Reframing the teaching and learning of high school algebra with the 5E model

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Introduction

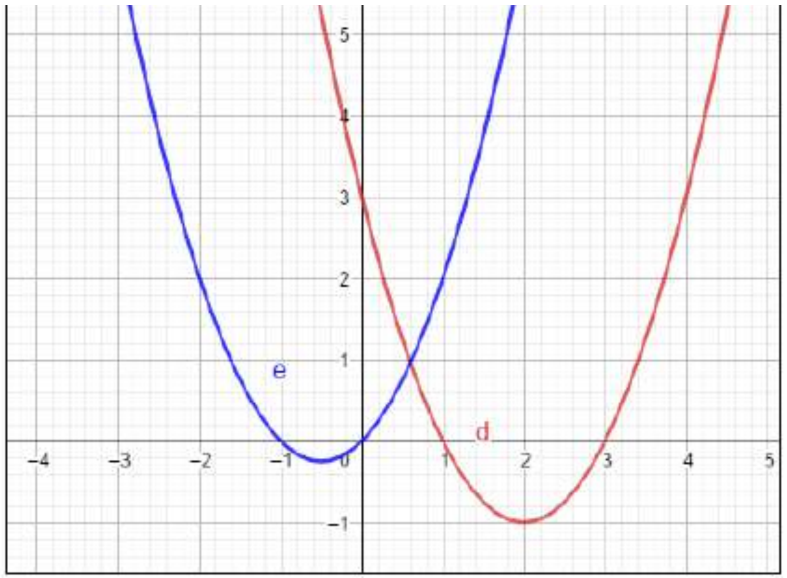
- Application of the three levels of inquiry (structured, guided and open) to mathematics is discussed generally in Wathall (2016)
- Application of inquiry-based learning to algebra instruction in a remedial algebra college course by Piercey (2017) resulted in those students performing as well on average as the students who were placed into the class above them
- Tuna and Kaçar (2013) found that applying the 5E model to the teaching of 10^{th} grade trigonometry improved both performance in the unit summative and long-term retention of trigonometric knowledge
- Teaching the rules of algebra is seen as a dry, unengaging “necessary evil”, and no specific examples of the 5E model applied to algebra could be found in the literature

Phases of the 5E model (BSCS Science Learning, 2020)

- Engagement – activate prior knowledge and spark curiosity
- Exploration – “play” with the topic in a way that leads to new understanding
- Explanation – precisely define the new concept(s)
- Elaboration – stretch, challenge, apply new knowledge
- Evaluation – assessment (both self- and summative), reflection, updating the big picture

Engagement

- Students engage with the new topic via focused inquiry questions rather than teacher-led examples
- A blend of hand-written mathematics and use of software tools (Geogebra) allows students to make the connection between algebraic and graphical solutions from the outset



Questions for discussion

- Why does $y = (x + p)(x + q)$ have roots at $x = -p$ and $x = -q$?
- How can you find values of b, c, p and q so that the two graphs are the same?
- Are there any values of b and c where $y = x^2 + bx + c$ can't be written as $y = (x + p)(x + q)$?

What is the y-value when $x = -p$ or $x = -q$?

Try changing b and c and then predicting what p and q would need to be.

Is it possible for a quadratic graph not to have roots?

Figure 1. Example Geogebra activity designed for pre-calculus students ([Mathematics Education Innovation, 2018]).

Exploration

- Graspable Math allows students to intuitively discover how algebra works by playing around with it, while still ensuring that they play by the rules ([Graspable Math, 2019]())
- Activities in which students try to manipulate an algebraic expression into a desired goal state lay the foundations for algebraic proof

