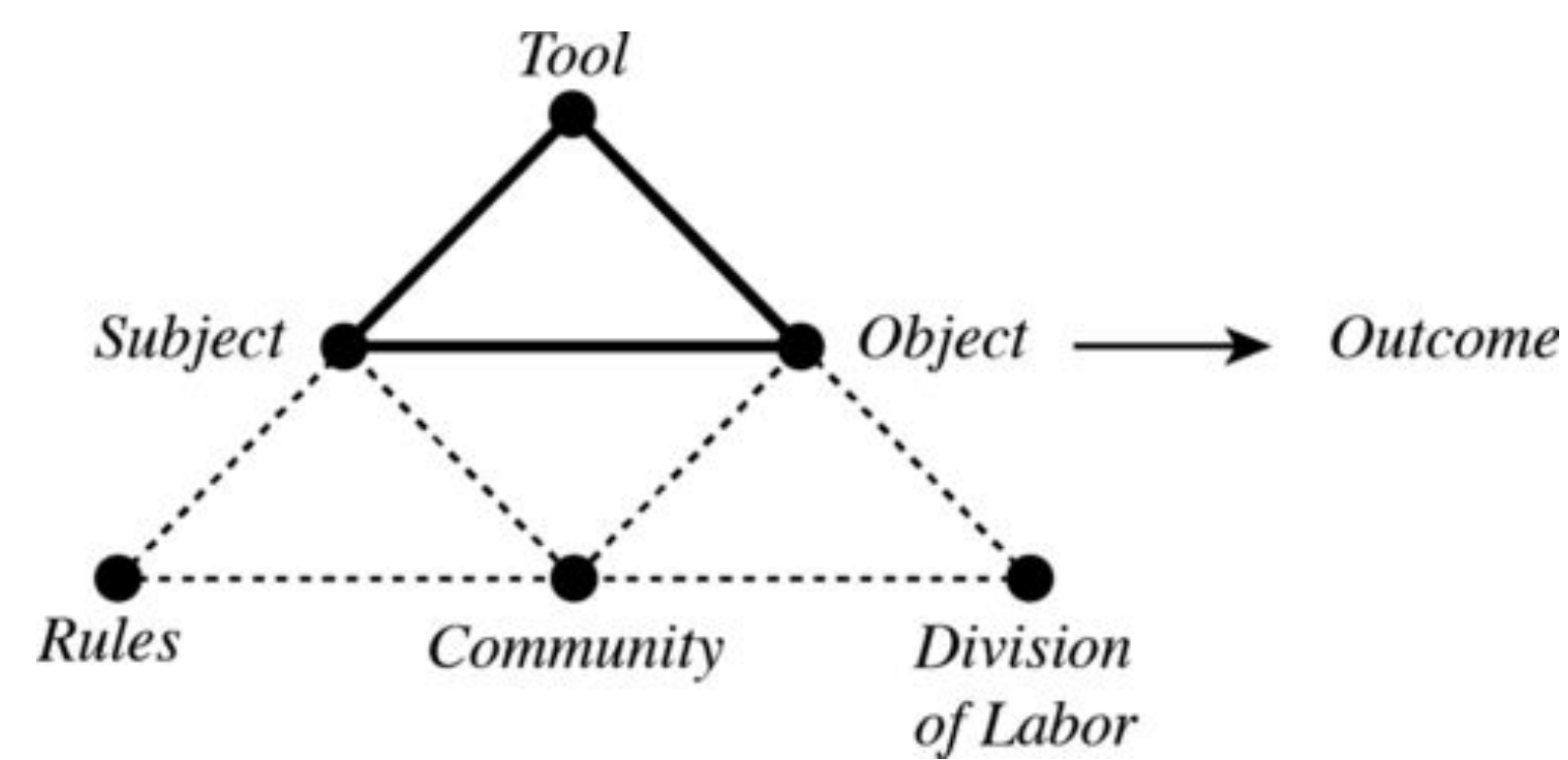


Sensemaking as cognitive process

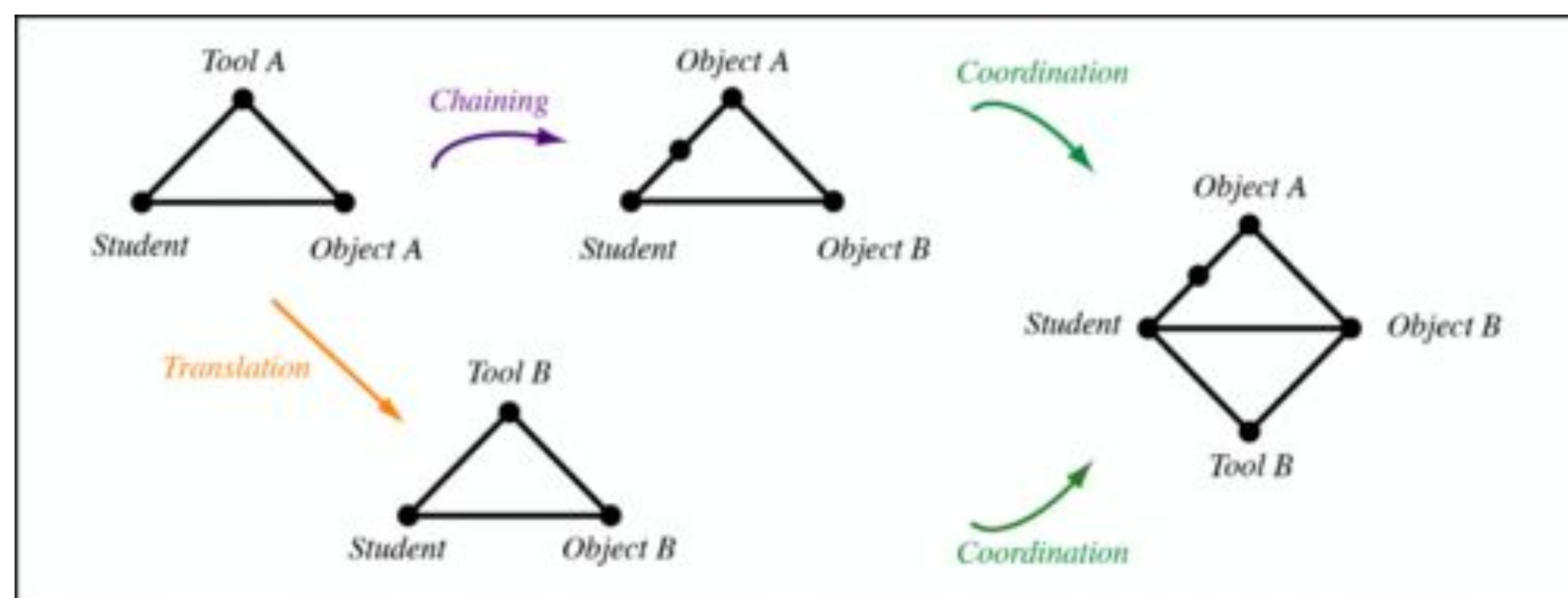


Gifford and Finkelstein's framework for mathematical sensemaking in physics is based in activity theory

