Interdisciplinary Thinking and Physics Identity

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Introduction and Background

Interdisciplinary thinking has been recognized as vital to the future of science and engineering in the United States. [1, 2] Physics in particular is full of interdisciplinary research opportunities (e.g. biophysics, atmospheric physics, and geospace physics). However, physics is sometimes thought of as monolithic with practitioners having few interests besides cloistering in a lab. It is in the interests of the physics community to attract interdisciplinary thinking students and to develop characteristics of interdisciplinary thinking in its classrooms.

For this study, we use a physics identity framework. Physics identity is a way of understanding how someone perceives themselves with respect to the field of physics. We build on the work of Hazari et al. [3] which built on the identity framework of Carlone and Johnson. [4] Subsequent modeling has found that only recognition and interest have a direct impact on identity. [5]

Since physics identity describes how a person identifies with the field of physics and is highly correlated with the choice of physics as a career, [3] it is a useful tool to understand what experiences, attitudes, and characteristics are related to identifying with physics. A visual synopsis of this study is sketched in Figure 1. Our two research questions are:

Q1. How are characteristics of interdisciplinary thinking related to physics identity?

Q2. What pedagogical and environmental characteristics of the physics classroom foster interdisciplinary thinking?

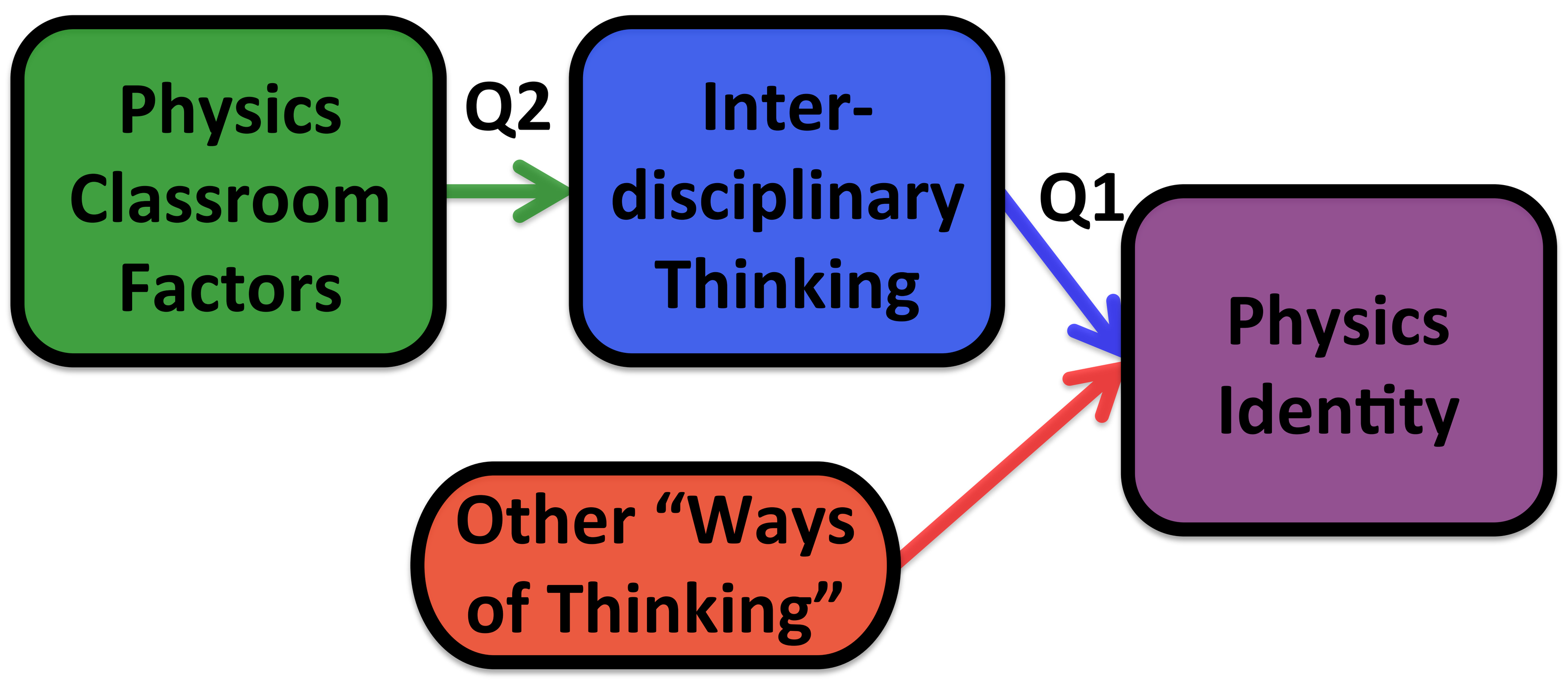

Figure 1: Organization of the study showing how our two research questions are investigating the relationships between the the physics classroom, interdisciplinary thinking, and physics identity.