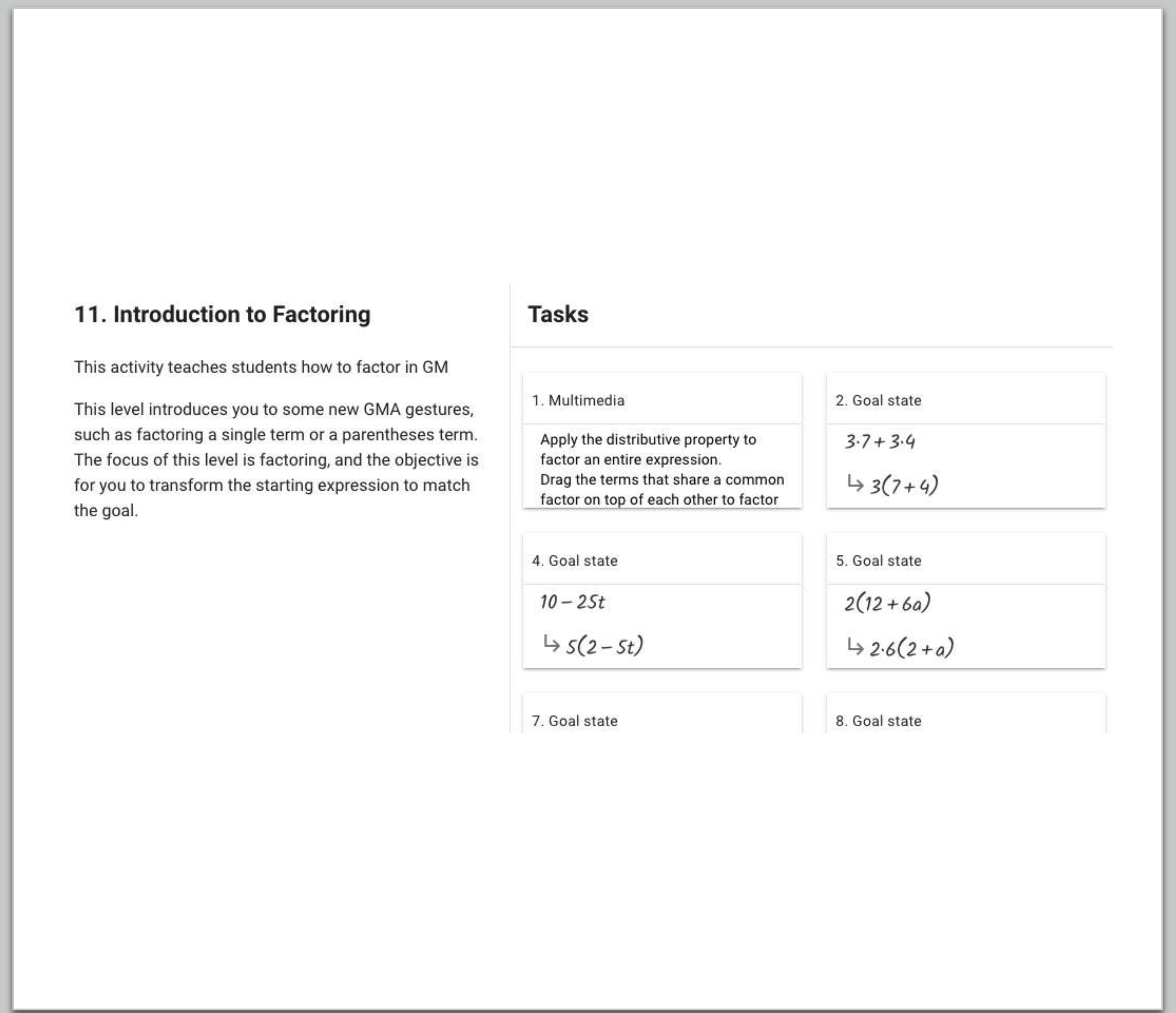


Figure 2. Example goal state-style activity suitable for middle school students ([Graspable, Inc., 2020]()). Note: access to this resource requires a subscription.

