Student response to a careers in physics lesson

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Prior research indicates that one barrier to pursuing a STEM degree is lack of alignment between perceptions of a STEM career and personal goals. The Careers in Physics lesson developed for the STEP UP project directly addresses this. In the lesson, students explore the profiles of modern day physicists and the many career options available to physics majors. Students then connect physics to their own career aspirations. In this study, students' career goals are analyzed under the framework of agentic and communal goals. Data collected include student open-ended survey responses, survey items, and student work such as a career profile in which students envision themselves achieving their career goals with a physics degree. We found evidence that this lesson effectively communicates that a career in physics can fulfill intrinsic agentic and communal goals, goals which are more strongly endorsed by female students.

I. INTRODUCTION

Currently, women earn only twenty percent of all physics bachelor's degree awarded in the U.S. [1]. Supporting Teachers to Encourage the Pursuit of Undergraduate Physics (STEP UP) is a nationwide collaboration with the goal of substantially increasing the representation of women in physics by providing high school physics teachers with research-based materials to aid them in recruiting girls into physics degree programs. Materials developed include two lesson plans and an Everyday Actions Guide [2].

Although women only represent one in five physics graduates, they constitute approximately half of all high school physics students [3]. Thus, high school is a critical moment for young women in deciding their majors and the final opportunity to reach many of these students.

The two lessons developed by STEP UP are Careers in Physics and Women in Physics. This work focuses on the Careers in Physics lesson. The focus of this lesson is to connect students' personal goals and values to careers available to physics graduates. We use goal congruity theory [4] to understand students' career preferences. The extent to which an individual perceives the goals of a career aligning with their own personal goals is examined. Several studies have shown that men and women prefer different goals when seeking careers, with men endorsing goals that benefit one's self (agentic goals) and women endorsing goals that benefit others (communal goals) [5–7].

Diekman et al. postulated that physics is not perceived as fulfilling communal goals [8, 9]. This could be one explanation as to why women are represented better in other STEM disciplines such as biology and chemistry at the undergraduate level. Agentic goals were divided into intrinsic and extrinsic agentic goals by Palaez [10]. Intrinsic agentic goals focus on self direction, demonstrating skills, and independence, while extrinsic agentic goals focus on obtaining power, status, and financial reward. Palaez found that college students (female and non-female) with high intrinsic agency had higher physics identities and persisted in the field longer. Importantly, communal goals were found to negatively correlate with short term persistence in physics.

In this work, we sought to understand students' career goals prior to completing either of the lessons and determine to what extent the Careers in Physics lesson communicates to students that communal goals can be fulfilled with a physics degree and alter students' perceptions of physics. If young women perceive physics as able to fulfill their goals, they may more seriously consider majoring in physics.

II. METHODS

A. Careers in Physics Lesson Overview

The Careers in Physics lesson seeks to connect student's personal goals and values to careers available to physics graduates. Because students are not generally well informed of what physicists do, this lesson aims to provide students with information about physics when deciding their own college major or career.

The lesson begins with students listing jobs they believe can be obtained with a physics degree, usually on sticky notes or some other visual media. The careers are then posted for the class to see and students proceed to have an in class discussion about physics careers, revealing any preconceptions they might have about those with physics degrees. Following the discussion, students are then instructed to complete a Career Goals survey in which they select factors important to them for their future career as well as the types of careers they might be interested in. Their selections are then used to assign students to one of 32 physicist profiles using the profile matching matrix. The profiles contain short biographies on modern day individuals possessing a bachelor's degree in physics and how they use it in their career, spanning a wide range of careers. After reading their assigned profile, students pair up and discuss their profiles with other students. They then proceed to again list potential jobs available to physicists on sticky notes and discuss them as a class.

Next, students complete a personal career profile in which they identify a career they are interested in and are challenged to incorporate a physics degree into that career. Students list the skills they need, what they want to contribute or accomplish through their career, and how a physics degree can help them based on what they read in the physicist profiles. Students are then instructed to create a future self poster in which they imagine themselves in the future working in their chosen career. They provide details about their personal life that are important to them, why they chose to earn a physics degree, and how they are using physics in their career. They end by offering advice to future students that are considering the same path. The posters are put on display for the class to view.

