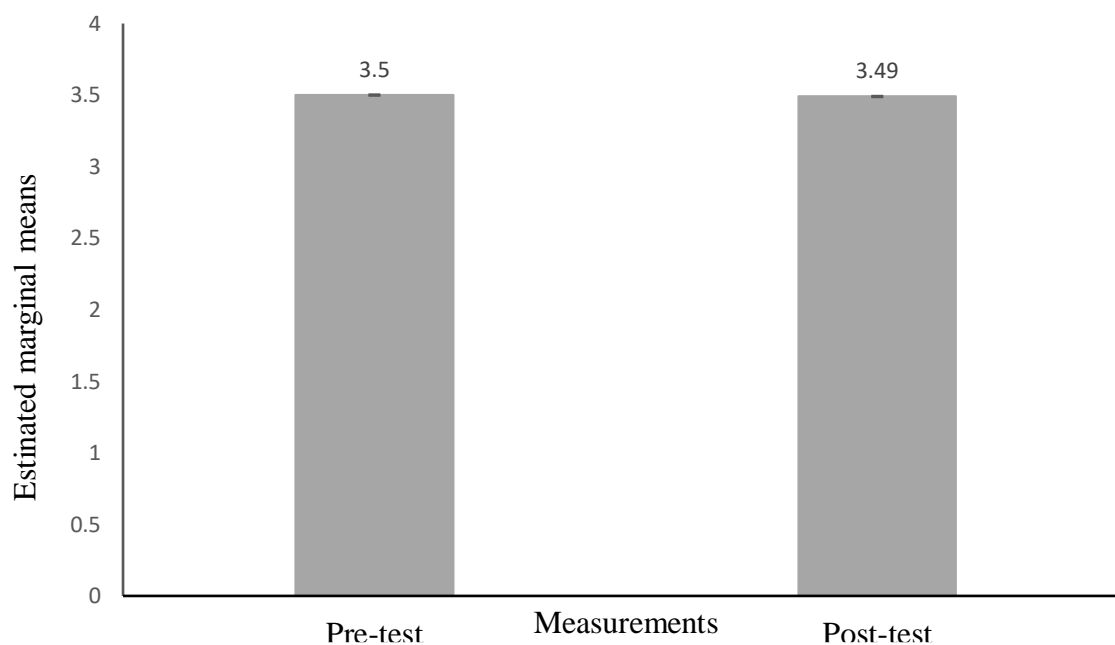
Table 4. Test of between-subject effect between comparison group and experimental group

Source	Type III Sum of Squares	<i>df1</i>	<i>df2</i>	<i>F</i>	Sig.	Partial Eta Squared
Intercept	360.57	1	147	1269.32*	.000	0.89
Gender	0.13	1	147	0.36	.548	0.00
Group	10.23	1	147	36.00*	.000	0.20