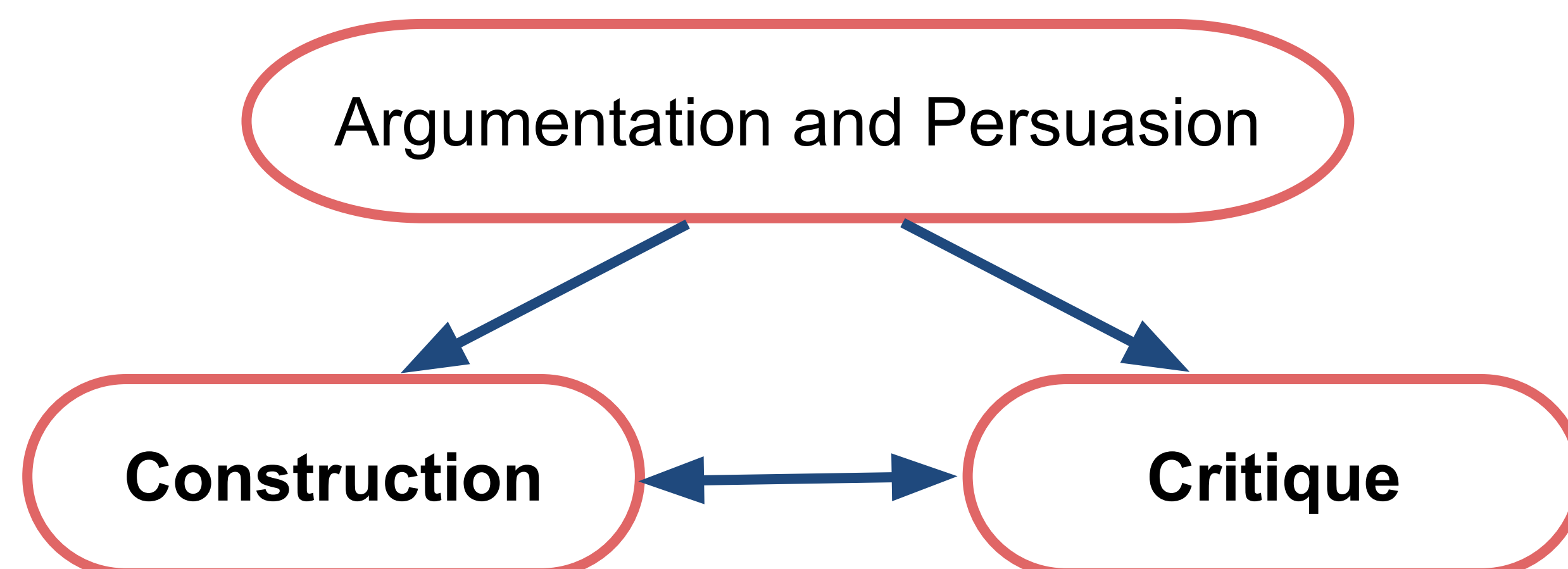
There are 4 reasoning modes which each depend on the tool being used to understand the object in the sensemaking process.

Modes can be combined and used together in different ways.

		Object of focus	
		Mathematical	Physical
Tool for sense making	Mathematical	<p>Mathematical Tools</p> <p>Msm - M</p>	<p>Mathematical Tools</p> <p>Msm - P</p>
	Physical	<p>Physical Model</p> <p>Psm - M</p>	<p>Physical Model</p> <p>Psm - P</p>



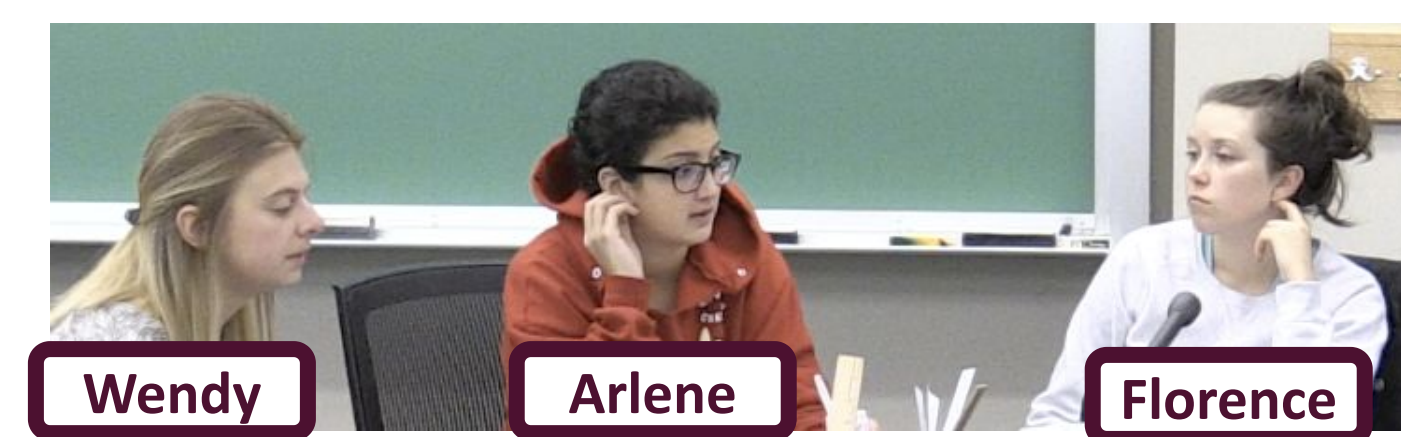
Sensemaking as discourse practice



References:
 M. J. Ford, A dialogic account of sense-making in scientific argumentation and reasoning, *Cognition and Instruction* 30, 207 (2012).
 J. D. Gifford and N. D. Finkelstein, Categorical framework for mathematical sense making in physics, *Physical Review Physics Education Research* 16, 020121 (2020).
 T. O. B. Odden and R. S. Russ, Defining sensemaking: Bringing clarity to a fragmented theoretical construct, *Science Education* 103, 187 (2019).

