Key Research Questions:

What factors influence students' use of real-world knowledge in physics problem-solving?

- How do we design problems to enable use of real-world knowledge?
- What prompts them or primes students to engage in real-world sensemaking during problem-solving?
- What do we mean by real-world knowledge?
- What are the different ways that students use real-world knowledge in physics problem solving?

Context-Rich Tutorial

In experiment 1 you measured your reaction time while paying attention and while distracted. Because of this (and other) experience with physics you have been hired as an intern for the Vancouver traffic planning department. The city council is concerned about the studies that have shown that talking on a cellphone impairs a drivers' reaction time while driving, and are considering implementing a ban on cellphones while driving. However, they want to investigate alternatives to a complete ban.

One potential solution is to have a *different* speed limit for drivers who are talking on their cellphone to compensate for the distraction. The idea is that if a distracted driver were moving more slowly, they might have the same braking distance as an alert driver. You investigate and find that an average car has a mass of 1300 kg, an average SUV has a mass of 1600 kg. The minimum legal deceleration for braking passenger cars is 0.6g under wet conditions.

Based on your calculations, what recommendations will you make to city hall?

Note: *Not all of the details in these headers will be relevant each week… they are only intended to give you an idea of the types of information that are relevant to that step*

1. **Interpret the problem**
   - Carefully read and visualize the events described in the problem
   - If necessary, sketch a picture to clarify sizes, directions and spatial relationships
   - Clearly state the GOAL of the problem: what do you need to calculate and/or compare?

2. **Identify the relevant Physics Concepts**
   - List briefly the major physical principles that are relevant to this situation. (e.g. conservation of energy, Newton's second law, 1-D kinematics with constant acceleration, etc.)

Note: *Steps a) and b) are in a different order this week. Because so little information is given in this problem it makes sense to start thinking about our assumptions first. Thinking about the relevant information and the assumptions you're going to make tends to happen at the same time, so feel free to go back and forth between these two steps as you work.*

3. **Create a Physics Model**
   - A physics model summarizes all of the information relevant to solving the problem, including any assumptions you make.

   a) Define Physics Assumptions and Relationships
   - Using words and formulas as appropriate, interpret how the situation affects the physics variables defined in step 3b. Be sure to state all:
     - Limitations or constraints on the physical variables (e.g. $v < 0$)
     - Relationships between the physical variables (e.g. $a_1 = a_2$)
     - Simplifying assumptions (i.e. friction negligible, massless rope, constant acceleration etc.)
     - Initial conditions (i.e. $V_i = 0$, $a_i = -g$)

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   b) Make a Diagram and Summarize the Relevant Information
   - Write down a description that summarizes all of the relevant information in the problem statement in a clear way. This could include pictures, equations, or descriptions, or any of the following, where appropriate:
     - A statement of known and unknown quantities, with appropriate symbols defined
     - Any intuitions or expectations about the answer. (e.g. "because of the situation in this problem, I would expect the speed of car B to be only a little bit faster than that of car A")
     - A specific physics diagram (free-body diagram, energy bar chart, motion diagram etc.)
     - A coordinate system that specifies the reference and direction of measurement for any spatial variables. (e.g. "x = 0 is the tabletop, positive x is down" or equivalent symbols)

Make a simplified diagram that shows all of the dimensions relevant to this problem. Be sure to label the diagram with all of the relevant information, including everything you assumed above.

4. **Solve the Problem**
   - Show all calculations

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5. **Check Your Answer (Error Checking / Sensemaking)**

- Demonstrate that your result has the correct units
- Compare results to known benchmarks
- If necessary, perform additional calculations to check your answer is sensible

L1M Tut7

Example of students in formula-hunting mode
Resisting several prompts from TA to engage in sensemaking
Show no evidence of having a clear mental model of the situation

14:32.3	S1	um, we have the acceleration...
14:33.8	TA	the acceleration, and you have..
14:35.3	S1	mass, and this, mass of the car
14:37.7	TA	and...displacement
14:38.9	S1	but we don't know the displacement
14:40.5	S2	what is the displacement? We don't have any numbers...
14:43.3	TA	oh, that goes under assumptions
14:45.9	S2	oh
14:46.1	S1	oh you assume?
14:46.2	TA	like for example, what's the initial velocity of someone who isn't distracted?
14:52.1	S2	**50 km per an hour?**
14:54.5	TA	that's about it, yes..
14:55.8	S2	(gasp, exasperated)
14:57.0	S1	oh...
15:00.2	S2	so how do you assume the displace... oh I'm so confused
15:03.5	TA	so how long would that person take to brake?
15:08.2	S1	usually 50 km per an hour
15:10.0	S2	50 km per an hour is average speed
15:12.4	S1	50?
15:13.6	S3	yeah, that makes sense
15:14.4	S2	yeah, 50. so how long would it take a person to brake?
15:16.8	TA	ok. how long would it take that person to brake?
15:22.0	S2	I dunno, uh, like timewise? or do you mean like distance?
15:26.6	TA	timewise or distance wise. which one is most useful in that context.
15:31.5	S2	I guess distance wise.
15:33.4	TA	why?
15:35.1	S2	I don't know! (laughs) I'm confused!

