Thinking about Representational Fluency in Terms of Epistemic Games

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Epistemic Game (ĕpˈĭ-stēˈmĭk ˈgām) or **E-Game** *noun:*

1. The set of rules and strategies that guide inquiry (Collins & Ferguson, 1993) *Normative*
2. A coherent activity that uses particular kinds of knowledge and processes to create knowledge or solve a problem. (Tuminaro & Redish, 2007) *Ethnographic*

Research Questions

1. Are epistemic games a useful way to think about students' use of representations?
2. What moves from the Graphical Analysis E-Game does this student use? Which moves are difficult?
3. How do the hints given by the instructor help the student proceed with the E-Game?

E-Game: Graphical Analysis

Target Epistemic Form

Graph

Knowledge Base

- Reasoning resources
- Lexical/symbolic resources
- Formal computational resources
- Conceptual resources

Entry Condition

When information is presented in a graph or a graph is generated

Constraints

Info cannot be changed on an existing graph

Moves

- Interpret lexical information (legend, axes, titles, units)
- Create a story
- Read-out values
- Compare data sets
- Identify features
- Extrapolate/Interpolate
- Make an estimation
- Calculate slope
- Calculate area
- Translate to a new representation

Ex. Motion of Two Particles

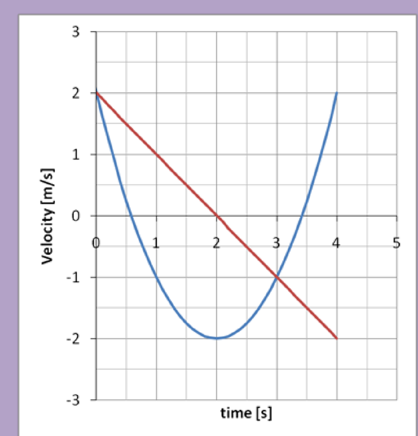
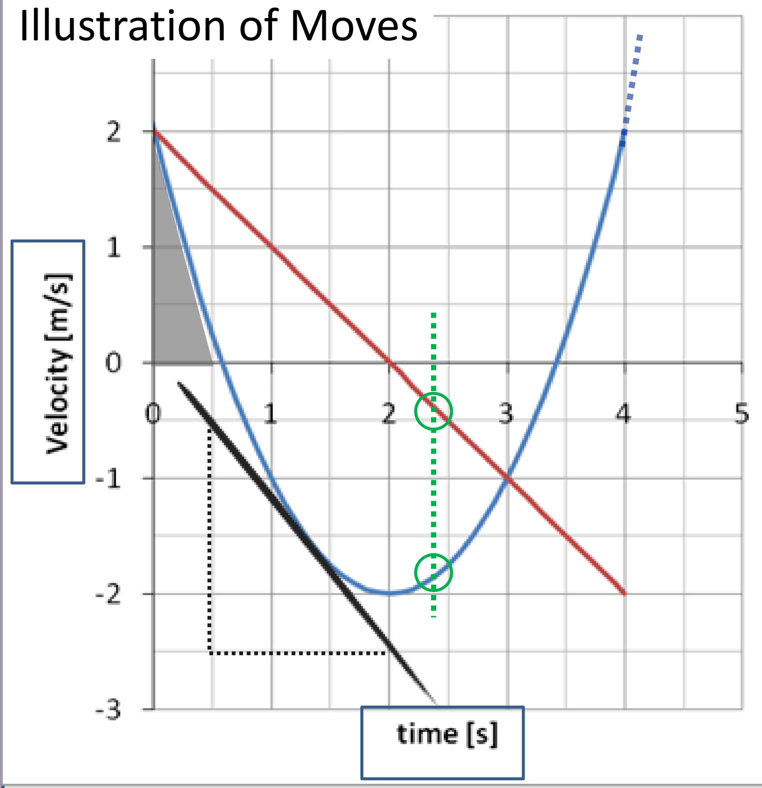
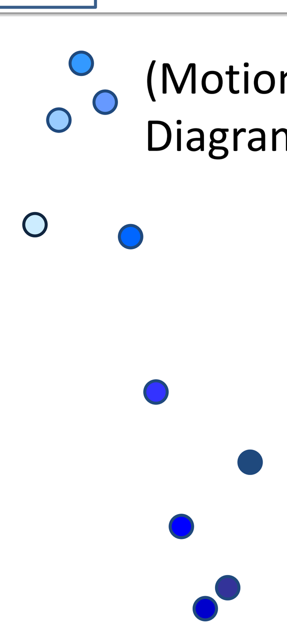


Illustration of Moves



Alternate Representations:



