# Designing an evaluation plan for the teaching and learning of high school algebra using an inquiry- and technology-based activity

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Educational technology advances of the 21st century have resulted in an increase in both the accountability requirements of standardised testing and the amount of data collected, and hence an increased emphasis on data-driven decision making in schools (Kekahio & Baker, 2013). To this end, this paper will propose a method for quantitatively evaluating the effectiveness of an inquiry- and technology-based activity that could be used in teaching 10th grade students how to find the roots of a quadratic equation. Hypothetical assessment data will be presented and analysed, and suggestions for how to generalise the approach for use in a continuous improvement system for mathematics teaching will be discussed.

## Activity selection

The choice of activity was inspired by Tuna and Kaçar's 2013 study that compares inquiry-based methods with traditional direct instruction methods for teaching 10th grade trigonometry. The authors found a statistically significant difference in both unit test scores and long-term retention of trigonometric knowledge in favour of the students taught using inquiry-based methods. Hence, it seems reasonable to assume that a similar approach could be used to test the efficacy of inquiry-based algebra instruction. The activity chosen was a Mathematics Education Innovation (MEI) GeoGebra task in which students are guided towards an understanding of the graphical meaning of the roots of a quadratic equation via a series of inquiry questions and through the use of dynamic graphing software. The guiding inquiry questions and an example of the graphing software output are shown in Figure 1 below.

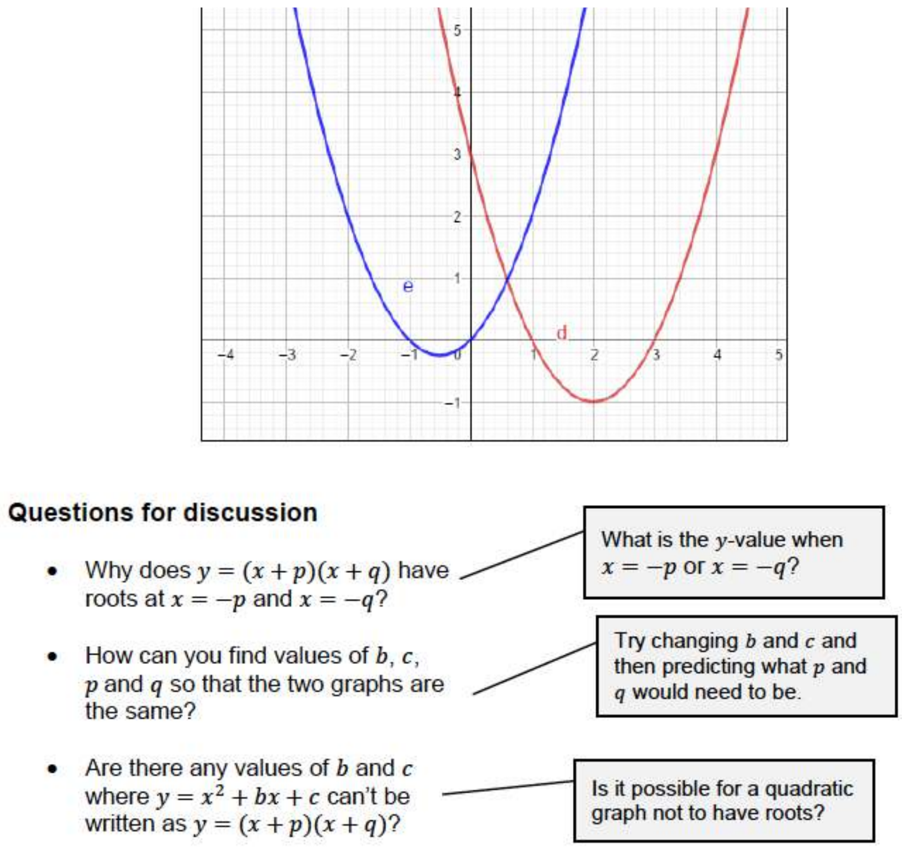


*Figure 1*. Inquiry- and technology-based high school algebra activity chosen for evaluation (Mathematics Education Innovation, 2018).

### Defining measurable outcomes and sources of data

Measurable outcomes were determined by first defining a specific question to be addressed, and then determining the data needed to answer it, as suggested by Kekahio and Baker (2013). Considering the specific algebra knowledge that the activity chosen for evaluation is attempting to develop in students, the question was framed as "does teaching quadratic equation roots using MEI's GeoGebra task improve the initial understanding and subsequent retention of that knowledge in Grade 10 students at International School Ho Chi Minh City (ISHCMC)?". The quantitative data needed to answer the question are the marks awarded on quadratic roots-related test questions both immediately (or soon) after the activity, and also at later points in time. In this way, both cross-section data and longitudinal data (Kekahio & Baker,

2013) are collected. Data would need to be collected for two different groups of students, one of which was taught how to find the roots of quadratic equations with the MEI task, and the other without. In the ISHCMC context, the specific assessments chosen from which to collect data are the Grade 10 algebra end of unit test (held soon after the activity), the Grade 11 placement test (held roughly 6 months later), and the “Welcome to Grade 11 Mathematics” test (held after the summer break at the beginning of Grade 11). Rather than comparing two different groups taught in parallel (as was done in the 2013 Tuna and Kaçar study), results from the previous year’s cohort will be compared with results from this year’s cohort (who will be taught how to find the roots of quadratic equations using the new inquiry-based activity).