The lesson concludes with a short interactive presentation on physics careers. The teacher provides students with information regarding salaries, employment rates, test scores, and much more about physics bachelor's degree holders. The presentation ends with information about physics careers that can help people and contribute to society.

B. Data Collection

This study is part of a larger work that seeks to increase the representation of women in physics. To achieve this, the STEP UP project developed interactive discussion-based lessons that were implemented in high school physics classrooms. The project recruited teachers from a random stratified sampling of schools [11] from Texas, Florida, Maryland and Virginia. The analysis presented here is based on a subset of the data collected.

To determine lesson effectiveness, surveys were administered at several points during the semester. The first survey was completed before any STEP UP lessons took place and serves as a starting point for students' perceptions of physics, as well as student goal endorsement. Survey questions regarding goal endorsement were absent on later surveys, so a qualitative assessment of student career profiles was used as a proxy to determine if new connections between student goals and physics careers were created. We received survey data from fifteen separate classrooms and career profiles from six. Of the six teachers that returned student career profiles, three classes were chosen for analysis due to the quality of the writing as some students simply did not elaborate enough to allow for meaningful analysis. This study followed a switching replications design where treatment group teachers administered STEP UP lessons in alternating orders. Of the three teachers we analyzed career profiles for, two administered the careers lesson first and one administered the lesson second.

In this work, we focus on students' career goals prior to the implementation of the lessons and on the impacts of the Careers in Physics lesson. We analyzed pre-surveys completed by all students in all groups at the beginning of the study and student written work completed as part of the Careers in Physics lesson. The pre-survey was administered before any lessons were implemented, and contained questions about goal endorsement, career intentions, and grades in other classes in addition to questions about physics identity. We analyzed 1233 pre-surveys completed by students in all fifteen classes. Furthermore, two writing assignments were examined: a Personal Career Profile and a Future Self Poster. In the Personal Career Profile, students describe their desired career and how a physics degree can be used in this career path. Similarly, in the Future Self Poster students write about themselves in the future having obtained their desired career through the use of a physics degree. 79 student writing assignments were analyzed in total, 33 female and 39 non-female.

C. Data Analysis

Our analysis consisted of two phases. In phase one, we examined the pre-surveys of students in all four groups. Survey questions included in this analysis consisted of Likert scale items on students' endorsement of goals, preferred careers, and the likelihood of pursuing a degree in physics. In phase two, we analyzed student work from the Careers in Physics lesson.

All analysis of student pre-survey data was conducted in R version 3.4.1. We conducted a confirmatory factor analysis on the goal endorsement items to verify that intrinsic agentic goals, extrinsic agentic goals, and communal goals are appropriate factors for this sample. Descriptive statistics were generated for each of these goal types for females and non-females. Wilcoxon rank sum tests were used to assess the significance of differences between female and non-female students' goal endorsement, utility value, and career intentions. Finally, linear regression was conducted to determine which factors significantly predicted students decisions to pursue careers in physics.

Students' written assignments were analyzed for emerging themes, instances where multiple students discuss the same idea or concept. Using the constant comparative method [12, 13], themes were collected and grouped into topical categories, which themselves were grouped into even broader categories. We examined students' writing for evidence of their career goals connecting to the perceived goals of a physics degree. This is evident when students form clear ideas as to how they fulfill their desired goals with a physics degree, using keywords and phrases associated with agentic and communal goals. As core ideas were assembled, connections between categories were examined in order to develop a theory of how the Careers in Physics lesson may impact students' career intentions.

III. RESULTS AND DISCUSSION

A. Phase One: Pre-surveys

Pre-surveys reveal students' career goals and initial perceptions of physics. Confirmatory factor analysis verified that student goal endorsements could be grouped into three factors (intrinsic agentic goals, extrinsic agentic goals, and communal goals) for this population of students. The CFI and TLI were both above the 0.9 threshold, at 0.975 and 0.962 respectively. The RMSEA was below the 0.1 threshold at 0.058, indicating a good fit [14].

We proceeded to compare the goal endorsements of female and non-female students. As shown in Table I, female students endorse communal and intrinsic agentic goals more than non-female students at a statistically significant level as determined by Wilcoxon tests. However, both groups endorsed extrinsic agentic goals equally.

