ROBERT H. TAI, ED. D.
UNIVERSITY OF VIRGINIA

Finding FOCIS:

A Framework for Examining Lessons and Learning Activities

Virginia Science Coordinators Meeting

Blandy Experimental Farm

Boyce, VA

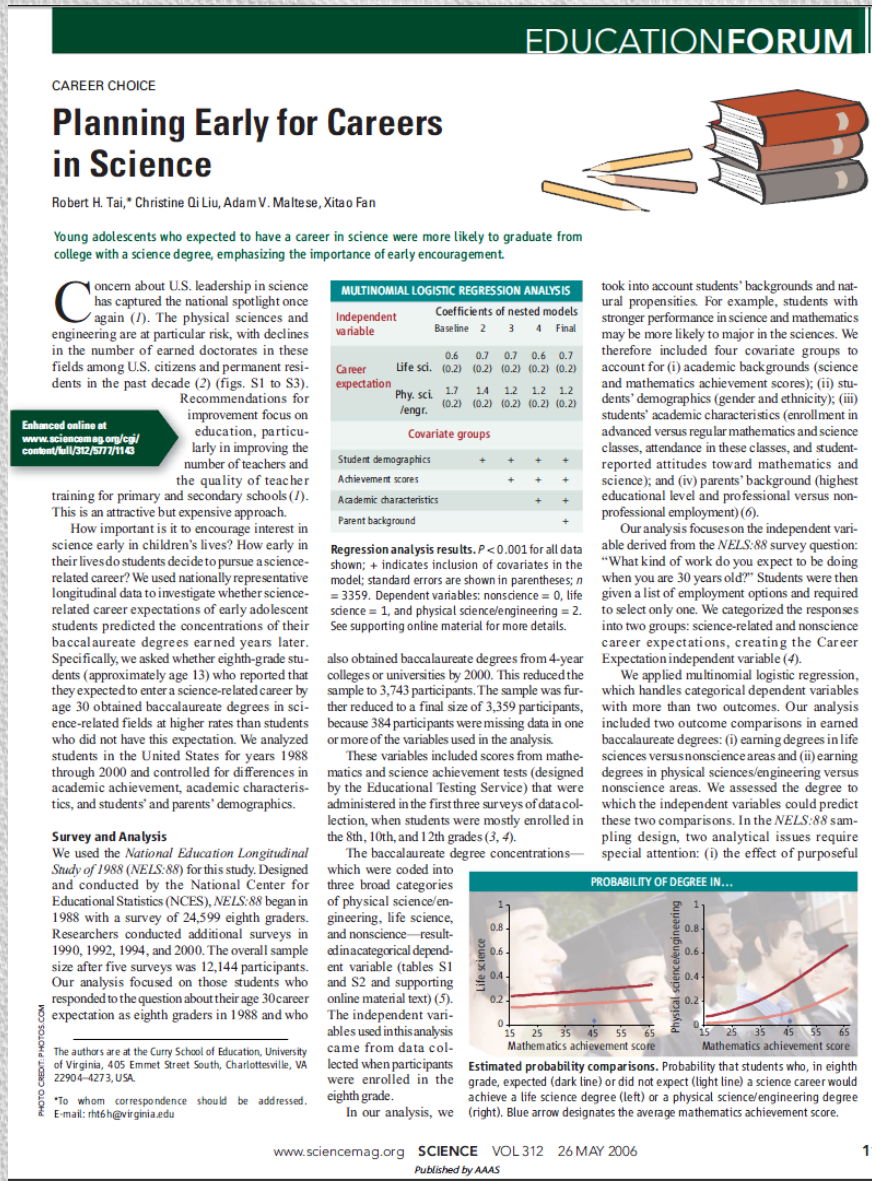
May 19, 2014

University of Virginia
Curry School of Education

Generating Interest among Students

An analysis of longitudinal data for 3300+ students spanning 12 years from ages 14 – 26 suggests that 8th graders with an interest in science are 2-3 more likely to earn degrees in STEM-related disciplines than those who do not report a similar early interest.

Tai, R. H., Liu, C. Q., Maltese, A. V., & Fan, X. (2006). Planning early for careers in science. *Science*. 312, 1143 – 1144. doi: 10.1126/science.1128690



EDUCATIONFORUM

CAREER CHOICE

Planning Early for Careers in Science

Robert H. Tai,* Christine Qi Liu, Adam V. Maltese, Xitao Fan

Young adolescents who expected to have a career in science were more likely to graduate from college with a science degree, emphasizing the importance of early encouragement.

Enhanced online at www.sciencemag.org/cgi/content/full/312/5777/1143

Concern about U.S. leadership in science has captured the national spotlight once again (*1*). The physical sciences and engineering are at particular risk, with declines in the number of earned doctorates in these fields among U.S. citizens and permanent residents in the past decade (*2*) (figs. S1 to S3). Recommendations for improvement focus on education, particularly in improving the number of teachers and the quality of teacher training for primary and secondary schools (*1*). This is an attractive but expensive approach.

How important is it to encourage interest in science early in children's lives? How early in their lives do students decide to pursue a science-related career? We used nationally representative longitudinal data to investigate whether science-related career expectations of early adolescent students predicted the concentrations of their baccalaureate degrees earned years later. Specifically, we asked whether eighth-grade students (approximately age 13) who reported that they expected to enter a science-related career by age 30 obtained baccalaureate degrees in science-related fields at higher rates than students who did not have this expectation. We analyzed students in the United States for years 1988 through 2000 and controlled for differences in academic achievement, academic characteristics, and students' and parents' demographics.

Survey and Analysis

We used the *National Education Longitudinal Study of 1988* (*NELS:88*) for this study. Designed and conducted by the National Center for Educational Statistics (NCES), *NELS:88* began in 1988 with a survey of 24,599 eighth graders. Researchers conducted additional surveys in 1990, 1992, 1994, and 2000. The overall sample size after five surveys was 12,144 participants. Our analysis focused on those students who responded to the question about their age 30 career expectation as eighth graders in 1988 and who also obtained baccalaureate degrees from 4-year colleges or universities by 2000. This reduced the sample to 3,743 participants. The sample was further reduced to a final size of 3,359 participants, because 384 participants were missing data in one or more of the variables used in the analysis.

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MULTINOMIAL LOGISTIC REGRESSION ANALYSIS

Independent variable		Coefficients of nested models				
		Baseline	2	3	4	Final
Career expectation	Life sci.	0.6 (0.2)	0.7 (0.2)	0.7 (0.2)	0.6 (0.2)	0.7 (0.2)
	Phy. sci. /engr.	1.7 (0.2)	1.4 (0.2)	1.2 (0.2)	1.2 (0.2)	1.2 (0.2)
Covariate groups						
Student demographics			+	+	+	+
Achievement scores				+	+	+
Academic characteristics					+	+
Parent background						+

Regression analysis results. $P < 0.001$ for all data shown; + indicates inclusion of covariates in the model; standard errors are shown in parentheses; $n = 3359$. Dependent variables: nonscience = 0, life science = 1, and physical science/engineering = 2. See supporting online material for more details.

These variables included scores from mathematics and science achievement tests (designed by the Educational Testing Service) that were administered in the first three surveys of data collection, when students were mostly enrolled in the 8th, 10th, and 12th grades (*3*, *4*).