## Data analysis methods

Marks awarded for quadratic roots-related questions in each test would be converted into percentages and then summarised for ease of comparison in Table 1 below. Means, standard deviations and p-values (to be compared with a 5% significance level) can be calculated using Stangroom’s t-test calculator for two independent means (2020), available online.

Table 1

*Template for comparison of marks awarded on quadratic roots-related test questions for Grade 10 students taught with (New method) and without (Old method) the MEI task*

| | Old method (*M, SD*) | New method (*M, SD*) | *p-value* (one-tailed) |
|---|---|---|---|
| Grade 10 Algebra Unit Test | | | |
| Grade 11 Placement Test | | | |
| Welcome to Grade 11 Test | | | |

*Note.* Locations for reporting degrees of freedom have been omitted for conciseness.

## Use in a continuous improvement system

Park, Hironaka, Carver and Nordstrum (2013) suggest that in order for quality improvement efforts to be considered continuous, they not only need to occur frequently, but also form part of a coordinated, organization-wide approach. This suggests that the above approach would need to be used across multiple activities in different branches of mathematics and different grade levels, and repeated annually, in order to be considered a continuous improvement system. This could easily be achieved with the test data we are currently collecting; however, it would require the department to collectively identify areas of weakness to focus on at the beginning of each school year and agree on the new teaching methods to be trialed with the aim of addressing those areas of weakness. The data analysis methods described above could then be applied to test questions related to the identified areas of weakness.

## Piloting the plan: a hypothetical data analysis

A typical quadratic roots-related question that might be given to students near the end of Grade 10 or at the beginning of Grade 11 is shown in Figure 2 below.

Consider $y = 2kx^2 - 4kx + 1$, for $k \neq 0$. The equation $y = 0$ has two equal roots.

(a) Find the value of $k$. [4 marks]

(b) The line $y = p$ intersects this quadratic. Find all possible values of $p$. [2 marks]

*Figure 2*. Test question assessing similar knowledge and understanding to that which the inquiry-based MEI task is used to teach (courtesy of Vanessa Leah, St Andrew's Cathedral School).

Hypothetical marks awarded for the two cohorts described above were entered into Stangroom's online calculator (2020), and the results are described in Table 2 below.

Table 2

*Comparison of hypothetical mean marks awarded for two different cohorts, one taught how to find the roots of quadratic equations using the MEI task, and the other without*

| | Mean marks awarded | Unbiased estimate of variance |
|---|---|---|
| Old method group (*N*=46) | 2.91 | 2.39 |
| New method group (*N*=42) | 3.62 | 3.61 |

*Note.* Marks have not been converted to percentages as they refer to the same question.

Based on the above hypothetical data, the following conclusion could be stated: the 42 students who were taught how to find the roots of quadratic equations using the MEI task achieved significantly higher marks on a quadratic roots-related test question than the 46 students who were previously taught the same skill using other methods, $t(86) = 1.92$, $p = .029$.

**Limitations of the data**

There are several limitations inherent in evaluating the effectiveness of an activity using the methods described in this paper. In the above analysis it was assumed for simplicity that both cohorts answered the same test question, when in practice, most test questions would be changed each year, in order to ensure valid, fair and reliable assessment practice. Comparing percentage scores from different test questions on similar topics across the two cohorts is still useful, but perhaps makes the results more subjective, as teachers must judge which "similar" questions should be included in the analysis. Moreover, comparing previous cohort results with those of current cohorts implies an inability to choose the two cohorts so that their demographics are somewhat similar, as could be done if the two cohorts were taught concurrently.

**Conclusion**

By applying a hypothesis testing approach to quantitatively evaluate the effectiveness of newly substituted teaching methods for certain mathematical topics, and systematically choosing those methods and topics based on historical assessment data, the teaching and learning of mathematics can be continuously improved. This benefits students through both improved test scores and greater long-term retention of mathematical knowledge and understanding.

References

Kekahio, W., & Baker, M. (2013, September). *Five steps for structuring data-informed conversations and action in education* (REL 2013–001). Retrieved from Institute of Education Sciences website: https://ies.ed.gov/ncee/edlabs/regions/pacific/pdf/REL_2013001.pdf

Mathematics Education Innovation. (2018, November 23). *MEI GeoGebra Tasks for GCSE Mathematics* (V2.3 TB). Retrieved from https://mei.org.uk/files/ict/geogebra-gcse-tasks.pdf

Park, S., Hironaka, S., Carver, P., & Nordstrum, L. (2013, May). *Continuous Improvement in Education*. Retrieved from Carnegie Foundation for the Advancement of Teaching website: https://www.carnegiefoundation.org/wp-content/uploads/2014/09/carnegie-foundation_continuous-improvement_2013.05.pdf

Stangroom, J. (2020). T-test calculator for 2 independent means. Retrieved August 09, 2020, from https://www.socscistatistics.com/tests/studentttest/default2.aspx

Tuna, A., & Kaçar, A. (2013). The effect of 5E Learning Cycle Model in teaching trigonometry on students' academic achievement and the permanence of their knowledge. *International Journal on New Trends in Education & Their Implications (IJONTE)*, *4*(1), 73–87.