TABLE I. Wilcoxon rank sum test results for goal endorsement and utility value, by gender (n = 1233). ***: $p < 0.001$, ns: not significant

	Female (n=585)	Non-Female (n=648)	Sig
Extrinsic	$3.34 \pm .05$	$3.50 \pm .04$	ns
Intrinsic	$4.20 \pm .04$	$4.07 \pm .04$	***
Communal	$4.23 \pm .04$	$3.86 \pm .04$	***
Utility Value	$4.62 \pm .13$	$5.25 \pm .12$	***

In order to determine which goal endorsements predict physics career intentions, we performed linear regression. The results are displayed in Table II. We found that extrinsic agentic goals were the only significant predictor of physics career intentions. Importantly, the goals female students endorse more than non-females, communal and intrinsic agentic goals, do not predict physics career intentions. It is worth noting that the R^2 is small for this model, indicating that goal endorsement accounts for a relatively small portion of the variance.

TABLE II. Regression model predicting physics career intentions (n = 1233). Multiple R^2 = 0.067, Adjusted R^2 = 0.063
***: $p < 0.001$, **: $p < 0.05$, *: $p < 0.1$, ns: not significant.

Parameter	**Estimate**	**Std. Err**	**Sig**
Intercept	-0.05	0.24	ns
Controls			
Math GPA	0.18	0.06	**
Family Support	0.32	0.03	***
Gender (0=Non-Female, 1=Female)	-0.42	0.09	***
Goals			
Extrinsic Agentic	0.10	0.04	*

B. Phase Two: Written work

Students' written work provided information about students' perceptions of physics following the lesson because survey rounds 2-6 did not include these items. In phase two of our analysis, we examined students' writing assignments for evidence of new connections being formed between communal and intrinsic agentic goals and physics degrees.

1. Goal Endorsement

One of the first questions on the profile assignment asks students what they want to accomplish and achieve in their careers. Students often stated the types of goals they endorsed here, but these were not generally goals directly associated with physics degrees. This portion of the profiles provided an opportunity to compare our qualitative results with the quantitative results in the pre-survey data. Students' goal endorsement covered all three categories in our framework; communal, intrinsic agentic, and extrinsic agentic. Kyle gives a clear example of someone who is motivated by communal goals:

> *"The sense that I am actually having a positive impact on people's lives is one of the best parts of the job."*

Anne provided evidence of her intrinsic motivations stating, "I love learning new things and challenging what I know." Mitch is similarly motivated by extrinsic goals, wanting to pursue a career in law, "...because it provides financial security."

We found that approximately twice as many female students endorsed intrinsic agentic goals compared to non-females. Interestingly, slightly more non-female students endorsed communal goals. There was no difference in the endorsement of extrinsic agentic goals. Female endorsement of intrinsic agentic goals agrees with our quantitative assessment, as does the equal endorsement of extrinsic agentic goals. The discrepancy in communal goals could be due to the wording of one of the profile questions, as it specifically asked students how they will help the world or contribute to it.

2. Connection to Degree

As students discussed their careers and how a physics degree would help them, they often elaborated on exactly how their degree would be helpful. Students connected the goals that they valued to what they believed could be achieved with a physics degree. Brandon's physics degree provided him with a source of intrinsic agency in his engineering career:

> *"Understanding physic [sic] concepts has given me an edge over the other architectural engineerings [sic] as it has allowed me to truly understand the nature of my designs before they are constructed."*

McKenzie realized that the skills her physics degree provided enabled her to achieve communal goals within her career as a family crisis manager:

> *"Physics has not only allowed me to form a pathway of creativity for connection to the children whom are at such a terrifying time in their lives, but also with the parents."*

We sought to determine whether students were forming new connections from communal goals and intrinsic agentic goals to physics degrees. Based on written work such as that shown in the examples, students made these connections. When comparing these connections between gender groups, we found that female students connected intrinsic agentic goals to their physics degrees over twice as often as non-female students, and connected communal goals slightly more often than non-female students.

3. Utility of Physics Degrees

The goals students perceive as being fulfilled through their physics degrees also impact a student's perception of the utility a physics degree offers. A student will likely not view physics as being very useful if they do not know what they can do with it. As students form new connections between their goals and those fulfilled by physics degrees, we expect the perceived utility value of a physics degree to grow as well. Table I shows that prior to lessons, non-female students placed a higher utility value on physics degrees than female students.