The baccalaureate degree concentrations—which were coded into three broad categories of physical science/engineering, life science, and nonscience—resulted in a categorical dependent variable (tables S1 and S2 and supporting online material text) (*5*). The independent variables used in this analysis came from data collected when participants were enrolled in the eighth grade.

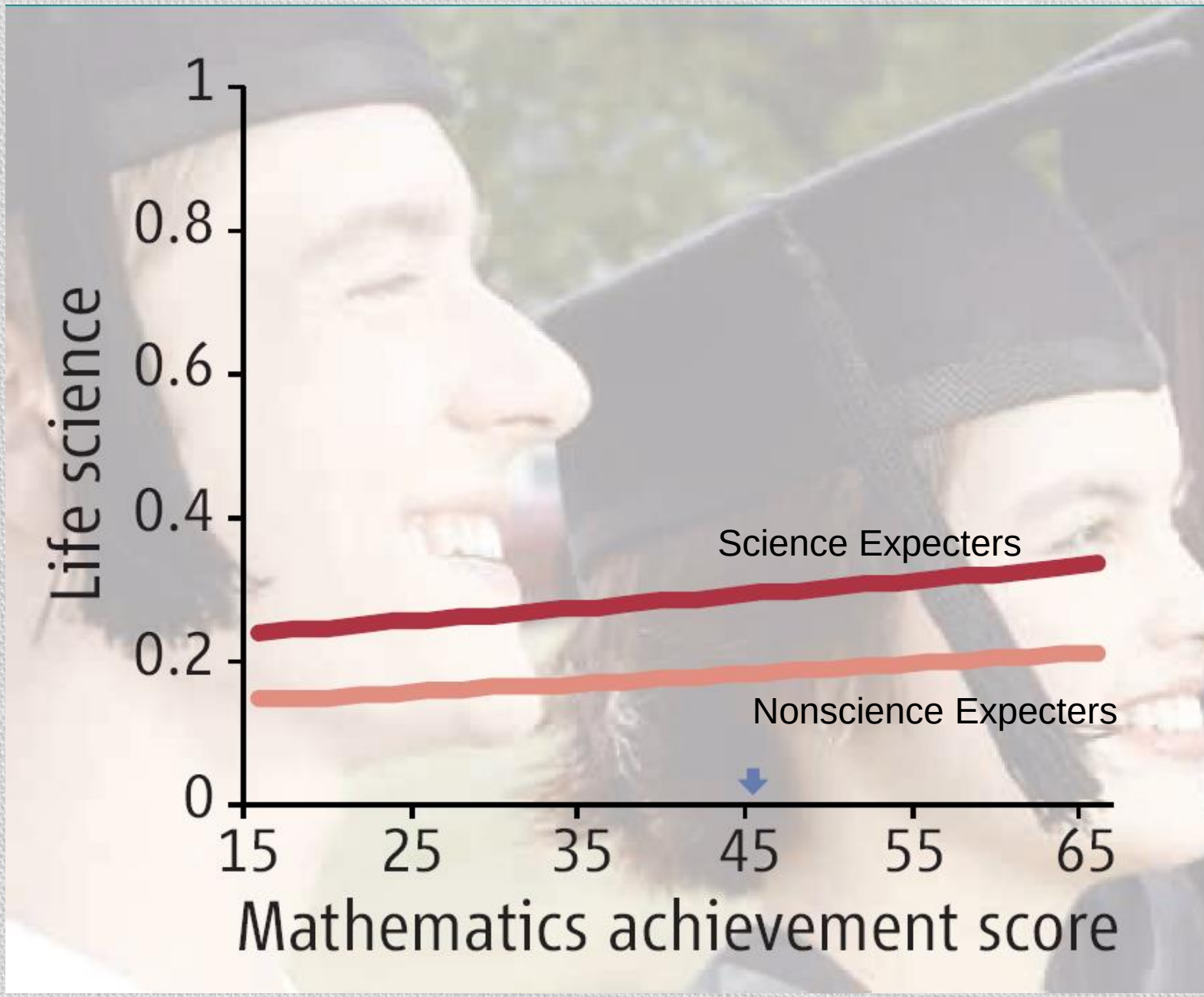
In our analysis, we took into account students' backgrounds and natural propensities. For example, students with stronger performance in science and mathematics may be more likely to major in the sciences. We therefore included four covariate groups to account for (i) academic backgrounds (science and mathematics achievement scores); (ii) students' demographics (gender and ethnicity); (iii) students' academic characteristics (enrollment in advanced versus regular mathematics and science classes, attendance in these classes, and student-reported attitudes toward mathematics and science); and (iv) parents' background (highest educational level and professional versus nonprofessional employment) (*6*).

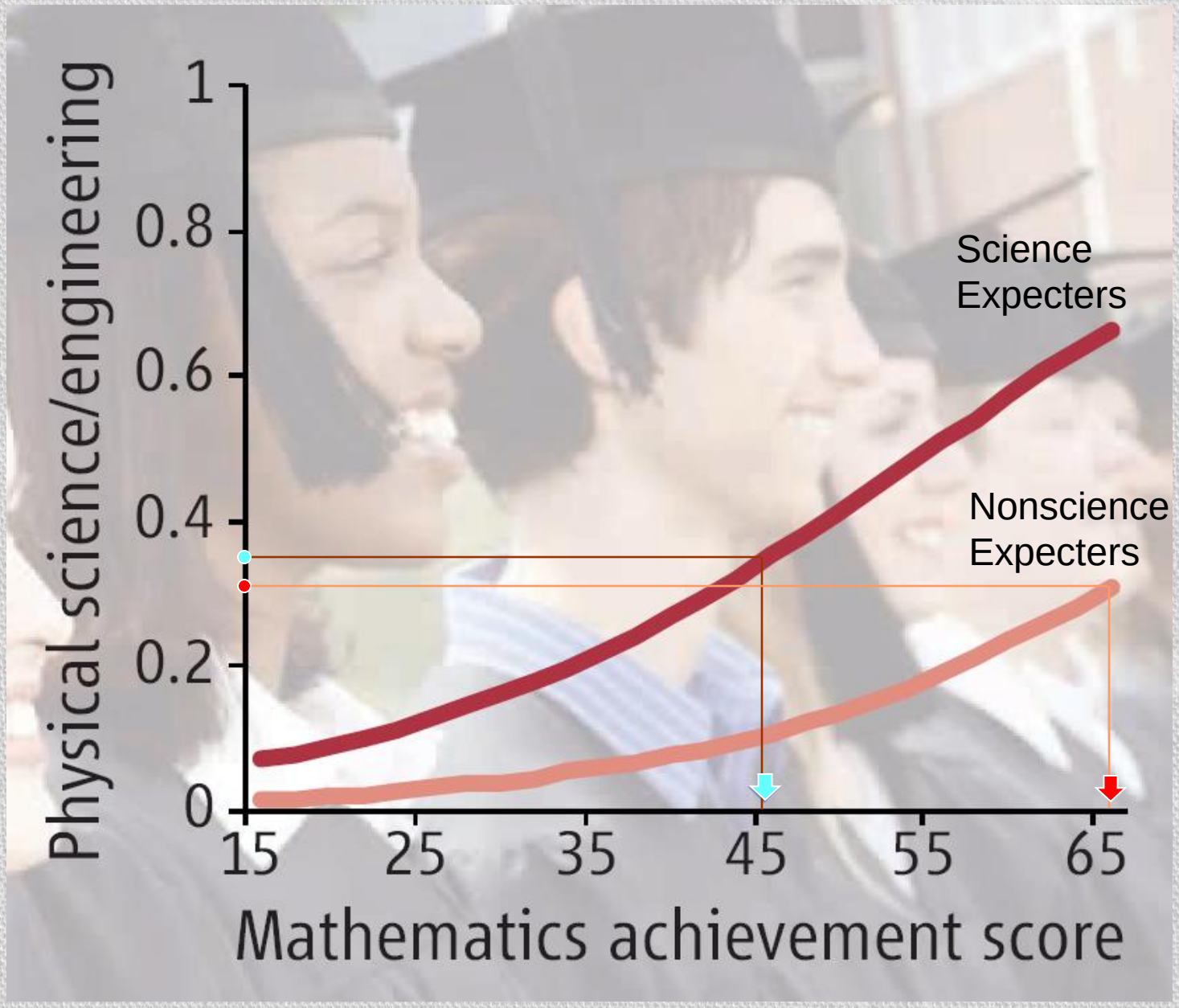
Our analysis focuses on the independent variable derived from the *NELS:88* survey question: "What kind of work do you expect to be doing when you are 30 years old?" Students were then given a list of employment options and required to select only one. We categorized the responses into two groups: science-related and nonscience career expectations, creating the Career Expectation independent variable (*4*).