Same tutorial later on

Students express disbelief about "standard" physics assumption

28:05.1	S1	... distracted ... use this value ...
28:14.3	S2	**see that doesn't make sense though. see, you know like, that doesn't mean it's constant acceleration if it's stepping on the brake. you know what I mean, it's like the car's decelerating, this is a constant acceleration question, it doesn't make sense**
28:25.3	S3	it's decelerating...
28:27.4	S2	**yeah I don't decelerate like that though. Let me tell you! (makes screech noise)** (laughs)
28:31.5	S3	well just assume it..
28:33.7	S1	so assumptions would be.
28:36.8	S3	just assume the acceleration (unintelligible)
28:40.3	S2	assumptions yeah assume acceleration is constant
28:41.6	S1	acceleration...
28:43.3	S4	we have to assume the velocity?
28:45.5	S2	no assuming the displacement. Assuming the displacement to find the velocity. Right?
28:51.5	S1	no we're assuming the velocity of the distracted car is 50 km/h
28:54.7	S2	the not distracted car
28:55.8	S1	sorry the nondistracted car. ... velocity....

Students addressing worksheet's call for answer checking and sensemaking

35:35.2	S1	(mumbling, writing) ... four... the before hitting the brake... it brakes... is 1.18 meters per second. so then we (unintelligible) this?
36:00.9	S4	so we can check our answers...
36:04.8	S1	our answer has the ... correct units. which is..
36:13.7	S2	(interrupting) correct units. and say it makes logical sense comparing it to the...
36:17.7	S1	the units, yeah I said that. Units for velocity. Meters per second.

Students addressing the workheet's call for a clear Model and Assumptions

46:30.2	S1	choos it... is friction negligible?
46:33.6	S4	yeah. where IS friction?
46:43.5	S2	oh, ok. so we can see that, wait, displacement of... um... displacement of car.. equals .. displacement... second car (writing). I'm just. it says make assumptions like that.
47:01.9	S1	do we need to say, like, distracted or not distracted
47:07.9	S4	yeah. I htink we should write that down too, that friction is negligible.
47:20.6	S2	uh.

47:20.7	S1	definitely also um... (mumble)
47:23.7	S2	oh, Vi?
47:23.8	S1	oh that velocity final is zero once you hit the brakes.
47:35.3	S2	there. I think it's good, just..
47:37.2	S1	the mass of the car is... the mass of the two cars is the same so we ignore the masses.
47:42.0	S4	mmm.
47:51.7	TA	(announcing) uh, ok everyone. so that's time,

L1EA7

Students are prompted to write assumptions
This actually does trigger a conceptual discussion

	s2	um... are we considering air resistance?
0:07:08	s1	no. we don't need to consider that. Because it's decelerating
	s3	assume no air friction then
0:07:15	s1	well, we don't even need to take that into account at all, because like, it's giving us... we can assume that he travels at a constant speed the whole time. so it's not slowing down, so why would he need to take into account air friction. And then when he needs to slow down and brakes with 0.6 g of deceleration, then why would we need to take air friction into account in that case either, right? it's like...
0:07:40	s3	so we're assuming nothing?
	s1	lemme think.
	s3	. oh assume reaction time
	s1	it's irrelevant, like, we can say that, like, friction, air friction, those concepts are irrelevant in this problem.
0:07:58	s4	so what about reaction time?
	s3	assume 3-4?
	s1	(interrupts) well we can assume, we assume that his reaction time would double from normal due to the distraction.
	s2	double to what? to six seconds?
	s1	six seconds. so we can make a reasonable assumption that his reaction time would be six seconds as opposed to, like, three seconds for another driver.
0:08:29	s3	**that's long**
	s1	can I see that?
0:08:30	s2	**do we also have to assume that the other driver is driving at the legal speed? I mean, if he's matching up with the other driver, right**? what if the other driver is...
	s1	(interrupts) well we have to assume how fast they're going probably in order to, like, calculate what kind of…
0:08:49	s1	actually, what was the problem again(laughs)
	s2	I dunno

Later on. Good example of real-world sensemaking
This type of real-world sensemaking is enabled by contextualizing your problems in situations familiar to the students

		(long pause)
	s4	initial time is zero
0:13:59	s2	does the car slide a bit?
0:14:05	s1	**no the car shouldn't slide. It would be horrible if the car slides, just like whenever it rains.**
	s4	(laughs) ok
	s1	OK
	s1	yeah a car's
	s4	oh wait so that's... this is for ice
0:14:18	s3	(ignoring s1, s2) we have to assume, um, constant velocity.
	s4	(ignoring s1, s2) assume constant velocity?
0:14:19	s1	**yeah, even on ice a car should *not* be sliding on the ice. Of course it's unavoidable.**
0:14:29	s3	(ignoring s1, s2) uniform motion
	s1	uniform motion? OK I guess... until it brakes anyways