Students' perception of utility value appears frequently in the profiles. Some student see a physics degree as a means for opening more job opportunities, while others note the versatility a physics degree offers. Anne explains how she would be able to use her degree in several situations when working in a hospital:

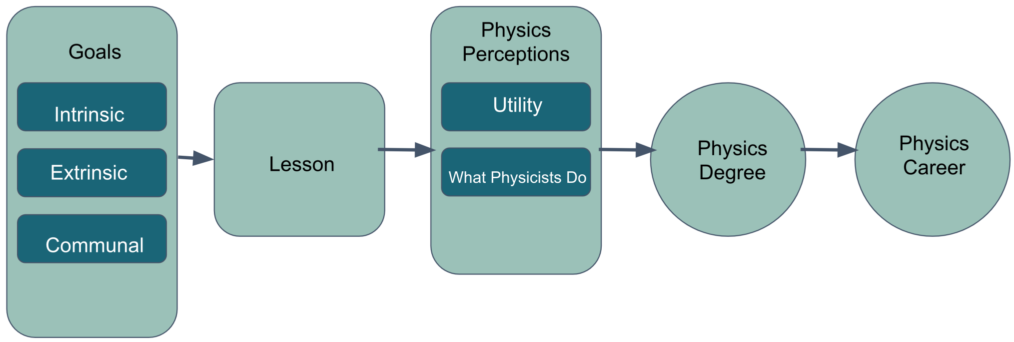

FIG. 1. Model of how lessons can impact student perceptions of physics, leading to the decision to pursue a physics degree and ultimately a physics related career.

> *"Physics degrees allow a doctor to have higher analytical thought process, and higher amounts of creativity which not only helps with the walls of an operating room, but also allows for deeper connection to the children."*

As the lesson communicates the fulfillment of goals within physics, it also communicates the utility of a physics degree. To change a students' perception of physics, the idea of utility must also change, and students' writing indicates that this is happening. This conclusion aligns with the findings of Cheng et al. [15] where significant gains in utility value were measured for all students following the Careers in Physics lesson, with female students receiving larger gains.

We found that prior to the Careers in Physics lesson, communal and intrinsic agentic goals, those preferred by female students, did not significantly predict physics career intentions. The lessons encouraged students to connect their values with what can be accomplished with a physics degree through the written assignments. This can, in turn, change students' perceptions of what a physics degree is useful for. In their writing, students appear to form new connections from communal goals and intrinsic agentic goals to physics degrees. This suggests that communal goals and intrinsic agentic goals may predict physics career intentions following the lesson.

Figure 1 illustrates the process by which student perceptions are altered as a result of the Career in Physics lesson. Students begin the lesson with their own personal goals and values, as well as a perception of what a physics degrees offers. During the lesson, students are informed of the many career possibilities open to physics graduates, which in turn allows students to see new ways of fulfilling their goals through a physics degree. Students also learn of the utility of a physics degree. If the fulfillment of communal goals is what is preventing young women from entering STEM career fields such as physics as hypothesized by Diekman [8, 9], this new information could alter a student's perception of physics, allowing them to perhaps see physics as a realistic career path.

IV. CONCLUSION

High school physics teachers participating in the Fall 2018 experimental study implemented the Careers in Physics lesson in their classrooms. Analysis of materials associated with the lessons showed that prior to the lesson, goals preferred by female students, communal and intrinsic agentic goals, were not significant predictors of physics career intentions. We sought to alter student perceptions of what goals could be achieved through physics in order to connect the communal and intrinsic agent goals to physics degrees, in turn causing them to become more interested in pursuing physics after high school.

After the lesson, we found that students were able to connect intrinsic agentic and communal goals to physics degrees, and that female students form these connections more often than non-female students. We also found that students attributed a high utility value to physics degrees after the lesson, agreeing with the results of prior research on the effects of the Careers in Physics lesson. Future work should survey students on both their goal endorsements and physics career intentions after the lesson to establish if communal and intrinsic agentic goals then predict physics career intentions.

The results of this study suggest that the Careers in Physics lesson could lead to more female students choosing to pursue physics in college due to better alignment with their goals, thus increasing women's representation in physics. As these lessons are distributed to more teachers across the U.S, we can hope to see more female students aware of the applicability of a physics degree to their careers.

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