We applied multinomial logistic regression, which handles categorical dependent variables with more than two outcomes. Our analysis included two outcome comparisons in earned baccalaureate degrees: (i) earning degrees in life sciences versus nonscience areas and (ii) earning degrees in physical sciences/engineering versus nonscience areas. We assessed the degree to which the independent variables could predict these two comparisons. In the *NELS:88* sampling design, two analytical issues require special attention: (i) the effect of purposeful

Estimated probability comparisons. Probability that students who, in eighth grade, expected (dark line) or did not expect (light line) a science career would achieve a life science degree (left) or a physical science/engineering degree (right). Blue arrow designates the average mathematics achievement score.

Published by AAAS


Life science
1
0.8
0.6
0.4
0.2
0
Science Expecters
Nonscience Expecters
15
25
35
45
55
65
Mathematics achievement score

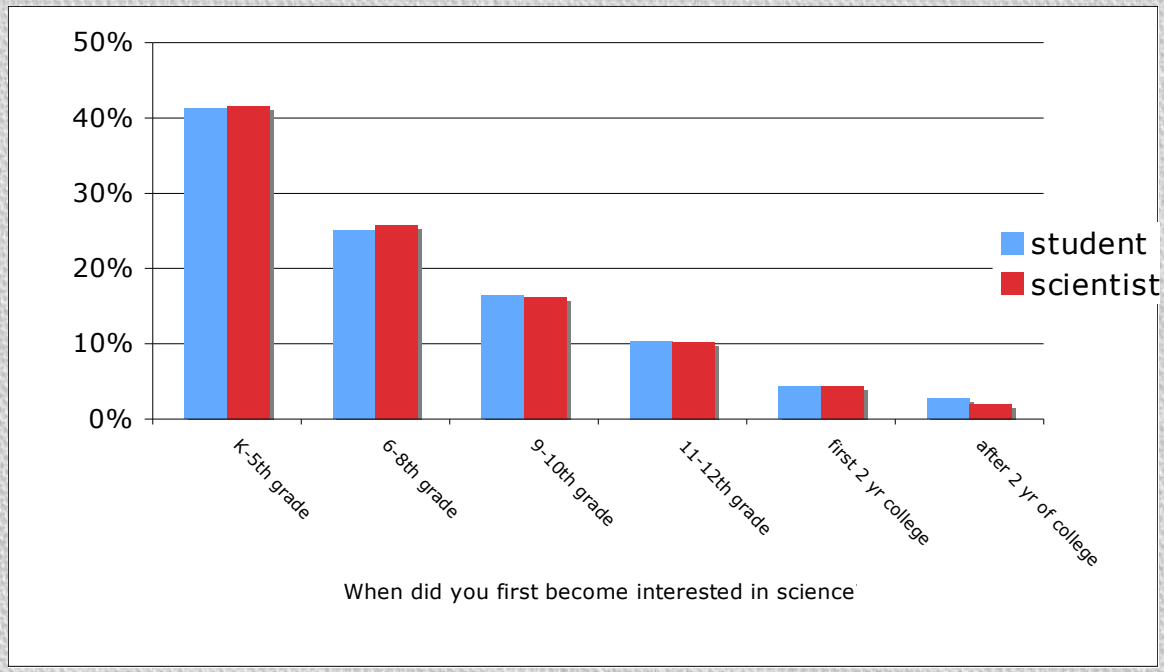

Physical science/engineering
1
0.8
0.6
0.4
0.2
0
15
25
35
45
55
65
Mathematics achievement score
Science Expecters
Nonscience Expecters

When do scientists and graduate students say they first became interested "science"?
(Scientist n = 3220; Grad students n = 1065)

70% of scientists and 69% of graduate students reported developing their interest in science in Grades K-8

24% of both scientists and graduate students in Grades 9 - 12

6% of scientists and 7% of graduate students in College



*Data from Project Crossover (NSF REC 0440002), PI R. H. Tai, University of Virginia

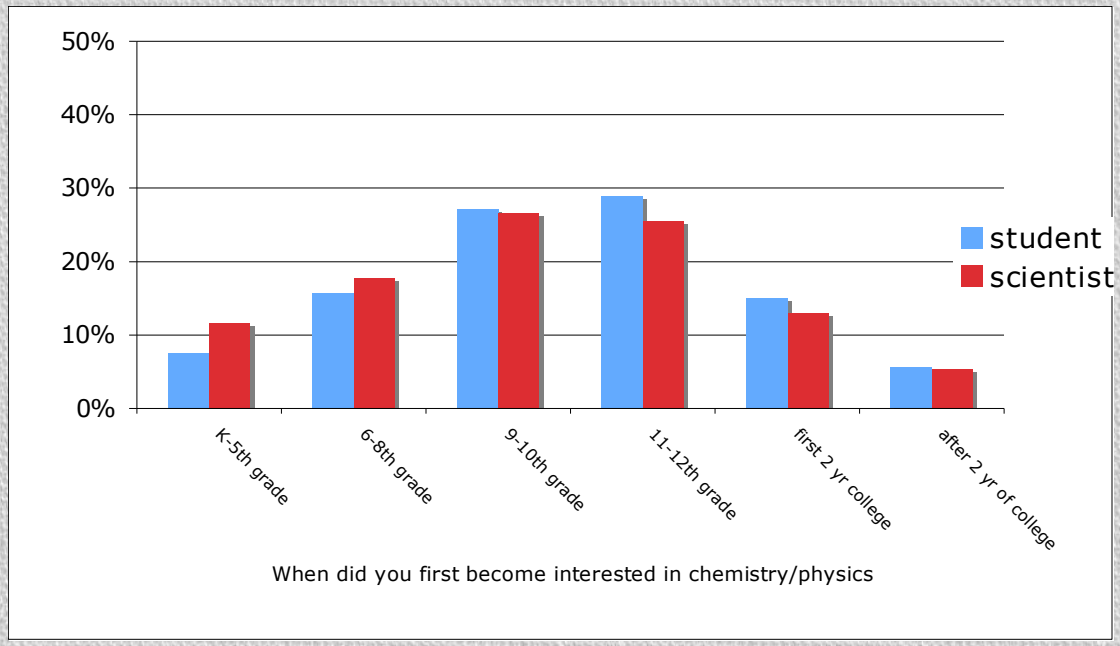
When do scientists and graduate students say they first became interested their career discipline?

