# Student Perspectives of and Experience with Sense-Making: a Case Study

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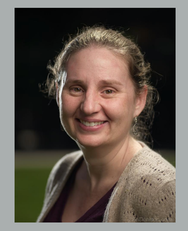


## Overview

Sense-making while solving physics problems involves coordinating the use of algebraic symbols with conceptual understandings, understandings of geometric relationships, and intuitions about the physical world.

- Shane believes his knowledge of sense-making strategies was refined but not expanded.
- Sense-making strategies became formal for Shane.
- Shane reports that he routinely does unprompted sense-making.

## Instructional Context

*Techniques of Theoretical Mechanics*

- 10 weeks, 50 min. meetings, 3 times a week
- Topics
  - ✓ Classical mechanics
  - ✓ Special relativity
- Spring 2017
  - ✓ Taught by author EG
  - ✓ 27 students completed course

Sense-making

- Treated on equal footing with the physics content goals

## Methods

Extreme Case: Shane

- Scored low on the multiple-choice portion of sense-making pretest
  - ✓ Shane: 1/7
  - ✓ Class average: 3/7
  - ✓ StDev: 1.8
- 5th highest grade in class
  - ✓ Assignments routinely asked for demonstrations of sense-making

Data Collection

- 5 semi-structured interviews with Shane
  - ✓ Approximately 30 minutes every 2-3 weeks
  - ✓ 6 questions repeated in all 5 interviews
- Triangulation
  - ✓ 5 homework assignments
  - ✓ Pre- and post- sense-making assessments

## Sense-Making was Formalized

> "*They [sense-making strategies] were never talked about in the general physics series. I didn't really exercise the more complicated sense-making strategies. But this class actually creating a list* [seen below] *of sense-making strategies brought them together.*"

Student-generated list of sense-making strategies

- Dimensional Checking
- Direction/Sign of Answer
- Reasonableness of Answer
- Limiting/Special Cases
- Graphical Analysis
- Compare to what you know
- Plug answer back into start
- Assumptions/ Idealizations
- Proportionality

Shane may have felt constrained to use only sanctioned sense-making strategies

> "*I didn't know that solving the question 2 different ways was an official sense-making strategy for this class.*"

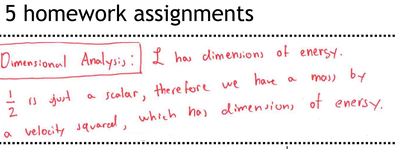
Shane believed that demonstrating sense-making without holding students accountable is insufficient support for students to learn how to do sense-making

> "*I think [introductory physics instructor] actually does a good job talking about them during lecture but it feels like the homework rubric in that class is outdated.*"

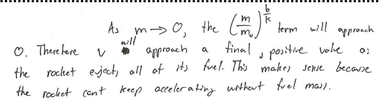
## Strategies used by Shane

43 instances of sense-making in response to explicit, open-ended sense-making prompts on 5 homework assignments

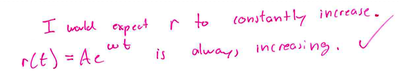
14 dimension checks



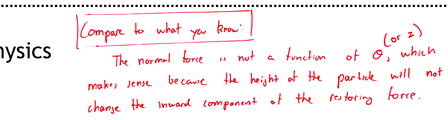

11 special/limiting cases



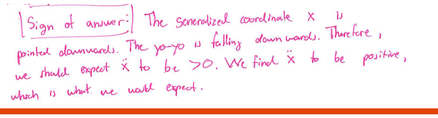

5 uses of functional dependence




4 connections to physics concept




4 checking signs



## Strategies Refined, Not Expanded

> "*All the sense-making strategies that we've gone over in class were things we covered in the general series, so I wouldn't say I've learned anything new or if there was anything really outstanding for me.*"

- Change from units to dimensions "*the first day of this class.*"
  - ✓ Proven switch on pre-and post- sense-making assessment
- New topics meant using strategies in new ways

> "*I've learned, kind of, new ways to apply the [sense-making strategies] I already knew.*"

- Pre- and post- sense-making assessment
  - ✓ Altered 2 strategies (eg. Question 5 below)
  - ✓ Increased score from 1/7 to 3/7

Q5: Imagine two boxes with different masses $m_1 < m_2$ connected by a massless rope over a massless pulley on a double-sided ramp where the two ramps have different inclination angles, $\alpha$ and $\beta$.
Which expression is most reasonable for the acceleration of the box with mass $m_2$?
Explain your reasoning for each answer choice.

## Did Unprompted Sense-Making

> "*Well I definitely do unprompted sense-making on the homework where like halfway through my solution I'll actually use a different color... so I'll circle the arguments of some kind of logarithmic function or exponential and I'll just check that its unit, dimensionless, like in the middle of the question.*"

$$\frac{k}{b}\ln\left(\frac{b}{k}v - v_{ex}\right) - \frac{k}{b}\ln\left(-v_{ex}\right) = \ln(m) - \ln(m_0)$$

$$\frac{k}{b}\ln\left(\frac{\frac{b}{k}v - v_{ex}}{-v_{ex}}\right) = \ln\left(\frac{m}{m_0}\right)$$

arguments are now unitless ✓

Using sense-making outside of *Theoretical Mechanics*

- Shane is an introductory physics learning assistant
  - ✓ Uses sense-making with intro. students in class and tutoring
- Taking 2 concurrent math courses: *Algebra and Sequences & Series*
  - ✓ Difficult to do sense-making due to of lack physical context
- Auditing *Introduction to Solid State*; graduate physics course
  - ✓ Mixed ability with sense-making

Oregon State University

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## References

[1] C. Singh, Am. J. Phys. **70** (2002).
[2] A. R. Warren, Phys. Rev. ST Phys. Educ. Res. **6**, 020103 (2010).
[3] E. F. Redish, Teaching Physics: With the Physics Suite (John Wiley & Sons, Hoboken, NJ, 2003).
[4] M. Lenz and E. Gire, in PERC Proceedings (2016).
[5] D. Hammer, Phys. Teach. **27**, 664 (1989).
[6] C. Stathopoulou and S. Vosniadou, **32**, 255281 (2007).
[7] W. Adams, K. Perkins, N. S. Podolefsky, M. Dubson, N. Finkelstein, and C. Wieman, Phys. Rev. ST Phys. Educ. Res. **2** (2006).
[8] J. Seawright and J. Gerring, Political Research Quarterly **61**, 294 (2008).

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