Note. Asterisk (*) means effect is significant at $p < .05$

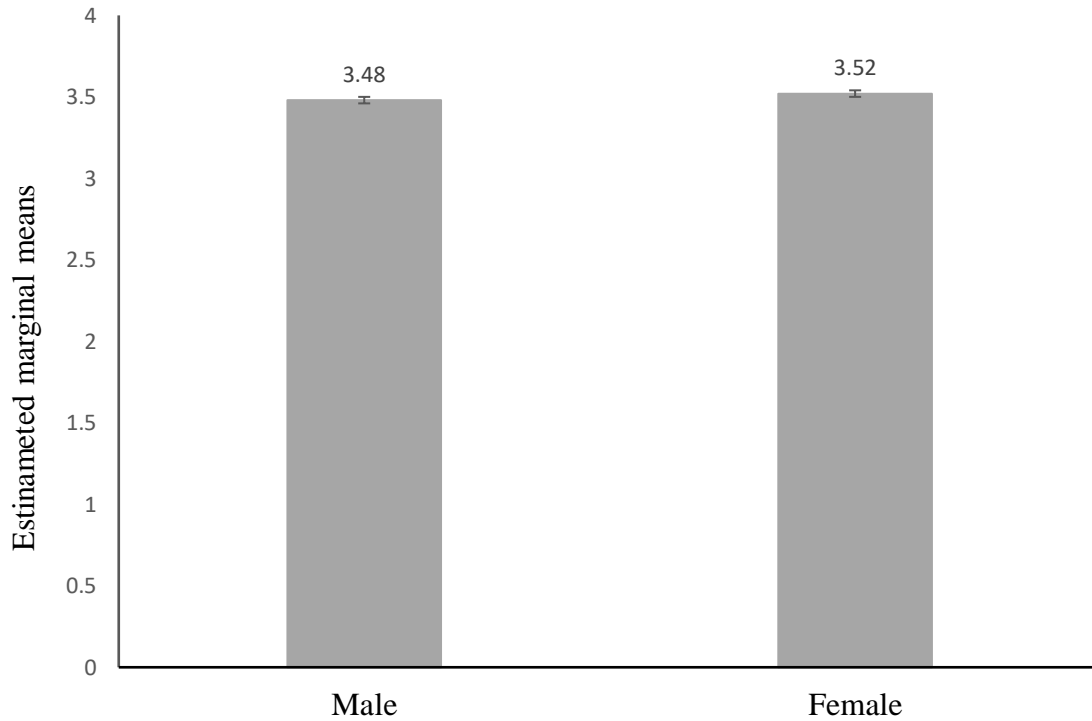
Firstly, Table 3 results show that the impact of time on mathematics self-efficacy was not significant, sphericity assumed, $F(1,147) = 1.07, p > .05$, Partial Eta Squared = 0.00 and 95% CI [-0.14, 0.16]. In other words, time between measures did not significantly predict students' mathematical self-efficacy, thus, pre-test and post-test scores were similar (see Figure 1).

Figure 1. Mathematics self-efficacy between pre-test and post-test measurements



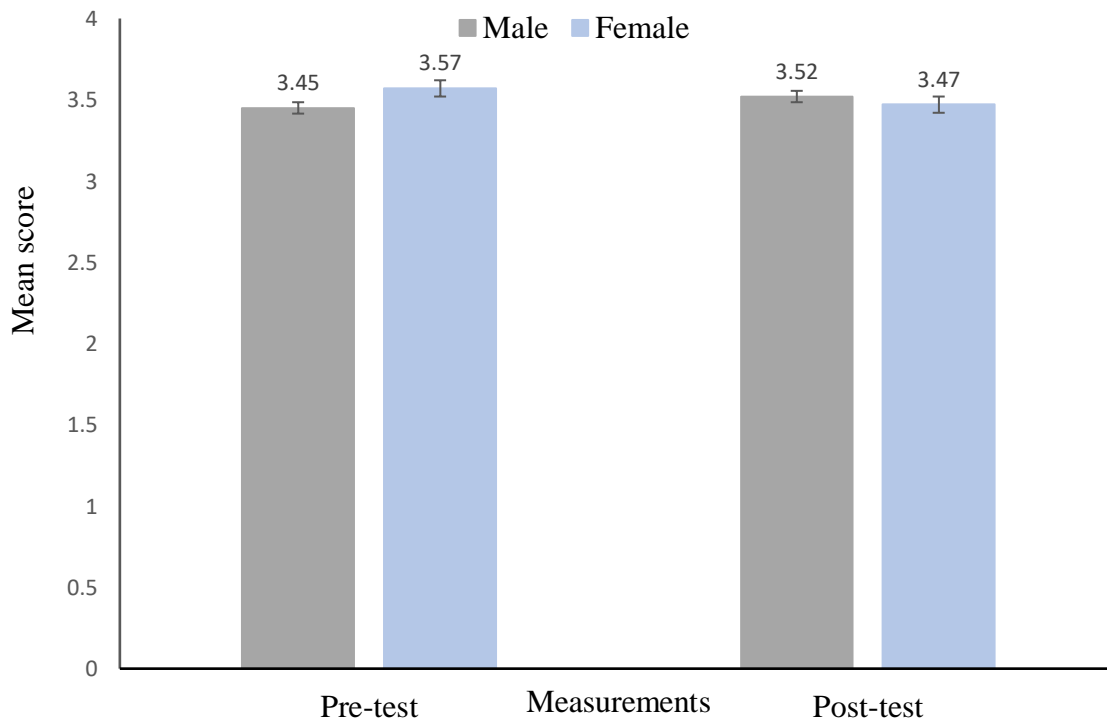
Secondly, results in Table 3 also revealed that the impact of gender of the student over time on self-efficacy was not significant, sphericity assumed, $F(1,147) = 1.42, p > .05$, Partial Eta Squared = 0.01 and 95% CI [-0.16, 0.09]. Thus, the gender of the student did not significantly predict students' mathematics self-efficacy over time (see Figure 2).