(Scientist n = 3220; Grad students n = 1065)

29% of scientists and 23% of graduate students reported developing their interest in chemistry/physics in Grades K-8

52% of scientists and 56% of graduate students in Grades 9-12

18% of scientists and 21% of graduate students in College

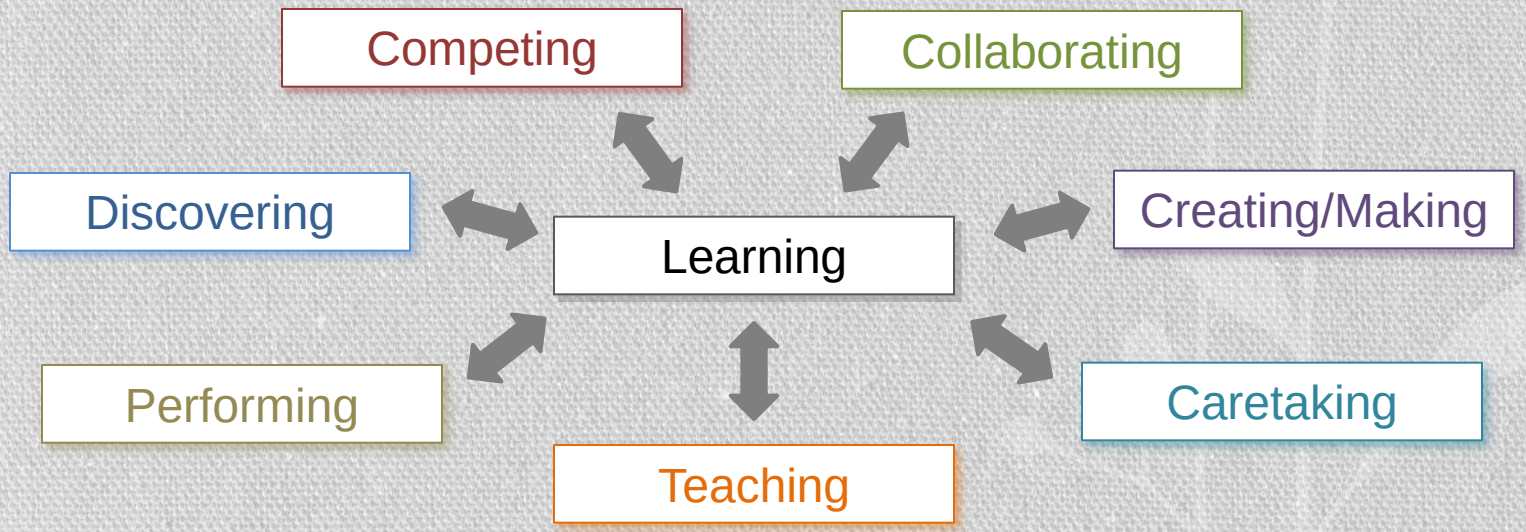


*Data from Project Crossover (NSF REC 0440002), PI R. H. Tai, University of Virginia

How do we hope to engage children's interest?

Through learning activities in both formal and informal settings.

An examination of curriculum and programs led to the development of a ***Framework for Observing and Categorizing Instructional Strategies*** **(FOCIS)** which is a LEARNING ACTIVITY typology.



Learning Activity Type	Survey Questions
Discovering	When I find out that an activity involves... Discovering and learning new things. I like figuring out how things work. I like taking things apart to see what is inside. I like trying different ways to figure things out. I like solving problems.
Creating/ Making	When I find out that an activity involves... Making or building things. I feel like doing projects where I make things. Whenever I can, I make the things I need. I like building things.
Collaborating	When I find out that an activity involves... Being in a group. Working with others is more fun than working alone. I like being part of a team. I learn better when I am working with others.
Competing	When I find out that an activity involves... Being in a competition. I get excited when I hear there will be a competition. I enjoy competing against other people. I like to focus on my own goals, rather than competing with others.
Presenting	When I find out that an activity involves... Presenting in front of lots of people. Performing in front of people is fun. I like telling people about my work. I like presenting my work to my class.
Caretaking	When I find out that an activity involves... Taking care of animals. Having a pet is a big responsibility, but something I like to do. I like to take care of things like plants and aquariums.
Teaching	When I find out that an activity involves... Helping people learn things. Helping others to learn things is fun. I like teaching things to others.

Example: "**Discovering**" Questions

16 **We want to know how you feel about different activities.** ***(Please mark only 1 box for each activity listed below.)***

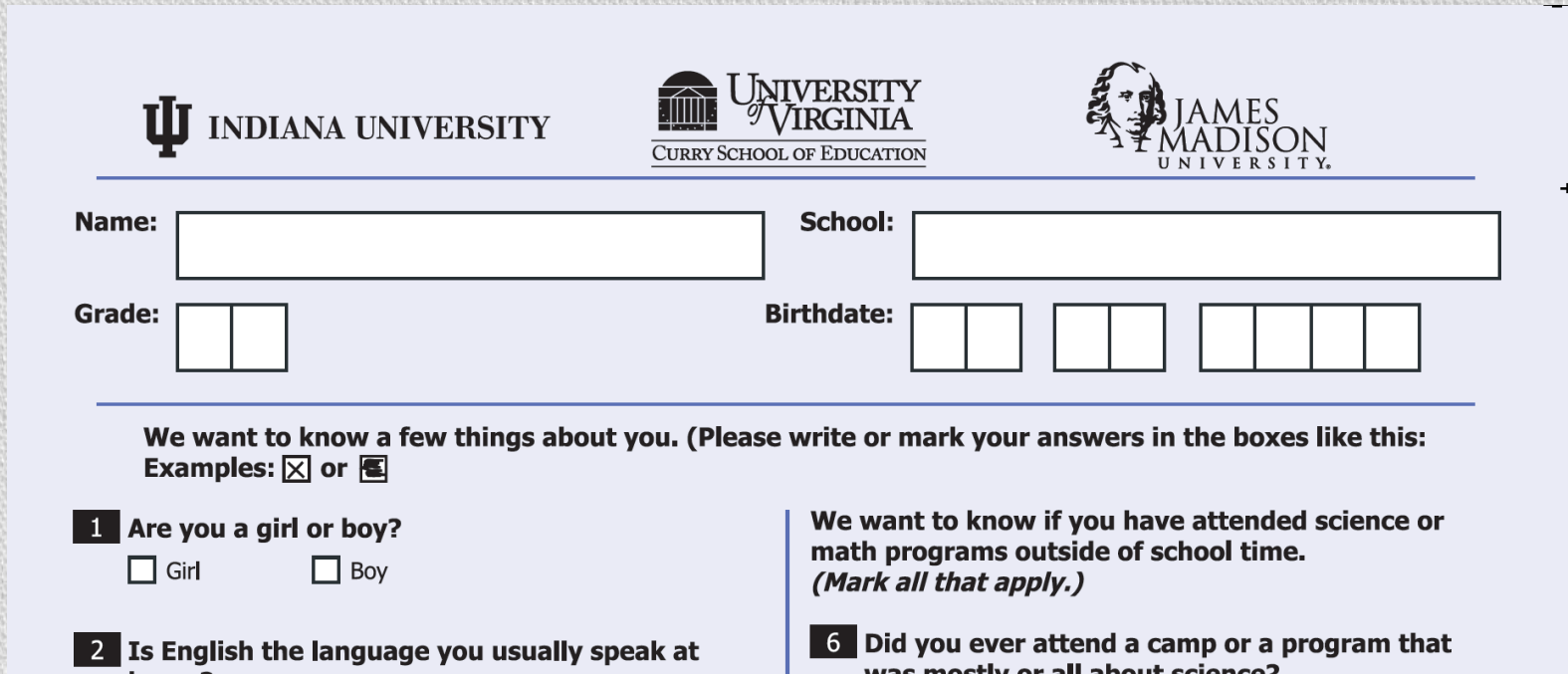
When I find out that an activity involves...	I feel... ☹ 1	2	😐 3	4	☺ 5
a. Being in a group,	☐	☐	☐	☐	☐
b. Being in a competition,	☐	☐	☐	☐	☐
c. Making or building things,	☐	☐	☐	☐	☐
d. Discovering and learning new things,	☐	☐	☐	☐	☐
e. Presenting in front of lots of people,	☐	☐	☐	☐	☐
f. Taking care of animals,	☐	☐	☐	☐	☐
g. Helping people learn things,	☐	☐	☐	☐	☐

