



# Ender: an Interactive Geometry Proof Tool

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## Motivation

Learning about geometry proofs helps students improve their **sequential logic**, but students struggle with understanding geometry proofs. (Soucy McCrone & Martin, 2004)

## Problem

### Two-column Style

More teacher presentation, less active student participation

Given:  
KLMN is a quadrilateral,  $\overline{LM} \cong \overline{NK}$ ,  $\angle KLM = 90^\circ$   
Prove:  
 $\triangle KLM \cong \triangle MNK$

Statement	Reason
1 KLMN is a quadrilateral	Given
2 $\overline{LM} \cong \overline{NK}$	Given
3 $\angle KLM = 90^\circ$	Given
4 $\angle KLM = 90^\circ = \angle MNK$	Def. Quadrilateral
5 $\overline{MK} \cong \overline{MK}$	Reflexive Property
6 $\triangle KLM \cong \triangle MNK$	HL Triangle Congruence

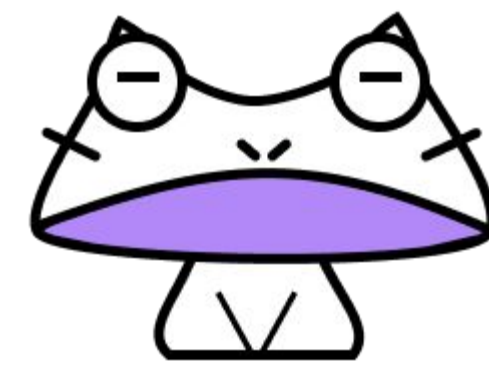
Sequential thinking: write extra steps that don't help them reach the end proof

Cognitive load: which segment is ML? which angle is KLM

Failure to understand why reasons has to be in a particular order

I can't **keep track** of all the segments and angles used in the proof.

I also don't know **why I need to prove this step** or why I have to do this in **this order**.



Ender includes **interactivity** and **visual elements** which makes reading and understanding geometry proofs easier.

## Methods (Semi-structured interview)

- U.S. high school teachers, 1 hour Zoom interview
- Do they use interactive geometry software? What other teaching methods?
- What geometry proof topics do students struggle with the most?
- Do they like our tool, would they use it in their classroom? What other functions would they like to add?

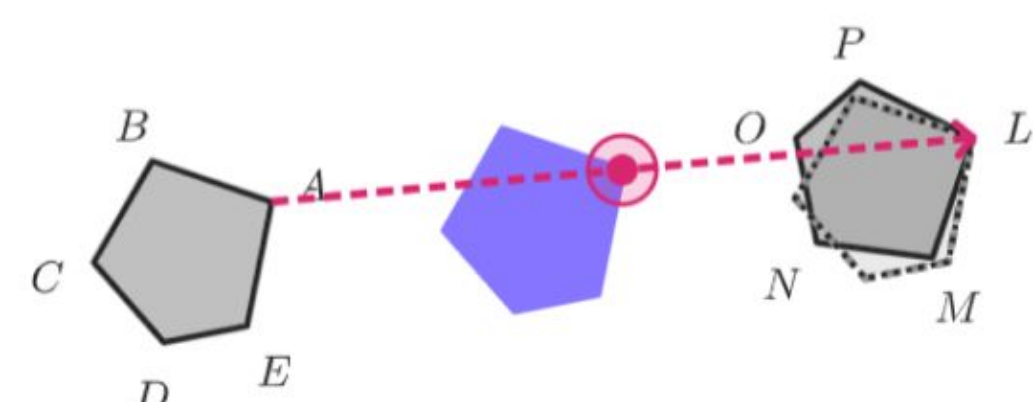
## Results (Semi-structured interview)

Overall trends in Geometry learning and teaching:

Focus on the discovery process, learning through active construction of diagram & shapes.

Verify that figure  $ABCDE$  is congruent to figure  $LMNOP$ .  
Select the transformations in any order

REFLECT TRANSLATE ROTATE



Less traditional formal proofs, because it takes longer to learn, most students struggle.

Ender could help as a teaching aid, or as a review material.



## Methods (Experiment)

1. Pre-test of Geometry basic logic (tick marks, triangle congruence)
2. Tutorial of interactive layout
3. Stage 1: Test if students used particular elements, do performance improve compared to static layout

### Interactive layout

Previous 13 / 25 Q1: If we assume all previous steps are true, which of the following is the correct reason to use in step 7? Yes No Pause Next

Given:  $\overline{AB}$  and  $\overline{CD}$  intersect at  $M$ ,  $\overline{AM} \cong \overline{BM}$ ,  $\overline{CM} \cong \overline{DM}$

Prove:  $\overline{AC} \cong \overline{BD}$

Statement	Reason
1 $\overline{AB}$ and $\overline{CD}$ intersect at $M$	Given
2 $\overline{AM} \cong \overline{BM}$	Given
3 $\overline{CM} \cong \overline{DM}$	Given
4 $\angle CMA \cong \angle DMB$	Vertical Angles Theorem

Reason Applied: Vertical Angles Theorem  
If two lines intersect each other, then the angles that are opposite from each other are congruent.

- 1 On diagram click, highlights the corresponding text
- 2 On text hover, highlights the corresponding diagram element
- 3 On symbol hover, shows definition of symbol
- 4 Highlights current step, hides not seen steps
- 5 Tick marks according to the current step
- 6 Relies on: bolds statements that the current statement needs
- 7 Mini figures: provide graphical representation of current reason
- 8 Reasons applied: text definition of current reason

VS.

Previous 14 / 25 Q1: Is there enough information to apply Converse of Def. Midpoint between steps 5 and 6? Yes No Pause Next

Given:  
 $\angle QPR = 90^\circ = \angle RMN$ , R is the midpoint of  $\overline{PM}$   
Prove:  
R is the midpoint of  $\overline{QN}$

Reasons Applied: Vertical Angles Theorem  
If two lines intersect each other, then the angles that are opposite from each other are congruent.

Statement	Reason
1 $\angle QPR = 90^\circ = \angle RMN$	Given
2 R is the midpoint of $\overline{PM}$	Given
3 $\overline{PR} \cong \overline{RM}$	Def. Midpoint
4 $\angle QRP \cong \angle MRN$	Vertical Angles Theorem
5 $\triangle QPR \cong \triangle RMN$	ASA Triangle Congruence

- 1 Color difference to distinguish between the steps
- 2 Expandable reasons to imitate textbook format

4. Stage 2: Test the overall layout and how that affects performance

## Next Steps

- Conducting the experiment with students who've taken geometry in the past 2 years
- Data analysis of performance, metacognition, usability
- In-depth analysis of interview data