Figure 2. Mathematics self-efficacy between male and female over time



Similarly, Table 4 and Figure 3 confirm the non-significant impact of gender over time between male ($n = 78$, $M = 3.48$, $SD = 0.04$) and female ($n = 71$, $M = 3.52$, $SD = 0.05$), equality of variance assumed, $F(1,147) = 0.36$, $p > .05$, 95% CI [-0.16, 0.09].

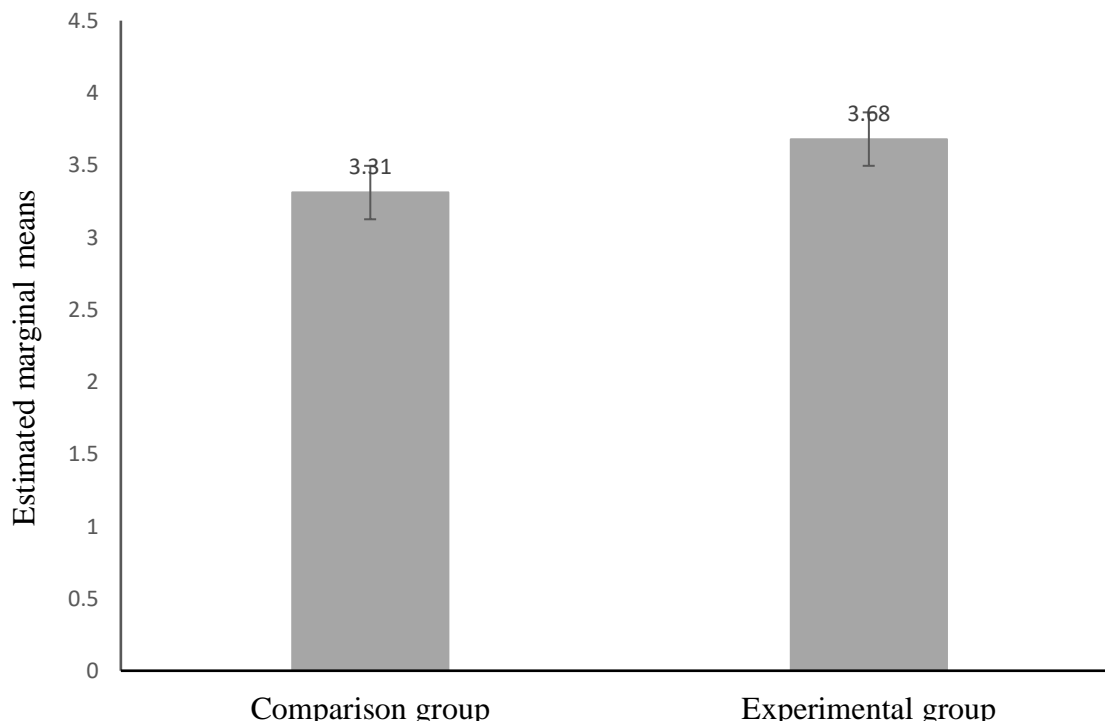
Figure 3. Mathematics self-efficacy between males and females over pre-test and post-test measurement