18 **We want to know what you think about each of the statements below. If you strongly agree, then choose 5. If you strongly disagree, then choose 1.** ***(Please select only 1 number for each statement below.)***

	👎 1	2	3	4	👍 5
g. I like figuring out how things work	☐	☐	☐	☐	☐
h. I like taking things apart to see what is inside	☐	☐	☐	☐	☐
i. I like trying different ways to figure things out	☐	☐	☐	☐	☐
j. I like solving problems	☐	☐	☐	☐	☐

Data Set

- Large-scale survey of all students in Grades 3-12 in schools from 4 Public School Districts.
- Urban, Suburban, and Rural
- Participating public school districts have strong enrollment numbers of students from minorities groups under represented in STEM (Black 20.9%; Latino/a 23.0%)
- Overall study enrollment (N = 7157)
- Elementary School – Grades 3-5 (n = 2486)
- Middle School – Grades 6-8 (n = 2502)
- High School – Grades 9-12 (n = 2169)
- Female 50.9%; Male 49.1%



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Name: **School:**

Grade: **Birthdate:**

We want to know a few things about you. (Please write or mark your answers in the boxes like this:
Examples: ☒ or ☒

1 **Are you a girl or boy?**

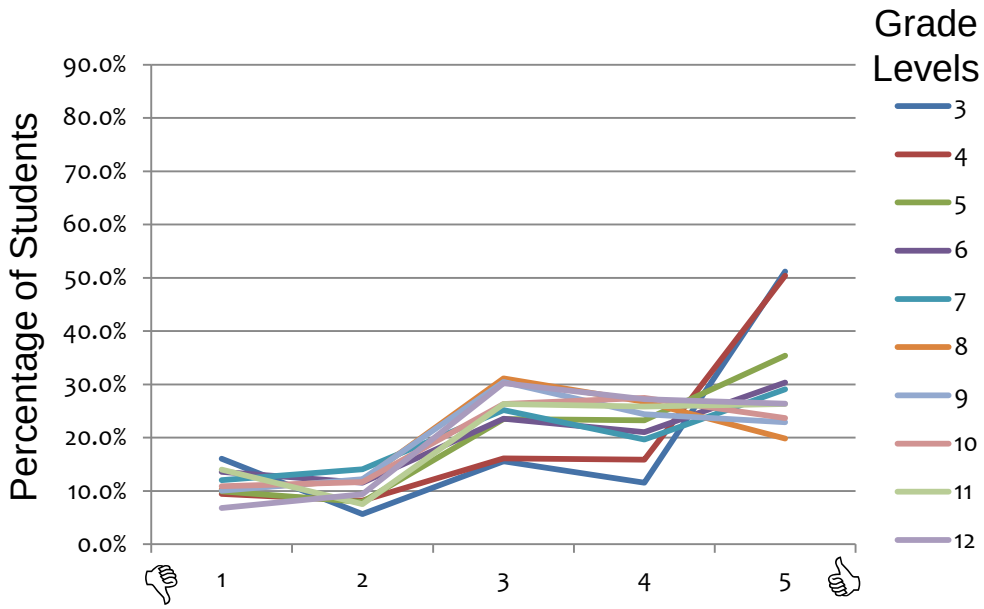
☐ Girl ☐ Boy

2 **Is English the language you usually speak at**

We want to know if you have attended science or math programs outside of school time.
(Mark all that apply.)

