7-2009

Measuring Physics Teachers' Strategic Knowledge: Domain-General or Domain-Specific?

Robert M. Talbot III
University of Colorado Denver, robert.talbot@ucdenver.edu

Valerie K. Otero

Derek Briggs

Measuring Physics Teachers' Strategic Knowledge: Domain-General or Domain-Specific?

Robert M. Talbot III, Valerie K. Otero, Derek C. Briggs

STEM Colorado — CU Teach & Learn Learning Assistant (LA) Model Discipline-Based Math & Science Education Research

Abstract

The development of reliable and valid measures of science teacher knowledge is essential for the evaluation of teacher education programs. A particular challenge is that most programs serve pre-service teachers with a range of disciplinary specialties. Is it best to measure science teacher knowledge within individuals' science specialty, or can this be measured domain-generally for the sciences? In this research, we investigated this question by developing a physics-specific measure of science teachers' strategic knowledge. We then conducted an experiment in which we randomly administered a domain-general measure or the parallel physics-specific measure to a population of pre-service science teachers. The empirical evidence gathered serves to further develop the Flexible Application of Student-Centered Instruction (FASCI) instrument, and contributes to our understanding of science teachers' pedagogical content knowledge.

Background

•The Flexible Application of Student-Centered Instruction (FASCI) instrument was designed as part of the CU-Boulder Learning Assistant (LA) Program (Otero, 2006)

•The FASCI was designed to be content neutral in order to be useful for measuring levels of the FASCI construct in individuals who come from a variety of STEM disciplines

•The content-neutrality of the existing FASCI scenarios could pose a threat to the validity of FASCI score interpretations if an individual's strategic knowledge interacts with their subject matter knowledge

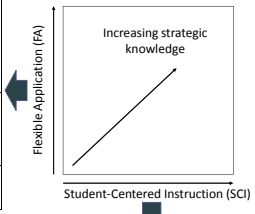
Research Questions

How do scores on the content-neutral version of the FASCI compare to scores on a physics-specific version of the FASCI for individuals with a range of physics expertise?

Are survey version, physics content knowledge, and intention to teach physics meaningful predictors of an individuals' FASCI scores?

The FASCI Construct

Level		Respondent Characteristics
Increasing FA	2	• The teacher has repertoire of strategies that can be used to facilitate student learning within a given class session. • If the teaching strategy comprised of these acts is not producing the desired result, sometimes it can be modified. • The teacher recognizes that the choice of a class activity and associated teaching strategy will depend upon variables specific to the classroom context.
	1	• The teacher has a repertoire of strategies that can be used to facilitate student learning within a given class session. • If an activity based on a particular teaching strategy is not producing the desired result, the activity can be modified by selecting a different strategy.
	0	• The teacher has a limited repertoire of strategies. • Once a particular activity has been selected for a class session, it is not easily modified with a different strategy.



•The two FASCI dimensions (FA and SCI) are similar to some aspects of Pedagogical Content Knowledge (PCK; Shulman, 1986, 1987)

•Although related, the FASCI instrument *is not* designed to measure PCK

Level		Respondent Characteristics
Increasing SCI	1	• Discussion of interactive teaching which would be *observable* to the teacher or to an outside "other." Teacher ⟷ Students and/or Students ⟷ Students
	0	• No discussion of interactive teaching • Teacher primarily views classroom activity as way to help students make sense of new ideas. Information goes from teacher to student. Teacher ⟶ Students

References

Lord, F. M. (1980). *Applications of item response theory to practical testing problems*. Hillsdale, N.J.: L. Erlbaum Associates.

Otero, V. (2006). *Recruiting talented mathematics and science majors to careers in teaching: A collaborative effort for k-16 reform.* Paper presented at the National Association for Research in Science Teaching, San Francisco.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-22.

This work is funded by the LA-TEST project, NSF grant ESI-TPC 0554616

Two Parallel Versions: the neutral-FASCI and the physics-FASCI

Content-Neutral FASCI (n-FASCI) example item

For the questions and scenarios that follow, please assume that you are teaching a high school course in physics, chemistry, biology, Earth science or math to a class of 25-30 students.

Students are working in groups of four to discuss a conceptual question you provided them at the beginning of class.

a.) How might this activity facilitate student learning?

As the activity proceeds, one group gets frustrated and approaches you—they've come up with two solutions but can't agree on which one is correct. You see that one solution is right, while the other is not.

b.) Describe both what would you do and what you would expect to happen as a result.

c.) If the approach you described above in (b) didn't produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?

Physics-FASCI (p-FASCI) example item

For the questions and scenarios that follow, please assume that you are teaching a high school course in physics to a class of 25-30 students. You have defined the following learning objectives for this class:

•Students should understand Newton's Third Law so that, for a given system, they can identify the force pairs and the objects on which the forces are exerted, and specify the magnitude and direction of each force.

•Students should be able to apply Newton's Third Law in analyzing the forces that two objects in contact exert on each other when they accelerate together along a horizontal or vertical line, or the forces that two surfaces that slide across one another exert on each other.

**The next set of questions refer to a large truck which breaks down out on the road and receives a push back to town by a small compact car, as in the picture below.*

Pick one of the choices a) through f) which correctly describes the forces between the car and the truck for each of the descriptions in questions 2 through 5 below.

The car is pushing on the truck, but not hard enough to make the truck move.

a) The force of the car pushing against the truck is equal to that of the truck pushing back against the car.
b) The force of the car pushing against the truck is less than that of the truck pushing back against the car.
c) The force of the car pushing against the truck is greater than that of the truck pushing back against the car.
d) The car's engine is running so it applies a force as it pushes against the truck, but the truck's engine isn't running so it can't push back with a force against the car.
e) Neither the car nor the truck exert any force on each other. The truck is pushed forward simply because it is in the way of the car.
f) None of these descriptions is correct.