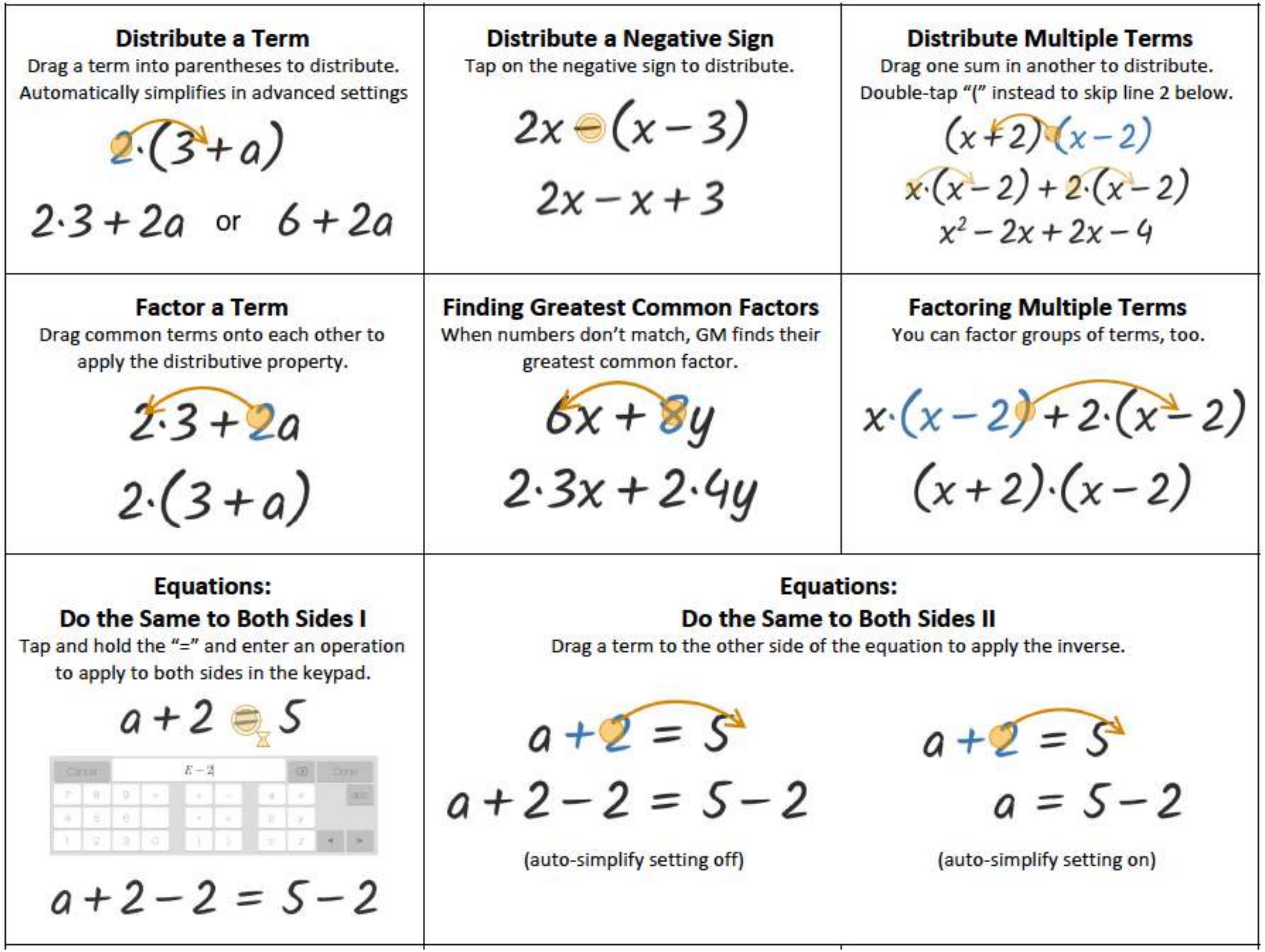


Figure 3. Extract from Graspable's "Frequently Used Gestures" tutorial (Graspable Team, 2020). The symbols shake when students attempt an incorrect operation.