Nevertheless, the results in Table 3 show that the impact of group of students over time was significant, sphericity assumed, $F(1,147) = 18.24$, $p < .05$, 95% CI [3.43, 3.55]. Group had a moderate effect size of, Partial Eta Squared

= 0.11, suggesting that group of the student accounted for 11% of the variation in students' mathematics self-efficacy results. These results therefore, showed that group membership was a significant predictor of students' mathematics self-efficacy and that students from experimental groups developed higher positive self-efficacy than those from comparison groups over time (see Figure 4).

Figure 4. Students' mathematics self-efficacy between groups over time



The test of between-subject effect in Table 4 also obtained significant results between students from comparison groups ($n = 71$, $M = 3.31$, $SD = 0.05$) and those from experimental groups ($n = 78$, $M = 3.68$, $SD = 0.04$), in terms of mathematics self-efficacy, $F(1,147) = 36.01$, $p < .05$, 95% CI $[-0.49, -0.25]$. The impact of group had a large effect size of, Partial Eta Squared = 0.20, suggesting that group of the student accounted for 20% of the variation in students' mathematics self-efficacy results. These results indicate that the majority of students from experimental groups acquired significant positive mathematics self-efficacy beliefs more than students from comparison groups.

In order to investigate the source of the differences between pre-test and post-test, univariate tests between comparison groups and experimental groups for pre-test and post-test respectively were conducted. The results are shown in Table 5.

Table 5. Univariate tests between comparison group and experimental group

Measurement	Mean difference	<i>df1</i>	<i>df2</i>	<i>F</i>	Sig.	Partial Eta Squared
Pre-test	-0.06	1	147	0.61	.436	0.00
Post-test	-0.68*	1	147	43.37	.000	0.23

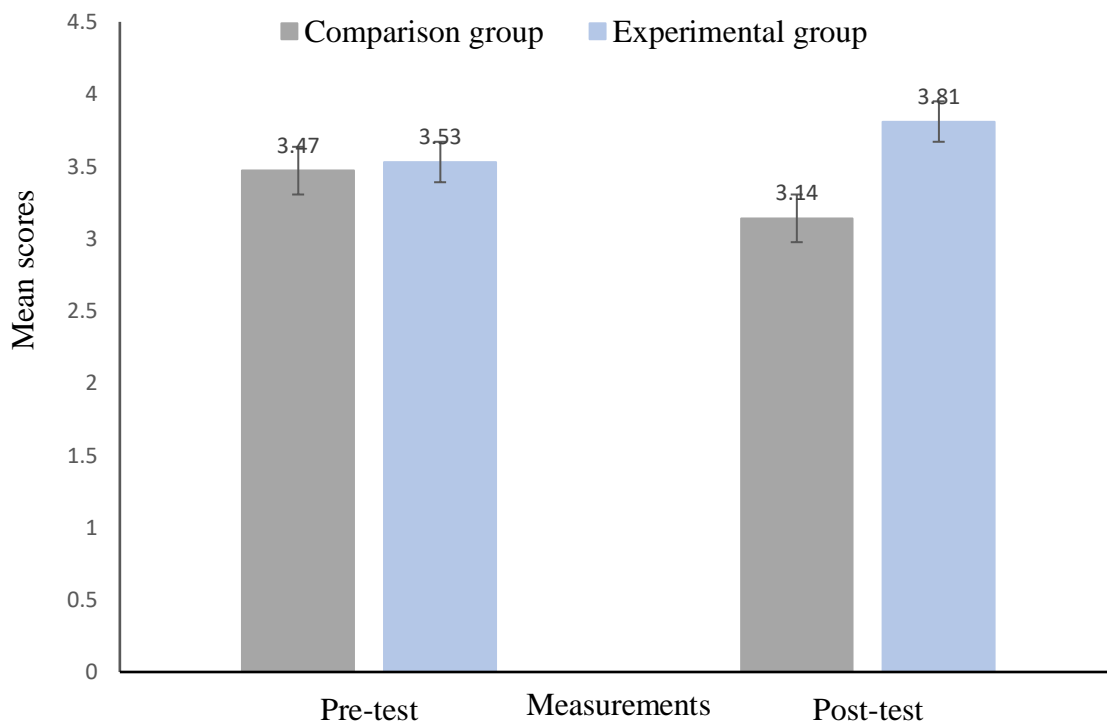
Note. Asterisk (*) means effect is significant at $p < .05$