6 **Did you ever attend a camp or a program that**

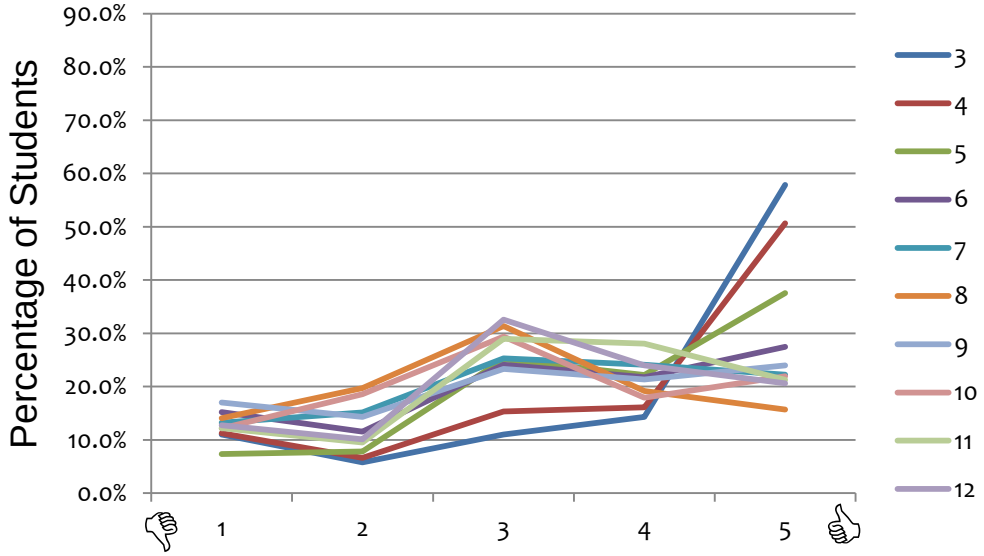
Males



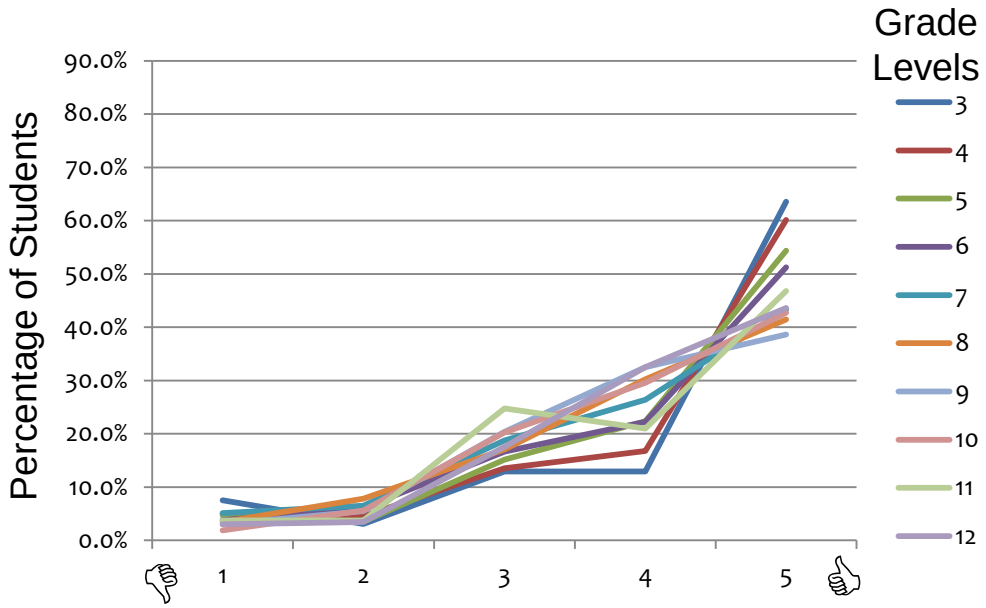
Discovering

Problem Solving

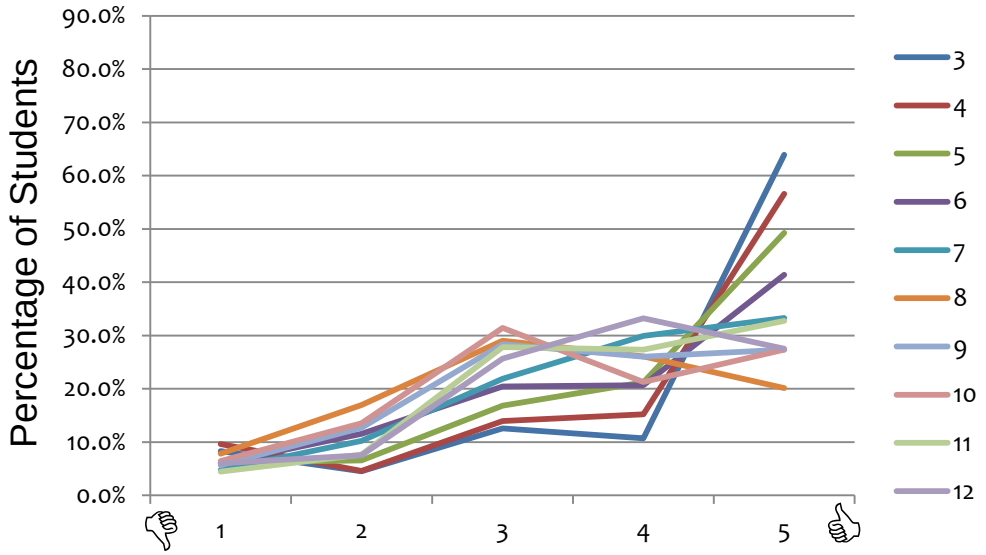
Females



Males



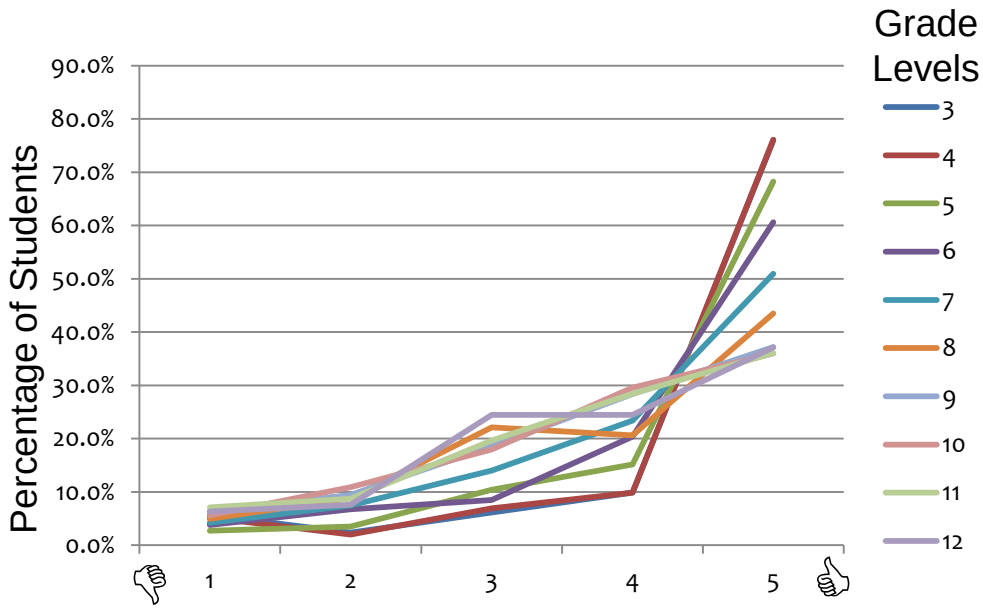
Females



Discovering

Figure Out How Things Work

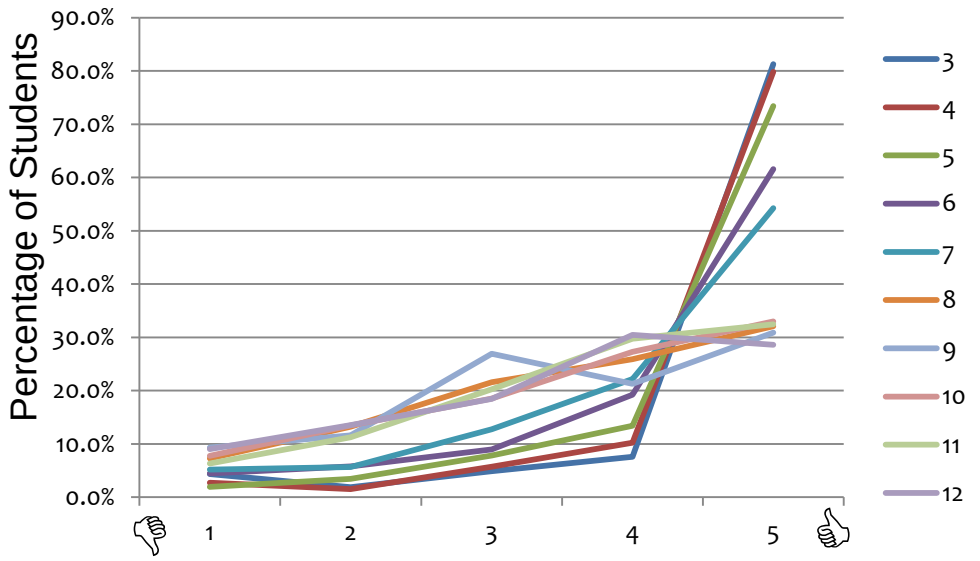
