# What does it mean to understand a physics equation? A study of undergraduate answers in three countries

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# Overview

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- Background
- Research questions
- Data collection
- Analysis
- Eight themes
- Creating questions
- Conclusions

# Undergraduate physics in Sweden

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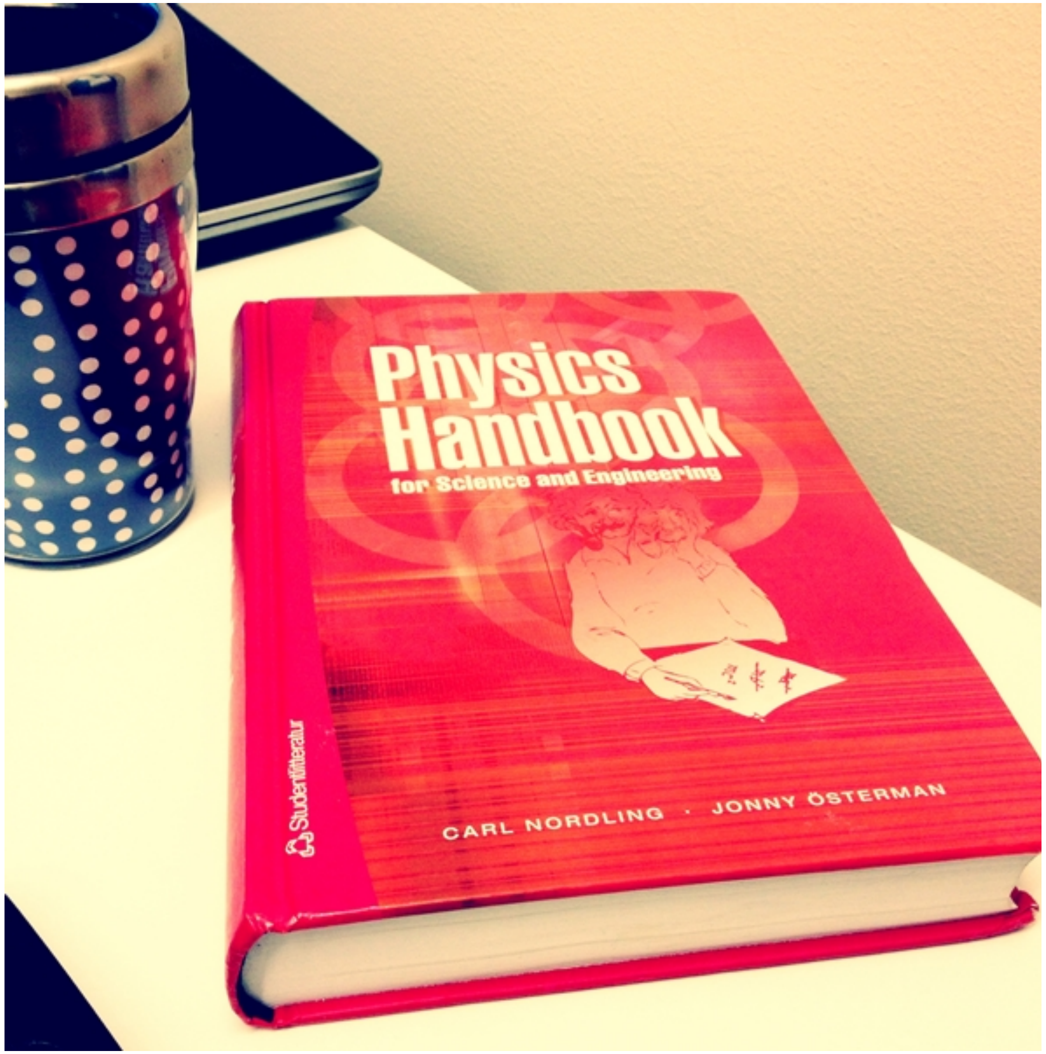
Physics handbook

Lists of physics formulae

Useful or Counterproductive?



## Background

- My experience

$$\lambda = \frac{h}{p}$$

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## Background

- Students seemed to think that they understood the equation because they could deal with it mathematically.
- Wondered how other students experienced equations.