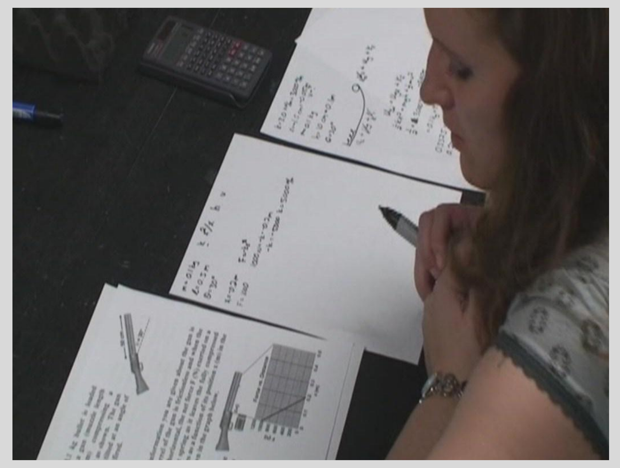
(Motion Diagram)

$v = 2-t$

(Equation)

Method

- 60 minute Teaching/Learning interview with a calc-based intro student "CC"
- Identified segments where student uses a graph
- Created a transcript of segments and coded transcript for Graphical Analysis moves



CC begins by identifying the information that is given in the problem statement and trying to match it to the equation she used in the previous problem (a statement of energy conservation). She identifies the quantities that are in this equation but are not given in the problem statement.

Int: How can you find x and k?

CC: Um… I'm thinking I might have to look at the graph. I'm just not sure how exactly. Um, right so, the graph is force vs. distance. Um so…ok, this is giving me the force that the spring exerts at a given compression of x. Um…I'm not sure where you'd start with that.

> **Begins Graphical Analysis E-Game** — Doesn't see how the moves she knows will be productive.
>
> **Interpret Lexical Info**
>
> **Create a Story** — Student attempts to connect the graph to the physical situation.

Int: Ok. Let's analyze the graph a little. At x = 0, then the force is what?

CC: 1000 N.

Int: Ok, that means at this point (points to the picture) the force is 1000N. And at x =0.2, like at this point (points to picture) what is the force then?

CC: Ok, zero. Ok.

Int: Zero. The force equal zero means the spring is compressed? Expanded? Or relaxed?

CC: Uh, yeah it should be relaxed at zero.

Int: Ok, so the spring is relaxed at 0.2 meter.

CC: Yes.

Int: No force.

CC: Right.

Int: Ok, so at 0.2 it is not compressed, and when you put the bullet in, then it's compressed to zero, it has a force of 1000. So, do you know, can you figure out the compression and the force?

CC: Ok, so when your x equals two meters (writes x=-0.2) – assuming, I put the 0.2 as zero. Um, and so then your force equals 1000 at that point. Um, I just, so I'd be able to find x… but I'm not sure how to do k from that.

> **Create a Story** — Interviewer helps student map the graph onto the physical situation.
>
> **Read-Out Value** — Student is able to do this and participates in the construction of the story.
>
> **Read-Out Value** — Student converts distance into compression.
>
> Student has difficulty identifying productive move.

Int: Ok, now you have known x, know the compression of the spring, and force at that compression. And how does your, how does this relate?

CC: Ok! Is it force equals, is it kx^2? Negative x^2.

Int: Mmmm…negative kx.

CC: Ok. Alright, since you know F and k is a constant, you can plug in any of the values.

> **Create a Story** — Interviewer tries to activate a conceptual resource.

CC plugs in the values of F and x that she translated from the graph and calculates a value for k. The interviewer gives a brief summary of the progress she has made: she has found k based on an analysis of the graph. The interviewer prompts CC to continue with her solution.

> **Read-Out Value** — No evidence that **Calculate Slope** is being done.

CC: Um, we don't know what x the actual value is for this instance. Um…and we need to know that. Um…I'm not sure.

Int: Ok, so this picture and this graph are related to each other, so you can use information here to apply here. (Pauses) When there is no bullet, then the spring is relaxed at 0.2 meter. And when there is a bullet, then it is compressed to 0 meter. So, what is the compression?

CC: 0.2 meters.

Int: 0.2, ok. So let's apply that to this situation.