Challenge. How to code this segment?
Are students talking about what is going on, or what to do? Conceptual / procedural?

	s1	the difference is that this guy reacts slower
	s3	but then what's
	s1	he takes longer to think that he needs to brake, but everything else takes the exact same amount of time
0:39:50	s4	should we include that to the time here? cuz they cancel out?
	s1	no, we don't because. we don't have to include it because. we don't need to include it because
	s4	cuz they both have it
	s1	it's they both have it. those values kinda cancel each other out.
	s3	ok
0:40:04	s1	so, additional two seconds of reaction time is, like, ridiculous (laughs) so, I say, I say... zero point.... probably like you subtract 0.2 seconds ... or...
	s2	I think we have to say what this is. So then, like, they won't mistaken it as, uh, that's how much time they have to
0:40:30	s1	(interrupts) you say like, the amount of time that, extra time he takes to think about "I need to uh brake" is probably, would probably be about point... point three seconds I'd say
	s3	that's what we have here right?
	s1	no no. 0.3, as in subtract 0.3, rather than 2
	s3	oh, i see 2?
	s1	rather than 2 (laughs)
	s3	so what is this? the time, the time to...

0:41:01	s1	that's the distraction. the amount of time he's distracted for. the extra time he takes to react.
	s2	not extra time.
	s1	yeah extra.
	s2	it's the amount of time he has to react
	s1	no it's the amount of time, the extra amount of time that it takes
	s3	(interrupts) cuz this is how, the time he has to react. And then add this, right?
	s1	this? yeah yeah. you're subtracting it off of ..
	s2	then shouldn't it be addition.. uh... extra on top of this?
	s1	no. no. he takes an extra. he takes a measure.. this is how long.. this is the brake time. This is how long they have, this is how long he has to hold the brakes. It decreases because he takes longer to react. It takes longer before he steps on the brakes. But they both must, y'know take the same amount of, y'know what I'm saying? They have to... aaaaaahhh it's hard to explain.
	s2	I think I get it but I don't... just is it?
0:42:03		

Jeopardy Question

Equation 1: The equation below describes an object undergoing some process. Solve for the unknowns, then construct a diagram depicting the process and explain a physical situation that could correspond to this description. Where necessary, provide a diagram of motion or energy flows.

Bonus points for a realistic situation

X g/hr * (1 hr/3600 s) * (10^6 J/1 MJ) * (1 kg/1000 g)* 30 MJ/kg * 40% =
[(0.1 W/(K * m)) * (20 °C -10 °C) * 2 (4m*10m + 4m*20 m + 10m*20 m)] / 0.2 m

L1HB tut6

Good example of protracted proposal / evaluation / refinement cycle
Multiple real-world connections

Interpreting terms in a jeopardy question
Discussing the source term (which is some sort of fuel being turned into energy)

121	07:02.4	S3	(interrupting) we just don't know what grams...
122	07:04.4	S2	well what would be heat... what would be
123	07:05.2	S3	yeah
124	07:05.6	S1	that's what we're after. that's what we're being..
125	07:07.4	S2	it wouldn't be a heater, cuz heater doesnt' need grams, right?
126	07:09.1	S1	no, because that's gonna be watts
127	07:10.4	S2	right
128	07:10.9	S4	yeah
129	07:11.6	S2	won't be how grams can give us heat
130	07:13.3	S1	it could be food
131	07:15.1	S2	how would food...
132	07:16.4	S1	because grams of carbohydrates for example
133	07:16.6	S2	(unintellible) inside the box?
134	07:19.4	S2	well what would be the box (unintellible)?

135	07:21.0	S1	well it could be the person into the house outside, like. I mean that wouldn't really make sense
136	07:25.7	S2	no, no. That would have to be a person.
137	07:29.4	S3	that box! (laughs)
138	07:33.1	S1	what about a fire?
139	07:34.1	S2	what?
140	07:34.8	S1	a fire.
141	07:36.0	S2	but then how would, how could we... the fire's next to the box?
142	07:40.5	S1	no, this could be a room, then we've got a fire on the inside..
143	07:44.1	S3	and you add amount of grams
144	07:46.4	S1	x grams of..
145	07:46.8	S2	grams of what?
146	07:47.9	S1	wood maybe?
147	07:47.9	S3	wood? or coal.
148	07:50.4	S1	i dunno, it doesn't really make sense.
149	07:51.7	S4	you could add grams of wood.
150	07:52.1	S2	fireplace?
151	07:53.0	S3	coal?
152	07:54.3	S4	I guess
153	07:54.5	S1	grams of what for a...
154	07:56.4	S2	could be a fireplace. fireplace is a box. Wait no, it's an open box.