Interdisciplinary Affinity: Definitions and Connections to Physics Identity

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Abstract. Though there has been much progress in research on interdisciplinarity over the last decades, two significant limitations still exist. First, there are inconsistent definitions of what interdisciplinarity is. Second, definitions are limited to performance elements. In a break from this prior work, and building on promising preliminary research, we seek to define interdisciplinary affinity, a measure of students' self-reported interests and beliefs about interdisciplinarity. On the basis of hypothesized dimensions of interdisciplinarity, we draw on a large-scale national survey to build a useful measure of interdisciplinary affinity. Also, we investigate relationships between interdisciplinary affinity and physics identity, and particularly, the interest and recognition dimensions of physics identity.

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INTRODUCTION

The last few decades have seen a call for interdisciplinary education to train students to tackle today's interdisciplinary problems [1, 2]. Some have also argued that interdisciplinary education is simply more effective [3]. Both arguments also apply to physics. With the development of new interdisciplinary research areas and the need to engage a broader base of physics students, physics would benefit from interdisciplinary perspectives, both to increase the number of physics graduates and to improve learning in the classroom.

However, research on interdisciplinarity is hindered by a diversity of definitions [4, 5, 6] and by a focus only on performance [e.g. 7, 8, 9, 10, 11]. One theme that seems to be generally accepted across the varying definitions is that interdisciplinarity requires "integration" of information and perspectives from multiple disciplines [10, 8, 4]. The second problem is the customary focus on student performance because it misses the importance of students' beliefs and interests. Understanding interdisciplinarity in the affective domain is especially important when trying to understand students' motivations and persistence. By studying interdisciplinary affinity, we can get at the heart of students' interdisciplinarity. In this study, we define interdisciplinary affinity as students' interest and desire to integrate information and perspectives from multiple disciplines as well as self-perceptions of their competence to do so.

To connect interdisciplinary affinity to physics, we chose a physics identity framework. Based on work by Gee [12], Carlone and Johnson [13], and Hazari et al. [14], physics identity is viewed as a way of describing how a person relates to the field of physics. Potvin and Hazari [15] summarize developments in quantitatively measuring physics identity. Following these researchers, this study looks at physics identity composed of students' interest in physics and their feelings of being recognized by others as a physics person. Because physics identity is a strong, significant predictor of physics career choice [14] we can use it to investigate how interdisciplinary affinity is connected to physics engagement.

In previous work we found a significant association between characteristics of interdisciplinary affinity and physics identity [16]. This is evidently a special connection because a link between interdisciplinary affinity and mathematics identity is weaker. These results raise intriguing questions about the nature of interdisciplinary affinity and its connections to physics identity.

Among the limitations of that previous work is that interdisciplinary affinity was defined by only two survey questions and physics identity by four survey items. Also, that work did not investigate any more specific questions such as how interdisciplinary affinity is connected to the different dimensions of physics identity.

This study is guided by two research questions:

Q1. How can interdisciplinary affinity be quantitatively measured?

Q2. How is interdisciplinary affinity connected with physics identity and, in particular, with the interest and recognition components of physics identity?

METHODS

This study draws from survey data obtained as part of the Outreach Programs and Science Career Intentions (OPSCI) project. The goal of this project is to investigate pre-college outreach-related factors and their influence on the choice of STEM major and on career interest. The data come from surveys administered in first year college English courses. Colleges and universities with a Science Talent Expansion Program (STEP) were asked to participate. Of these, 27 institutions returned 15,847 individual surveys.

The survey asked about a variety of topics including physics identity and hypothesized qualities of interdisciplinarity. For reasons outlined by Potvin and Hazari [15], this survey focused only on the interest and recognition dimensions of physics identity. Factor analysis confirmed the clear distinction of the two dimensions. The interest component of physics identity was constructed from students' responses to "I am interested in learning more about physics," "Topics in physics excite my curiosity," and "I enjoy learning about physics." Recognition was built from responses to "My physics teacher sees me as a physics person," "My family sees me as a physics person," "Others ask me for help in physics," and "My friends/classmates see me as a physics person."