Table 5 results show that there was no significant difference in mathematics self-efficacy between students from comparison groups ($M = 3.47$, $SD = 0.50$) and those from experimental groups ($M = 3.53$, $SD = 0.54$) before the intervention, equality of variance assumed, $F(1, 147) = 0.61$, $p > .05$, 95% CI $[-0.24, 0.10]$. Nevertheless, the

non-zero and equivalent self-efficacy revealed that students acquired significant baseline self-efficacy before the intervention, $F(1,147) = 1269.32, p < .05$, partial eta squared = 0.89 (see Table 4). Additionally, a priori study by the Mwamba et al., (2025) investigated the mathematics proficiency levels of the students in the six classes before the intervention. Using achievement test scores, the results showed that there was no significant difference in the academic performance among the students before the intervention, $F(5, 143) = 0.69, p > .05$. These finding provided a reference point for interpreting the impact of rubrics on students’ mathematics self-efficacy after the intervention.

After the intervention, there was a significant difference in mathematics self-efficacy between students from comparison groups ($M = 3.14, SD = 0.66$) and those from experimental groups ($M = 3.82, SD = 0.58$) in favor of students from experimental groups, equality of variance assumed, $F(1, 147) = 43.37, p < .05$, 95% CI [-0.88, -0.47], Partial Eta Squared = 0.23. Thus, students who used formative rubrics significantly improved their self-efficacy compared to those from comparison groups after the intervention as shown in Figure 5. Similarly, the study by the Mwamba et al. (2025) on the same sample also found significant difference in the academic performance in favor of the students from experimental groups, regardless of the schools where the students came from, $F(5, 143) = 12.77, p < .001$.

Figure 5. Mathematics self-efficacy between comparison group and experimental groups across measurements



4. Discussion

Self-efficacy beliefs in learning mathematics have been discussed as some of the most important affective variables influencing students’ ability to learn mathematics (Clemente et al., 2024; Negara et al., 2021; Zakariya, 2022; Živković et al., 2023). The findings of this study show that, students who used rubrics to obtain feedback and support self-assessment significantly improved their self-efficacy associated with learning quadratic equations than their counterpart who did not use rubrics. This study’s findings support the direct relationship between the improved use of formative assessment and mathematics self-efficacy, demonstrating the potential of rubrics in influencing positive changes in secondary students’ mathematics self-efficacy. This study’s findings are a significant contribution to research on rubric implementation and its impact on students’ mathematics self-efficacy beliefs as the current literature on rubrics is contradictory and heavily weighted in higher education (Al Umairi, 2024; Bürgermeister et al., 2021; Fraile et al., 2023; Myyry et al., 2022; Panadero et al., 2013; Rapi et al., 2022; Smit et al., 2023). Brookhart (2024) reviewed four studies that investigated the effect of rubrics use on primary and secondary school students’ self-efficacy between 2014 and 2024. Three studies found an indirect relation on self-efficacy (Smit et al., 2017), while one study found no significant difference in self-efficacy between experimental groups and control group (Liu