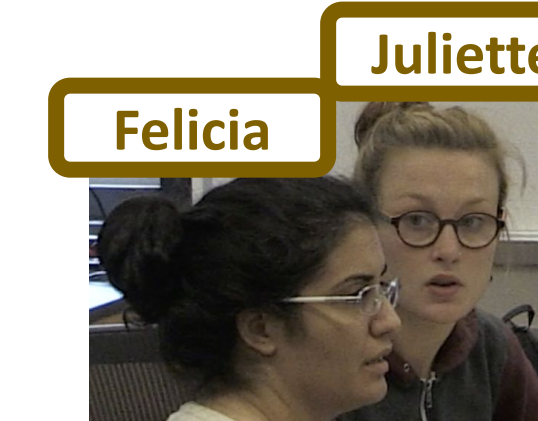
Data

Episode 1



Florence: So, frequency of light is gonna be, so frequency is related to wavelength and the wavelength is gonna say how much energy it's gonna get
Wendy: I think it has something to with this actually, on the first page. This like $eV_{stop} = hf - E_0$.
Arlene: We did not get the slope, but that's ok.
Wendy: Is that all supposed to be [inaudible]?
Arlene: Yeah
Wendy: If you have a greater frequency, are you gonna have a greater E?
Florence: Yeah, I mean if you ignored the E_0 part, they're directly related.
Wendy: Well E_0 's constant right, for the metal?
Florence: Yeah, because that's the work potential or the work function. [pause] Yeah, work function of the metal, so that's constant. Planck's constant is constant, so when you change frequency it'll directly change the stop

Episode 2



Juliette: So when you have no current, you have no frequency.
Felicia: So we need the threshold frequency, how do we determine the threshold frequency from the chart? And that is when $eV_{stop} = 0$. That is the x-intercept. So this is the threshold, which means anything above that is not going to leave.
Juliette: Above the threshold.
Felicia: No no.
Juliette: So it's gotta get to the threshold before it starts to escape or whatever [inaudible] So the threshold is where it crosses the x axis, and that's E_0 , or E_{stop} .
Felicia: Yeah, E_{stop} , and anything below where it crosses the x axis would not work.

Episode 3



Amrita: So what is the equation?
Sam: $y=mx+b$ so that would correlate to
Bertha: Oh, is one of the questions to sketch the graph? Or print one copy of your graph? (looking at the graph) It's linear?
Sam: So, basically this.
Amrita: For?
Sam: So, this is the slope.
Amrita: Yeah, that's the equation.
Sam: This is your x
Bertha: So what did you graph though?
Sam: (continues to point and explain) This is your b.
Bertha: Did you put the, um, the stopping potential? What are on the axes?
Sam: So x is the frequency because we essentially change the frequency while changing the wavelength right
Bertha: Yeah.
Sam: So then what changes is your V_{stop} .
Bertha: (interrupts) So why not graph the wavelength?
Sam: Well it would be more roundabout to incorporate that since the equation is designed for frequency.
Bertha: Ok, so eV_{stop} is on the y axis
Sam: Yes.

Analysis

Wendy and Florence are both translating between the Msm-P and Psm-P modes using **coordination** to answer the question, building on each other's responses.

They are **collaboratively constructing and critiquing** their collective explanation.

Felicia and Juliette are **separately constructing explanations**. Felicia is using **chaining** and Juliette is using **coordination**.

The **critique** for Juliette's explanation seems to come from Felicia's **construction** of her own explanation and her feedback on Juliette's explanation.

Bertha's questions are a **critique** for Sam's **construction** of an explanation, causing shifts between modes using **chaining**.

Sam's **response to critique** also provides space for Bertha to contribute to the **construction** of the explanation.

Conclusions

- We verified the Gifford and Finkelstein framework as a tool to understand student sensemaking
- We highlight the connections between this cognitive framework and the discursive aspects of sensemaking