Reinventing the teaching and learning of proof with Graspable Math

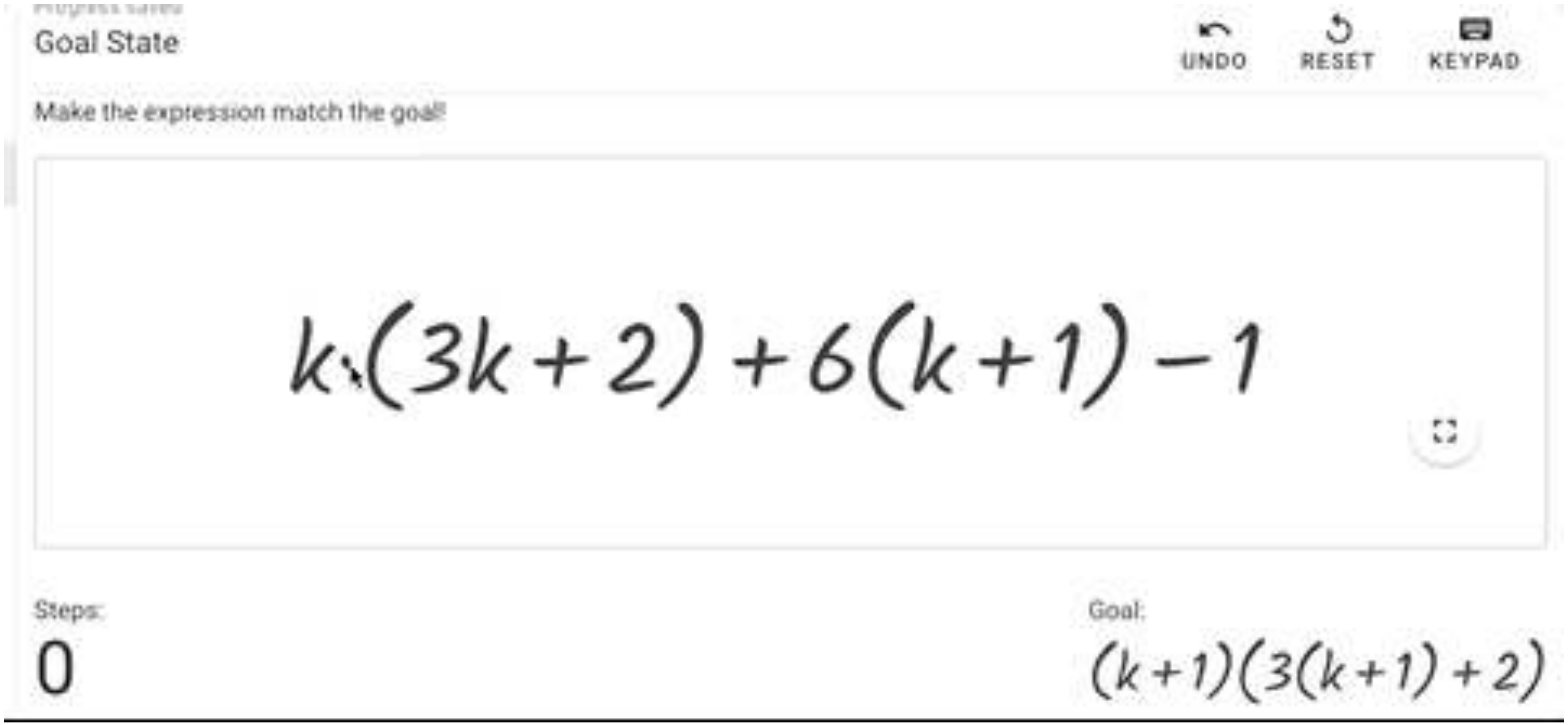


Figure 4. Proof by induction example suitable for Grade 10 students, created by the author.

Explanation

- Ideally, the explanation should be student-generated ([BSCS Science Learning, 2020](#))
- For weaker students, this phase could be modified to include a structured inquiry worksheet or a cloze activity

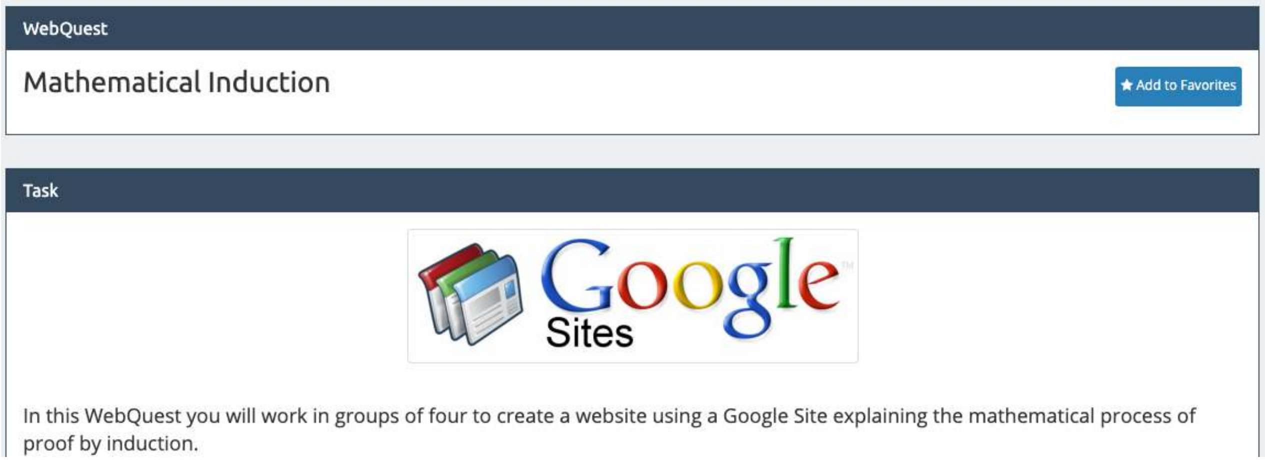


Figure 5. Proof by Induction “WebQuest” suitable for older students (Wathall, n.d.).