Methods

- This study draws from survey data obtained as part of the Sustainability and Gender in Engineering (SaGE) project (http://www.clemson.edu/~gpotvin/SaGE.pdf). The survey was administered in introductory English courses at 50 colleges and universities to obtain a nationally representative sample of 6,772 responses. A map of all respondents' zip codes is shown in Figure 2.
- The physics identity indicator for this study was constructed from recognition and interest factors.
  - "My parents/relatives/friends see me as a physics person." (recognition)
  - "My physics teacher sees me as a physics person." (recognition)
  - "I am interested in learning more about this subject." (interest)
  - "I enjoy learning about this subject." (interest)
- Our interdisciplinary thinking indicator is built from responses to:
  - "I hope to gain general knowledge across multiple fields."
  - "I identify relationships between topics from different courses."
- Analysis was done using R version 3.0.0 [6]
  - Multiple imputation was performed using the Amelia II package to obtain a sample size of 2,066 [7].
  - Linear models were built using the Zelig package.
- For all linear models, we used an $\alpha = 0.01$ significance threshold to reduce the chance of type I error.

Overview

One goal of education is to help students become well-rounded citizens who can think broadly across boundaries. In addition, individuals with interdisciplinary thinking skills can be valuable contributors to modern research challenges by understanding and recognizing interdisciplinary connections and working in diverse teams. However, there is little research on the connection between interdisciplinary thinking and physics education. What aspects of physics classroom practices and experiences foster interdisciplinary thinking? What effect does interdisciplinary thinking have on the development of students' physics identities? Using a physics identity theoretical framework with data from a national survey, this study found that characteristics of interdisciplinary thinking are significantly correlated with higher levels of physics identity development. Also, several factors of the physics classroom environment and pedagogies are significantly related to interdisciplinary thinking.

Results

Table 1: Regression model predicting physics identity (N=2066). **: p<0.01; ***: p<0.001; ns: not significant.

Parameter	Estimate	Std. Error	β	Significance
Intercept	-1.74	0.12		***
Controls				
Race, ethnicity, and SES				ns
Physics grade	0.09	0.01	0.15	***
Family science hobbies	0.24	0.05	0.09	***
Father/male guardian is a scientist	0.38	0.16	0.07	***
Gender (0 = Female, 1 = Male)	0.51	0.04	0.21	***
Physics class topics were relevant to their life	0.08	0.02	0.08	***
Physics teacher explained ideas clearly	0.04	0.01	0.05	**
Interest of fellow students in physics class	0.24	0.02	0.25	***
"Ways of thinking" predictors				
Interdisciplinary thinking indicator	0.11	0.03	0.07	***
"Learning science will improve my career prospects"	0.11	0.03	0.12	***
"Science has helped me see opportunities for positive change"	0.18	0.03	0.16	***
"The scientific method always leads to correct answers"	0.07	0.02	0.07	**
Adjusted $R^2 = 0.40$				

Table 2: Regression model predicting interdisciplinary thinking (N=2066). **: p<0.01; ***: p<0.001; ns: not significant.

Parameter	Estimate	Std. Error	β	Significance
Intercept	1.61	0.09		***
Controls				
Race, ethnicity, and SES				ns
Family saw science as a way to have a better career	0.17	0.03	0.10	***
English scores†	0.43	0.09	0.10	***
Physics classroom factors				
Spent time doing individual work in class	0.06	0.02	0.07	***
Topics were relevant to their life	0.04	0.01	0.08	**
Level of conceptual understanding required	0.06	0.02	0.07	**
Questions required several steps of calculations	0.11	0.04	0.06	**
Teacher's enthusiasm for physics	0.06	0.01	0.12	***
Adjusted $R^2 = 0.09$				

† A composite built from self reported scores of class grades and standardized tests