et al., 2016). Rakoczy *et al.* (2019), who examined a formative assessment intervention on self-efficacy in a high school mathematics course, was also unable to find a significant effect. Similarly, a meta-analysis by Panadero *et al.* (2023) only found a small impact from four studies that investigated the effect of rubrics on self-efficacy. However, it is important to note that in previous studies with insignificant or mixed findings, teachers did not share the rubrics with students in a timely manner for formative assessment (Nsabayezu *et al.*, 2022), or provided them only when the assessment was already underway or during summative assessments that did not require additional feedback (Hubber *et al.*, 2022; Panadero & Jönsson, 2013). The provision of rubrics and ensuring that students used them not only to understand teacher expectations and for self-assessment, but also to improve their own work, was the significant feature of the intervention in the current study. This explanation seems consistent because the students who reported to have experienced increased enjoyment and engagement with quadratic equations, increased confidence and ability to cope with quadratic equations instructions as well as improved understanding of the usefulness of quadratic equations in real life also had higher achievements in the quadratic equation's performance test (Mwamba *et al.*, 2025). This finding is supported by a satisfactory body of research (Balan, 2012; Steiner, 2007; Tella, 2007), reporting that students' mathematics self-efficacy about themselves may indirectly or directly affect their academic performance. This study therefore, delivers new and insightful results, suggesting that teachers from secondary schools can equally influence positive changes in students' mathematics self-efficacy beliefs by integrating rubrics into formative assessment practices.

Possible explanations for improved students' self-efficacy beliefs are that formative use of rubrics enabled students to plan and carryout the actions required to achieve specific types of performances, to evaluate their own performances in order to get immediate feedback through self-assessment, especially on weaknesses. These weaknesses became the goals for improvements (Clemente *et al.*, 2024; Ling, 2024). Previous studies (Blondeel *et al.*, 2024; Brookhart, 2024; Hagos & Andargie, 2022; Malespina & Singh, 2022; Myry *et al.*, 2022; Shirawia *et al.*, 2024; Smit *et al.*, 2023), also report similar findings that the use of rubrics enable teachers to deliver nuanced feedback about where the students were going, how they were doing, and how to move on. Ling (2024) also reported that the feedback provided by a rubric surpasses a mere grade.

In addition, the use of rubrics also enabled students to estimate their grades prior to the submission of assignments while providing accurate self-assessment judgments (Panadero *et al.*, 2024; Panadero & Dochy, 2014; Panadero & Jönsson, 2013). Descriptive statistics revealed that students from comparison groups found quadratic equations difficulty to understand and very challenging, and that they avoided anything to do with quadratic equations even after learning quadratic equations in full. These are probably the reasons the students reported a decrease in self-efficacy towards lower confidence in their own abilities to cope with quadratic instructions compared to their answers before interventions. These findings confirm the social cognitive theory (Bandura, 1997; Özcan & Kültür, 2021), which holds that failure in mathematics lowers self-efficacy while decreasing perseverance and efforts whereas success in mathematics increases self-efficacy (Negara *et al.*, 2021; Živković *et al.*, 2023). The theory further indicates that giving students the possibility to engage in assessment as early as possible and discussing assessment criteria well in advance enable them to develop study skills and to build confidence, which is crucial for progression in their learning programs (Brookhart, 2024; Meer & Chapman, 2014). The transparency of assessment created by formative rubrics through clear learning goals, explicitly criteria and detailed feedback which encouraged self-assessment is by far an important ingredient for improved self-efficacy associated with secondary school mathematics (Jönsson, 2020; Jönsson & Svingby, 2007; Ling, 2024). This study's findings is supported by previous findings that, a lack of transparent in assessment is a major source of negative self-efficacy (Clemente *et al.*, 2024; Myry *et al.*, 2022; Schimmelpfennig, 2025).

While teacher characteristics such as grading bias and expectations bias may have influenced the findings (Brookhart, 2024; Ling, 2024; Yan & King, 2023), teacher training, standardized instructional materials, formative feedback, and collective lesson planning helped minimize the effect of teacher variability on student learning (Panadero *et al.*, 2023). Monitoring teacher adherence to the formative guidelines also ensured consistence and fidelity of the intervention.