Using Flipgrid to develop student voice

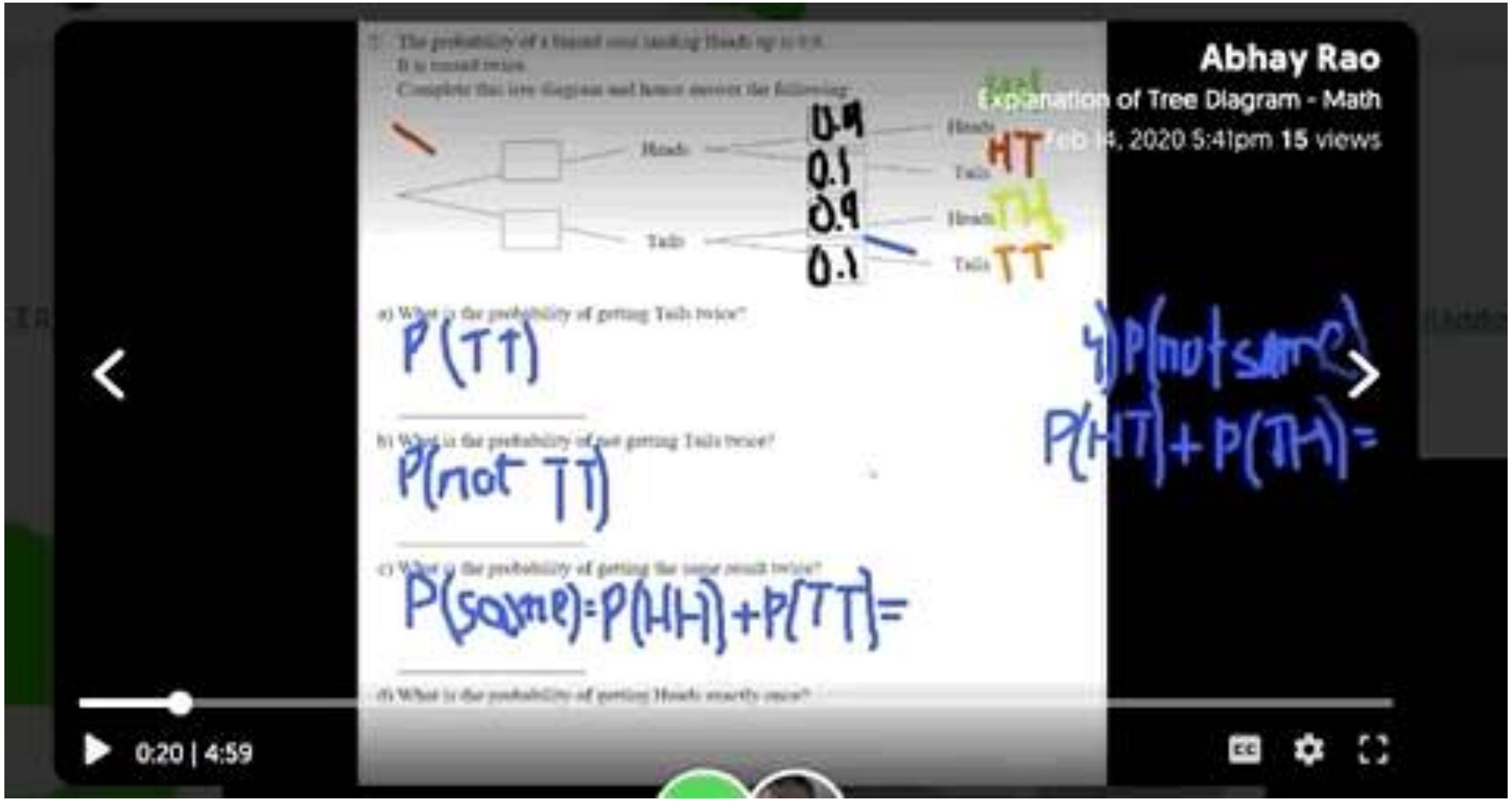


Figure 6. Example ISHCMC student video explanation posted on Flipgrid (Rao, 2020).

Elaboration and Evaluation – business as usual

- The usual extension and enrichment activities and problems can be given to students as they are ready for them in the Elaboration phase
- Evaluation is both a summative assessment and a student reflection

Comparison with traditional methods

- Similar timeframes possible – students may need longer to explore before they are ready to explain, but by applying technology to the learning of algebra we can augment, modify and redefine certain tasks (as suggested in Puentedura's 2013 SAMR model) and thus gain that time back in other ways
- Students take a more active responsibility for their learning of mathematics and arrive at new mathematical understandings from prior knowledge, rather than waiting for the teacher to "show them"
- Teaching role rebalances towards facilitation of discovery rather than direct instruction

Conclusion

The main challenge in applying the 5E model to the teaching and learning of high school algebra is finding ways to implement the “Engage” and “Explore” phases before the “Explain” phase

A variety of technology tools that have the potential to redefine the teaching and learning of high school algebra are now available

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