Males



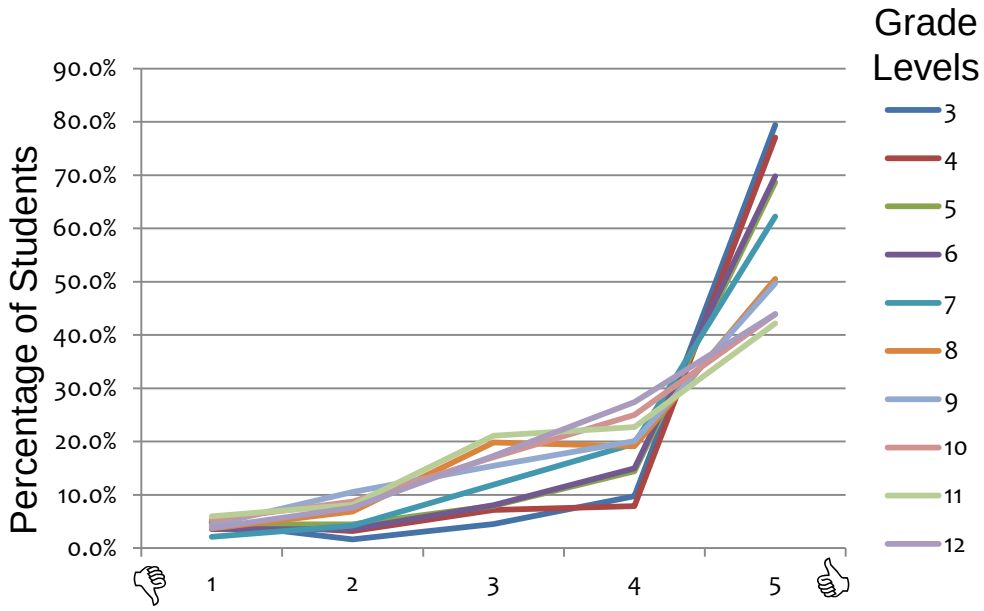
Creating/ Making

"Make" Things

Females



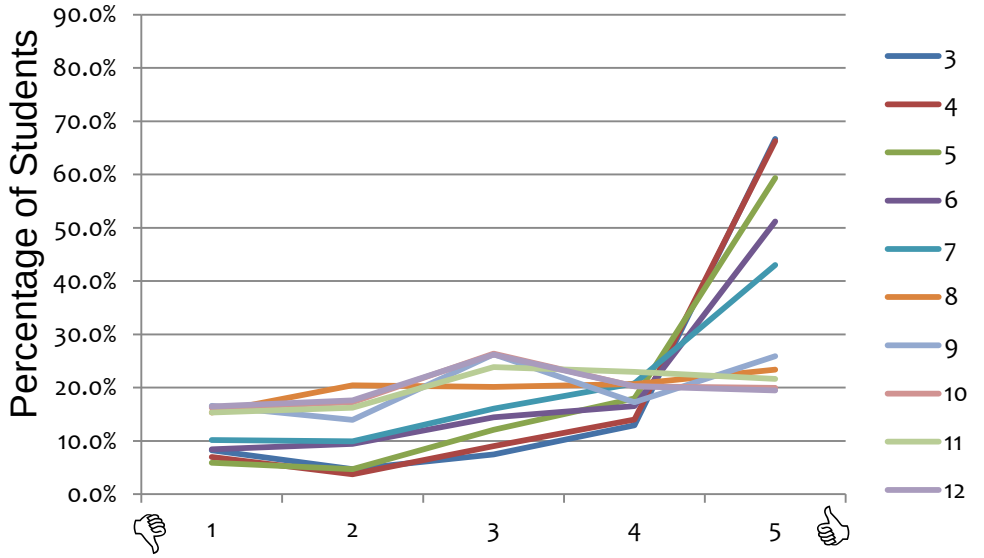
Males



Creating/ Making

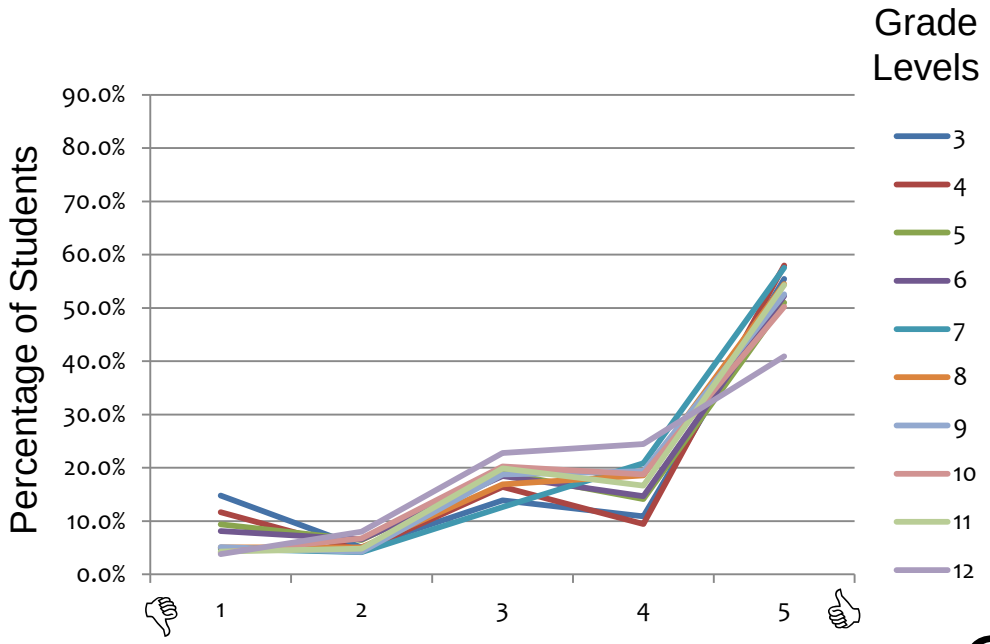
"Build" Things

Females



Collaborating

Males



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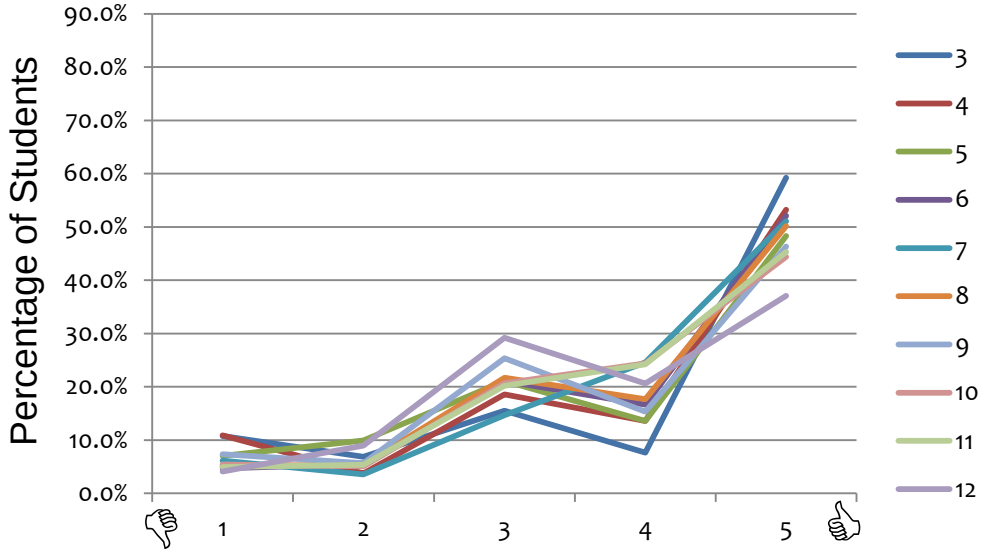