Students are working in groups of four to discuss the conceptual questions about the car pushing the truck.

a.) How might this activity facilitate student learning?

As the activity proceeds, one group gets frustrated and approaches you—they cannot agree on the answers regarding the forces exerted by the car and truck on each other.

b.) Describe both what would you do and what you would expect to happen as a result.

c.) If the approach you described above in (b) didn't produce the result(s) you anticipated by the end of that class session, what would you do in the next class session?

*Note that the same physics content questions (12 total) are included at the end of the n-FASCI

Item Analyses

Reliability Estimates for each dimension on each version of the FASCI

Version	Dimension	Cronbach's Alpha
n-FASCI	FA	0.60
	SCI	0.65
p-FASCI	FA	0.52
	SCI	0.16

The lower reliability of the p-FASCI is hypothesized to be due to the fact that p-FASCI respondents often focus on discussing the physics content

Item difficulties (p-values) for each dimension and version of the FASCI

Dimension	Item	n-FASCI	p-FASCI
FA	1	0.48	0.52
	2	0.36	0.36
	3	0.42	0.35
	4	0.26	0.27
	5	0.25	0.33
SCI	1	0.96	0.82
	2	0.24	0.09
	3	0.16	0.09
	4	0.32	0.28
	5	0.56	0.56

Scores

Open-ended responses to FASCI items are scored by trained raters using scoring guides based on the construct maps. Raw scores will be scaled using Item Response Theory (IRT, Lord, 1980). Below are the raw (not scaled) pre-test scores. Maximum FA score = 10, maximum SCI score = 5.

Mean (SD) FA and SCI Raw Scores on n-FASCI

University	*n*	FA mean (SD)	SCI mean (SD)
A	14	3.00 (1.18)	2.00 (1.35)
B	0	.	.
C	2	4.50 (2.12)	2.50 (0.71)
D	8	3.88 (2.30)	2.50 (1.41)
E	2	5.00 (1.41)	2.50 (2.12)
All Universities	26	3.61 (1.75)	2.24 (1.33)

Results of t-tests between n- and p-FASCI groups on FA and SCI- all universities

	Version	*n*	Mean (SD)	Significance
FA_Total	neutral	23	3.61 (1.75)	.940
	physics	21	3.57 (1.54)	
SCI_Total	neutral	25	2.24 (1.33)	.143
	physics	26	1.77 (0.86)	

Mean (SD) FA and SCI Raw Scores on p-FASCI

University	*n*	FA mean (SD)	SCI mean (SD)
A	11	2.67 (1.63)	1.56 (0.73)
B	8	4.00 (1.23)	2.00 (0.63)
C	2	5.00 (.)	2.00 (0.00)
D	12	3.63 (1.60)	1.75 (1.28)
E	1	5.00 (.)	2.00 (.)
All except B	26	3.44 (1.63)	1.70 (0.92)
All Universities	34	3.57 (1.54)	1.77 (0.86)

•t-tests show no statistically significant difference between FA or SCI scores on the n-FASCI and the p-FASCI

•This is also true when excluding university B (which only responded to the p-FASCI and were therefore not part of the random assignment).

Sample and Method

The groups responding to the n-FASCI and p-FASCI are comparable (no statistical difference) on the following covariates: gender, ethnicity, age, subject they want to teach, years of teaching experience, and physics content knowledge (as measured by content items on each version of the FASCI). The is a difference ($p = 0.049$) in number of physics courses taken when including university B in the p-FASCI sample.

Either the p-FASCI or n-FASCI were administered by random assignment to a population of pre-service teachers, both pre and post-semesters' instruction. Administration was conducted online using QuestionPro (www.questionpro.com). Average completion time for each version was about 45 minutes.

Regression Results

Separate multiple regressions were conducted in order to model FA and SCI scores based on FASCI version (p-FASCI = 1 if version is physics-FASCI, else 0), physics content knowledge, and intention to teach physics. Main effects of each independent variable and all interaction terms were modeled. No interaction terms were found to be statistically or substantively significant.

Dependent Variable: FA	Model		
Predictor	1	2	3
Intercept	2.240 (.000)	1.463 (.005)	1.455 (.007)
p-FASCI	-.593 (.050)	-.614 (.040)	-.610 (.047)
Physics Content Knowledge		1.143 (.089)	1.161 (.114)
Teach Physics			-.022 (.951)

Dependent Variable: SCI	Model		
Predictor	1	2	3
Intercept	3.480 (.000)	1.999 (.005)	1.790 (.013)
p-FASCI	-.274 (.512)	-.314 (.435)	-.214 (.599)
Physics Content Knowledge		2.178 (.019)	2.660 (.009)
Teach Physics			-.594 (.214)

•FASCI version is a significant predictor of FA, but not of SCI

•Physics content knowledge is a statistically significant predictor in the SCI models

•Intention to teach physics is not significant

Conclusions

Based on our analyses to date, we tentatively arrive at the following conclusions:

There is no statistically significant difference between scores from the neutral-FASCI and those from the physics-FASCI

The physics-FASCI is a less reliable measure of the FASCI construct, especially with respect to the SCI dimension

Physics-FASCI respondents discuss more of the content in their responses, and less about the students

Future analyses of another set of responses from each group (post-semester) will allow us to characterize how each version is able to capture change in respondents' strategic knowledge. Interview and observation analyses will also contribute to our further understandings.