5. Conclusions

The findings of this study have demonstrated that rubrics, along with the learning activities such as clear learning outcomes, providing detailed feedback, and self-assessment have the potential to improve secondary school students' self-efficacy in mathematics. These findings suggest that secondary teachers of mathematics can influence positive changes in students' self-efficacy by integrating rubrics into formative assessment practices. However, teachers and students need to familiarize themselves with the characteristic of rubrics before they can start getting the benefits.

In addition, the findings of this study provide indications to believe that the use of formative rubrics has an indirect beneficial effect on reducing secondary students' level of performance-avoidance self-regulation in mathematics learning. Secondary students who used rubrics reported more confidence in their own abilities to handle quadratic equation problems, leading to lower levels of performance-avoidance self-regulation.

5.1 Limitations and opportunities for future studies

The inability to assign classes randomly to teachers and into groups and the reliance on a moderate sample (n=149) limits the extent to which the findings of this study maybe generalized. However, these findings may be relevant to populations whose characteristics are the same as those of the sample studied.

While the findings are positive, this study covered only six weeks, and it will be informative to assess the potential long-term impact of rubrics to validate this study's findings. The use of a single instrument introduces test specific bias. Other data collection instruments such as daily dairies and interviews provide nuanced information on how effectively rubrics were implemented. Amidst these methodological and contextual limitations, this study's findings provide important implications for practitioners and researchers in mathematics education.

5.2 Recommendations for teacher practice

This study's findings show that students may leverage the use of rubrics to obtain constructive feedback and use the opportunity to assess their own learning progress and determine what to learn next. This imply that giving students the opportunities to engage in assessment as early as possible and discussing assessment criteria well in advance may help them improve self-efficacy. When students understand the learning outcomes, they have ownership of their learning and feel more confident in their own abilities to tackle challenging questions, which may help them to improve their performance not only in school but also in life.

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Appendix 1: Task specific formative rubric

Table 1A. Task specific formative rubric for assessing solutions to quadratic equations

Assessment criteria	Characteristics of students' responses based on the SOLO taxonomy levels				
	EAL	RL	MSL	USL	PSL
Factorization method	➤Able to apply and compare different quadratic concepts and procedures with reasons to find correct values of x in quadratic contexts and in real life situations.	➤Able to verify and justify correctly solutions to quadratic equations using procedures that show clear understanding of quadratic equations.	➤Able to verify and justify given solutions to quadratic equations using at least two methods, yet, procedures used are not consistent (are disjoint).	➤Used simple manipulation to partly find solutions to quadratic equations. ➤Procedures used contain a lot of errors. ➤One x – value is known.	➤Wrong answers given. ➤Procedures used are incorrect. ➤Not able to find solutions to quadratic equations using any method. ➤Unknown x – values
Completing squares method					
Quadratic formula method					
Graph method	Able to draw two quadratic graphs on the same axes, interpret the x – axis, y – axis, x – intercepts and y – intercepts to find solutions to quadratic equations correctly, including the use of extrapolation in the context of the problem and beyond	Able to construct tables of values, draw two quadratic graphs on the same axes and interpret x – axis, y – axis, x – intercepts and y – intercepts to find correct solutions to quadratic equations in context of the problem	Able to construct tables of values and draw at least one quadratic graph, but cannot interpret x – axis, y – axis, x – intercepts and y – intercepts to find correct solutions to quadratic equations.	Attempted to draw graphs but work characterized by absence of table of values, inappropriate scaling, graph not being smooth and no clear labelling of the axes.	Not able to construct and draw tables and graphs. Works are omitted/incomplete, inappropriately scaled, unorganized and mathematically incorrect graphs.

Note. EAL=extended abstract level, RL=relational level, MSL=multi-structural level, USL=uni-structural level, PSL=pre-structural level.