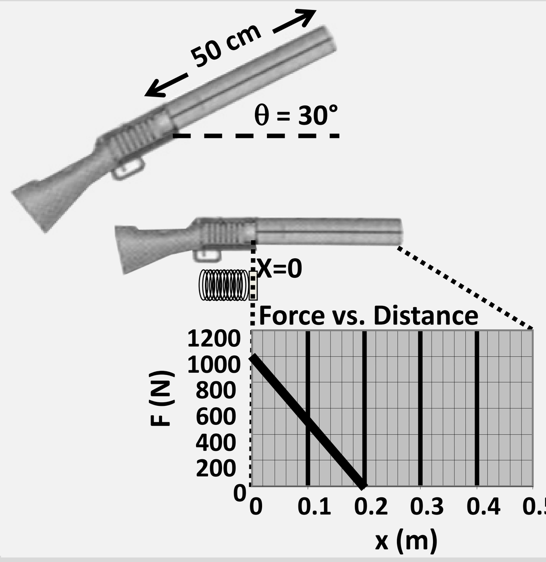
> **Create a Story** — Student doesn't acknowledge a connection between the graph and problem situation. Interviewer makes this connection explicit.
>
> **Read-Out Value**

Physics Problem

A 0.1 kg bullet is loaded into a gun (muzzle length 0.5 m) compressing a spring as shown. The gun is then tilted at an angle of 30° and fired.

The only information you are given about the gun is that the barrel of the gun is frictionless and when the gun is held horizontal, the net force F (N) exerted on a bullet by the spring as it leaves the fully compressed position varies as a function of its position x (m) in the barrel as shown in the graph below.

What is the muzzle velocity of the bullet as it leaves the gun, when the gun is fired at the 30° angle as shown above?



After CC has solved the problem correctly, the interviewer asks her to reflect on the problem.

CC: This one [problem] was more involved because you weren't given all of the variables in the question. Definitely the trickiest part is using both the diagrams (points to upper picture and lower picture+graph) together to find your x and to find your force which then you could find your k.

> **Create a Story** — Student acknowledges that using the connection between the graph and the physical situation is tricky.

The interviewer further probes whether the student can solve the problem without calculating the spring constant. CC speculates that she might perform a substitution of $k = -F/x$ into $U_s = ½ kx^2$.

Int: Ok. In the other problem you cannot do it but in this problem you can do because you have the graph. Look at the graph and see how you can extract information about U_s without calculating k and x.

> **Begins Graphical Analysis E-Game** — Interviewer redirects the student's attention to the graph.

CC: Ok, you can find x from it easily, but if we say that your spring is compressed 0.2 meters and you have 1000N…(trails off)

> **Create a Story** — Student tries to invoke the meaning of the graph but this doesn't lead to a productive move.

Int: So the potential energy of the spring is equal to the work done by the spring force. How do you calculate the work done by a force when you have the graph of force distance?

CC: Um, is it the integral of it? The area underneath? Or…I'm not sure. Cause your work equal force times distance (write down an equation). And you know the force.

Int: Do you know the force in this case?

CC: Hmmm…would it be 1000? Or…

Int: Actually, in this case, you have a bunch of values of force. Because you see (points to the graph) as x changes, force changes also. So you don't know what value of force to plug into that equation. So you cannot do it that way. And there is another way to calculate the work done by the force when you have a graph of the force vs. distance. What is that? You have talked about it already.

> **Identify a Feature** — Interviewer points out the shape of the line and its implication for the computation.

CC: I have?

Int: You have. When I asked you how the work was related to the graph.

CC: Is it the integral, the area underneath it?

Int: Yes. That's it! Ok, so the work done by the force on the graph is the area underneath the graph (points to the graph). So, which is the area in this case?

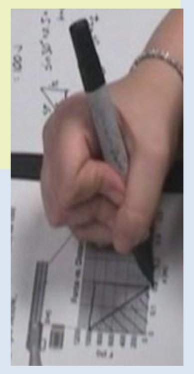
> **Calculate Area** — Interviewer indirectly indicates that taking the area is a productive move.

CC: For this one I would use geometry because it's a straight line instead of a curve, so…

> **Identify a Feature** — Student makes computational decision based on the shape of the curve.

Int: So, could you point out which area you're going to calculate?

CC: Yeah (shades in the graph). I need to calculate this area here. First I would find the area for, well, I'd just do it this way (draws a rectangle) and then divide by it two.



CC calculates the area under the curve. The interviewer remarks that the value is the same as she had previously calculated. Both the interviewer and CC acknowledge that this method is easier/quicker. The interviewer remarks that in order to use this method, one needs to know calculus and understand what the graph means.

> **Calculate Area** — Once the student engages in this move, the student makes the computation competently.

Discussion

- The student readily makes moves **Interpret Lexical Info** and **Read-Out Value** and **Calculate Area** once she realizes this will be a productive move. She has trouble with **Create A Story**.
- Interviewer uses **Read-Out Values** to help student participate in **Create A Story**

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