The items used to measure interdisciplinary affinity were primarily inspired by the work of Borrego and Newswander [10] who analyzed interdisciplinary research grants and defined four characteristics of interdisciplinarity. We included 13 items on the OPSCI survey, intentionally designing them to assess "disciplinary grounding," "integration," "communication and translation," and "critical awareness." A list of the 13 items and their corresponding dimension of interdisciplinarity is shown in Table 1. All identity and interdisciplinary affinity items asked for responses on an anchored six point scale from strongly disagree to strongly agree.

The particular items were informed by previous work [16], a small pilot study, and discussion among the authors. Two of the items, "I identify relationships between topics from different courses" and "I hope to gain general knowledge across multiple fields," were part of the previous work establishing a connection between interdisciplinarity and physics identity [16]. They were included here to maintain a link to that previous work. Other ideas came from a small pilot study which was conducted in an introductory physics class. This consisted of an open ended survey, that asked students to respond to the two previously used items and asked for the reasons behind their answers. In particular, the pilot study led to the inclusion of "Being 'well rounded' is important to me."

To answer research question 1, we used exploratory factor analysis to see how the survey items in Table 1 grouped into factors. Poorly loading items were removed and factors were evaluated for face validity. In addition, factors were correlated with students' interest in a range of academic fields to support concurrent, criterion-related validity of our measurement of interdisciplinary affinity.

Research question 2 required taking the resulting interdisciplinary affinity measure and seeing how it correlated with physics identity and the components of physics identity. For both research questions, statistical analysis was done using R version 2.15.3 [17].

RESULTS AND DISCUSSION

The first step was to establish a valid and more complete definition of interdisciplinary affinity than was previously used. We used exploratory factor analysis to build a measure of interdisciplinary affinity from the items shown in Table 1. Note that the table only represents the theory behind our work. If our data were to confirm the framework of Borrego and Newswander [10], we would find four factors with the individual survey items falling into groups as shown in Table 1. Instead, the result was only two factors which do not fit the theory. In short, one factor, which we called "Expert", consisted of the items "I am certain of my chosen career path," "Being an expert in my chosen field of study is important to me," and "Being 'well rounded' is important to me." The second, called "Integration", consisted of "I identify relationships between topics from different courses," "I hope to gain general knowledge across multiple fields," "Talking with people who have different interests than me is fascinating," and "People in my intended major could learn a lot from other fields." The first two of these integration items were used in the preliminary study to allow some continuity in the research process.

The first result from this analysis was that our items were not able to validate the four components of interdisciplinarity presented by Borrego and Newswander [10]. The "Integration" factor includes survey items from across three of the four hypothesized components of interdisciplinarity. Somewhat surprising was that being "well rounded" was factored with the two items intended to measure "Disciplinary Grounding." A possible explanation is that, while some students associate being "well rounded" with interdisciplinary integration, it may also transcend that definition in students' minds because being "well rounded" is so emphasized in education contexts as being a beneficial outcome of education. In other words, when students consider being "well rounded,"

TABLE 1. List of interdisciplinary related items included on the OPSCI survey including the dimension of interdisciplinarity each was hypothesized to fit.

Disciplinary Grounding	"I am certain of my chosen career path" "Being an expert in my chosen field of study is important to me"
Integration	"Being 'well rounded' is important to me" "It is fun to see how STEM courses overlap with each other" "It is fun to see how STEM courses connect with non-STEM courses" "I hope to gain general knowledge across multiple fields"[a] "I identify relationships between topics from different courses"[a] "A lot of the high school courses I took are useless"[b]
Communication and Translation	"My friends have different interests than I do" "Talking with people who have different interests than me is fascinating" "When working in groups, I prefer teammates who are like me"[b]
Critical Awareness	"People in my intended major have biases" "People in my intended major could learn a lot from other fields"

[a] included in the SaGE survey and used in preliminary work [16]
[b] reverse coded

they may see it as a goal they want to achieve in their education (like being an expert in their chosen field of study) rather than what it means in the context of interdisciplinary integration. This is supported by the distribution of student answers to this item which is skewed toward "strongly agree" in the same way in which the other two items in our "Expert" factor are. On the other hand, the survey items that factored into "Integration" all exhibited an approximately normal distribution. The items in the "Integration" factor come from across three of the hypothesized interdisciplinary components of Table 1. This could mean that distinctions between these components cannot be found by these survey items or that these distinctions do not exist. It is also possible that college students (mostly freshmen) have not developed the expertise to recognize the nuance of Borrego's factors, which emerged from a study of research grants. Further research should explore these possibilities.