# Research background

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- Previous research on equations has mainly focused on student approaches to problem solving

(see overview in Hsu, Brewe, Foster, & Harper, 2004,

More recent example Hedge & Meera 2012)

- Seminal work by Sherin (2001) looked at students’ ability to construct equations.

- The plug and chug approach.

(Tuminaro, 2004)

# Collecting dead leaves?

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*It's as if physics were a collection of equations on fallen leaves […] These are each considered as of equivalent weight, importance, and structure. The only thing one needs to do when solving a problem is to flip through one's collection of leaves until one finds the appropriate equation. I would much prefer to have my students see physics as a living tree!*

Redish (1994)

# Research background

- Little work has been done on how physics students experience equations.

(Domert et al., 2007; Hechter, 2010)

# Research questions

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1. How do students in three countries say they know that they have understood a physics equation?

2. What different disciplinary aspects of equations can be identified?

3. How might a more holistic view of the understanding of equations be communicated to students?

# Data collection

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Students were asked one simple question:

***How do you know when you understand a physics equation?***

# Data collection

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Over 350 students in three countries

Sweden (n=105)

USA (n=83)

Australia (n=168)

Short written answers

# The responses

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”… when I know how and in which context I can l use it”

”When I can twist and turn it so that I can obtain what I need”

*”…when I know where the equation comes from (derivation) and of what use it can be.”*

*When I can remember it*

”When the the answer is 42.”

*”When I calculate and get it right:”*

” …when I can calculate a solution that I also can measure in practice.”

*”[When] I can explain it to a 10-year old.”*

# Analysis

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Initially phenomenographic approach

Looking for a hierarchy

Looking for some sort of developmental path

Looking for differences across countries

# Later analysis

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Treated whole dataset as a ”pool of meaning”

Open coding

Leading to a set of themes

# The resulting categories

Inital analysis resulted in thirteen categories

Managed to get these down to eight themes

# Recoding

Inter-rater reliability

- American 74%
- Australian 78%
- Swedish 88%

# Eight themes

- Significance: Why, when, where
- Origin
- Describe/visualize
- Predict
- Parts
- Other equations
- Calculate
- Explain

# Research questions

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1. How do students in three countries say they know that they have understood a physics equation?

2. What different disciplinary aspects of equations can be identified?

3. How might a more holistic view of the understanding of equations be communicated to students?

# Where next?

Usually researchers stop here.

Eight themes.

Not very useful for students and teachers.

New methodological approach.

Went back to the original data.

Created questions for each theme.

# Where next?

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Set of questions for each theme

Claim:

Being able to answer these questions for any equation leads to a more holistic understanding.

Note: Not necessarily better

# 1. Significance: Why, when, where

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Do you know why the equation is needed?

Do you know where the equation can and cannot be used? (boundary conditions/areas of physics).

Do you understand what the equation means for its area of physics?

What status does this equation have in physics? (fundamental law, empirical approximation, mathematical conversion, etc.).

## 2. Origin

Do you know the historical roots of the equation?

Can you derive the equation?

## 3. Describe/visualize

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Can you use the equation to describe a real-life situation?

Can you describe an experiment that the equation models?

Can you visualize the equation by drawing diagrams, graphs etc.

## 4. Predict

Can you use the equation to predict?

# 5. Parts

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Can you describe the physical meaning of each of the components of the equation?

How does a change in one component affect other components in the equation?

Can you manipulate/rearrange the equation?

# 6. Other equations

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Can you relate this equation to other equations you know?

Can you construct the equation from other equations that you know?

## 7. Calculate

Can you use the equation to solve a physics problem?

Can you use the equation to solve a physics problem in a different context than the one in which it was presented?

When you use the equation to calculate an answer do you know:

- How your answer relates to the original variables?
- The physical meaning of this answer?
- Whether your answer is reasonable?

# 8. Explain

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Can you explain the equation to someone else?

# Is this useful?

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We believe the questions have the potential to help physics students who think they understand a physics equation to check whether there are other aspects that they have not considered.

# Future work

Testing the questions with students

Asking the same questions to lecturers

# References

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