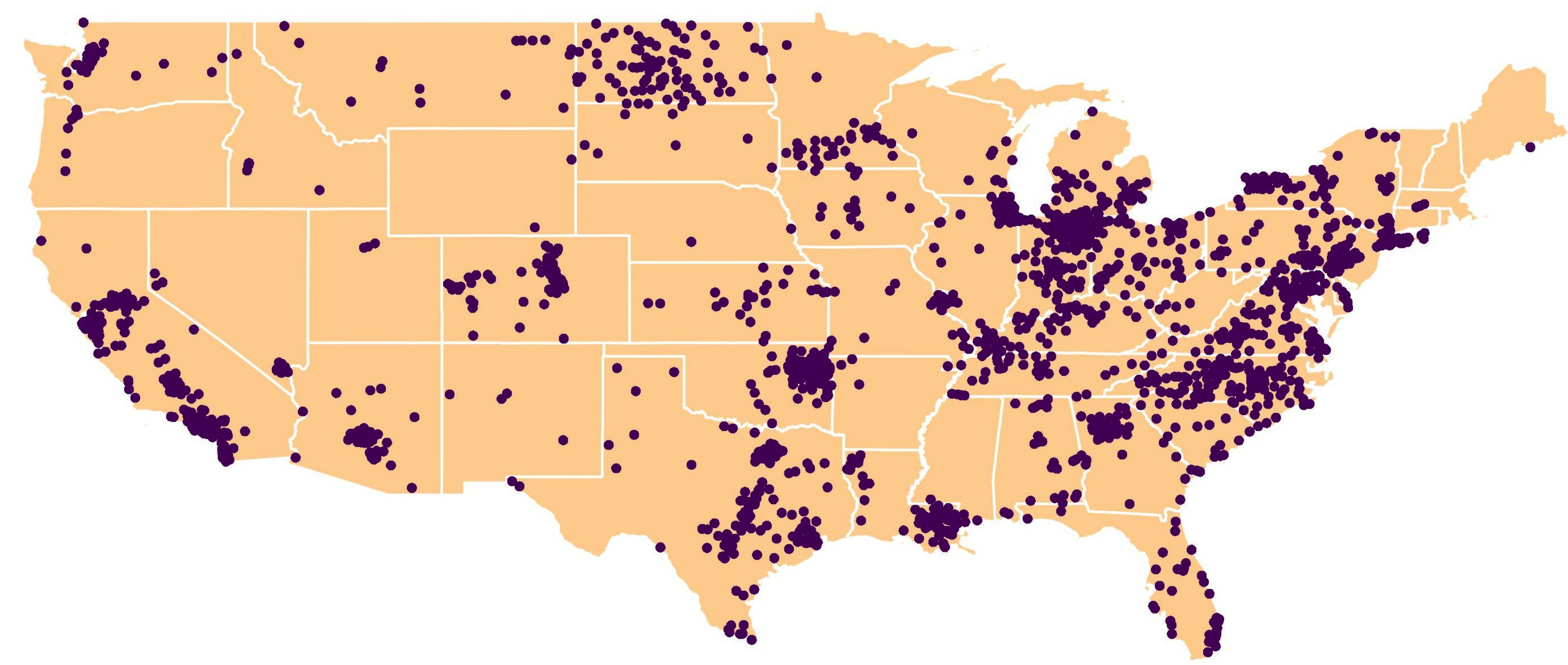

Figure 2: Map of home zip codes of SaGE study student participants. There is one dot per zip code regardless of the number of participants from each code.

Conclusions and Future Work

As shown in Table 1, it is clear that characteristics of interdisciplinary thinking are significantly related to the development of physics identity. This is in contrast to mathematics identity for which there is apparently no significant relationship.

Table 2 presents several physics classroom pedagogy and environmental factors were found to be significantly and positively related to interdisciplinary thinking characteristics. Some are related to the teacher's ability to exude enthusiasm and foster interest in their students. Other pedagogy-specific factors were related to an effective classroom that fosters independence, synthesis, and conceptual understanding.

Future work should focus on examining the causal link between these particular pedagogies and interdisciplinary thinking. For example, what does a good multi-step problem look like? Are some forms of independent work better than others at developing interdisciplinary thinking? Also, better models of interdisciplinary thinking are needed. The interdisciplinary thinking indicator used in this study was made of only two items that cover the most obvious characteristics of interdisciplinary thinking. Future work should explore other characteristics that should be included in a more robust model.

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