To further validate our measure of interdisciplinary affinity, we looked at correlations with interests in a variety of academic topics. On the OPSCI survey, a series of questions asked students to rate their interest in the following areas, "languages (including English)," "physical sciences," "athletics," "biological and life sciences," "math and computer science," "social studies," "art, music, theater, etc.," and "engineering." A factor analysis showed that these items factored into the following five categories: (1) science (physical and biological/life), (2) math/engineering, (3) arts (fine arts and languages), (4) social studies, (5) and athletics. Responses to these five categories were averaged to measure breadth of interests (a higher rating indicates higher interests in more areas). Our integration factor significantly and positively correlated with broad interests ($r = 0.40$, $p < 0.001$, $n = 12,605$). While "Expert" was also significantly correlated with broad interests, the correlation was smaller ($r = 0.18$, $p < 0.001$, $n = 12,939$). It is likely that, though a certain degree of disciplinary grounding is required for interdisciplinarity, it is also a characteristic of a large number of students who have no interdisciplinary affinity. As such, including it in a quantitative measurement of interdisciplinary affinity is problematic. Instead, we chose to focus only on the "Integration" factor, especially as it is regarded in the literature as the essential component of interdisciplinarity [8, 10, 4]. It has the benefits of connecting to prior work, as well as of face and criterion-related validity. Therefore, for the remainder of this work, we used the four survey items of the "Integration" factor as our measure of interdisciplinary affinity.

For the second research question, we calculated correlations between interdisciplinary affinity and physics identity (including interest and recognition components). In each case, correlations were significant and positive. A summary is shown in Table 2. The correlation between interdisciplinary affinity and physics interest was greater than the correlation between interdisciplinary affinity and physics recognition. This difference was statistically significant. This is consistent with qualitative research currently underway seeking to explain the link between interdisciplinary affinity and physics identity which highlights the importance of students' interests.

To further investigate research question two, we also built multivariate linear models so potentially confounding effects could be considered. Though agency and epistemological beliefs were not included in the OPSCI study, it did include control variables comparable to those used in the previous work [16]. These include gender, socio-economic status (SES) related factors, grades, enjoying physics class, and the role of science in family life. Table 3 shows a model with physics identity as

TABLE 2. Correlations between interdisciplinary affinity (IA) and physics identity, physics interest, and physics recognition

	r	*p*	*N*
IA and Physics Identity	0.25	<0.001	12,146
IA and Physics Interest	0.26	<0.001	12,573
IA and Physics Recognition	0.22	<0.001	12,271

TABLE 3. Regression model predicting physics identity (N=4,313). **: p<0.01; ***: p<0.001; ns: not significant.

Parameter	β	**Sig.**
Intercept		***
Race and SES	controlled	
Gender (0 = Female, 1 = Male)	0.25	***
Physics grade	0.10	***
Family science hobbies	0.07	***
Mother had STEM related career	0.01	ns
Father had STEM related career	0.04	***
Liked their physics class	0.47	***
Interdisciplinary Affinity	0.17	***
Adjusted R^2 = 0.44		

the outcome and interdisciplinary affinity and controls as predictors. The result is very similar to the previous work [16]. Models focusing on physics interest and recognition as outcomes showed similar results with only minor variations in effect size.

CONCLUSIONS AND FUTURE WORK

This study makes progress in measuring interdisciplinary affinity. While Scott et al. [16] used only two survey items, we now have four valid survey items for measuring interdisciplinary affinity. Unfortunately, the data did not confirm the theoretical framework of Borrego and Newswander [10]. Only one factor useful for measuring interdisciplinary affinity emerged instead of four. Additional work should be done to develop more survey items and try to distinguish different dimensions of interdisciplinary affinity.

Correlations and results of the linear models showed that interdisciplinary affinity is a significant, positive predictor of physics identity as well as both interest and recognition components of identity. The slightly stronger link to physics interest is consistent with qualitative research currently underway and is an area for further investigations seeking understand the mechanisms by which interdisciplinary affinity is linked to physics identity.

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