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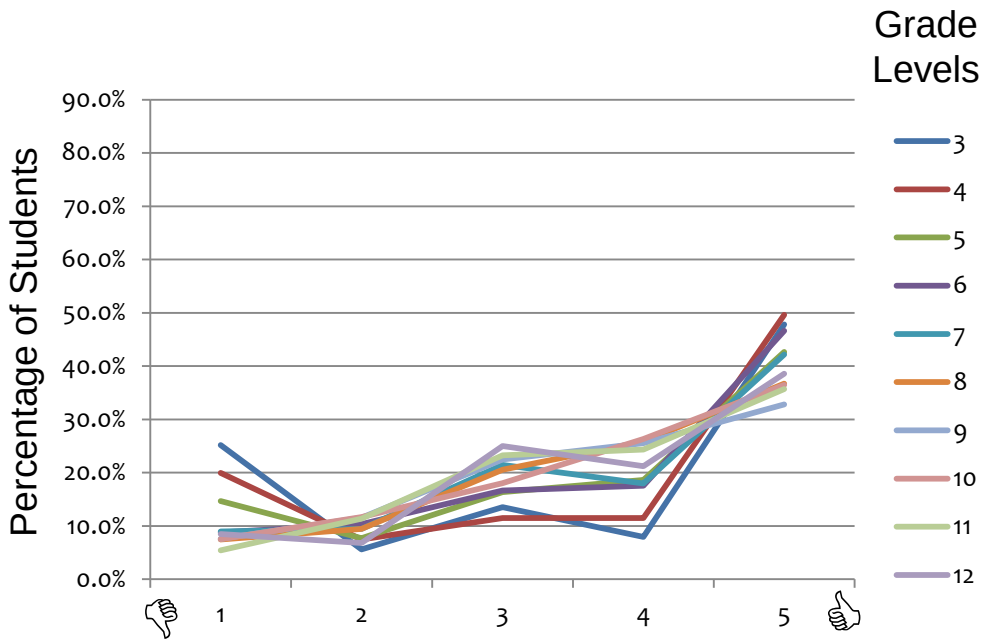

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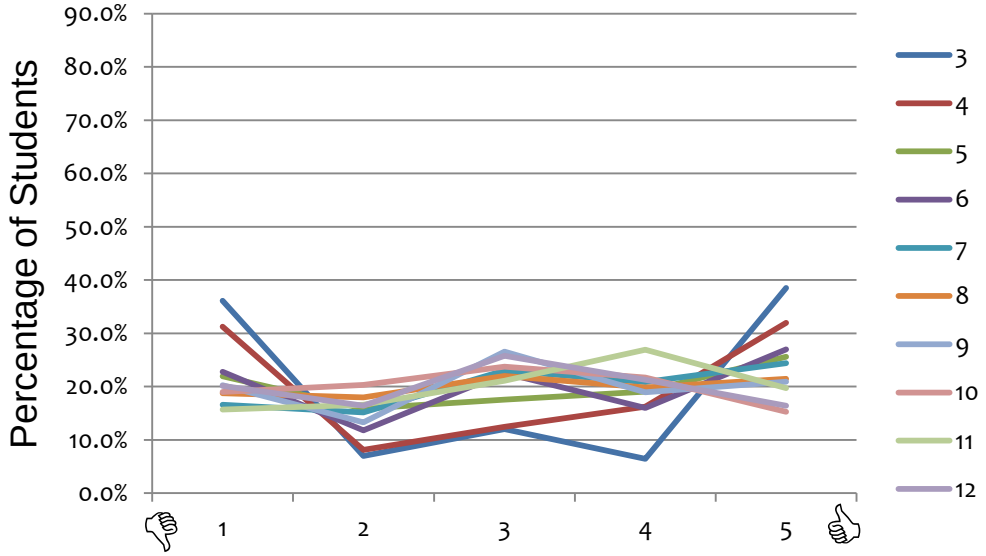
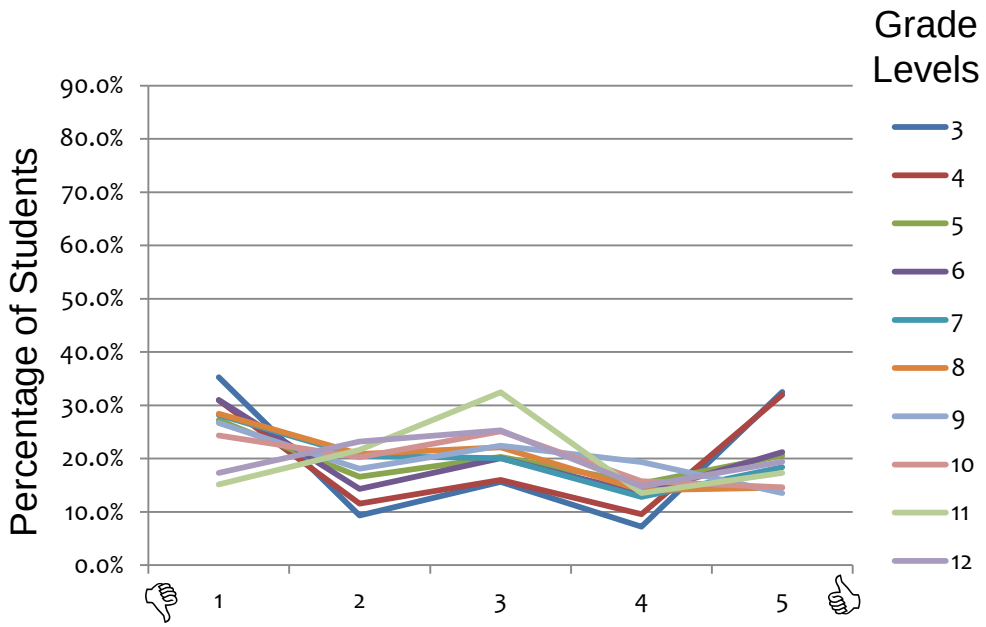


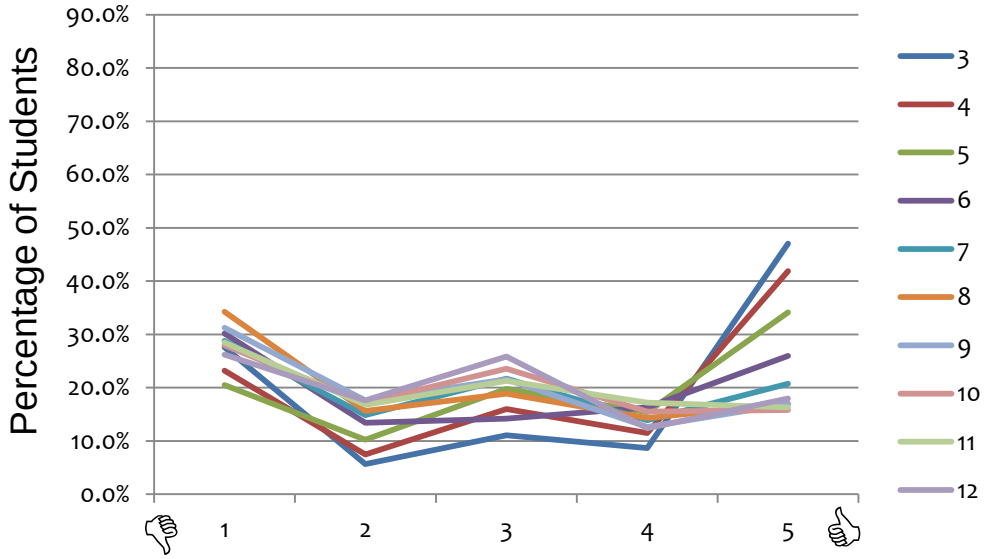
Competing

Males



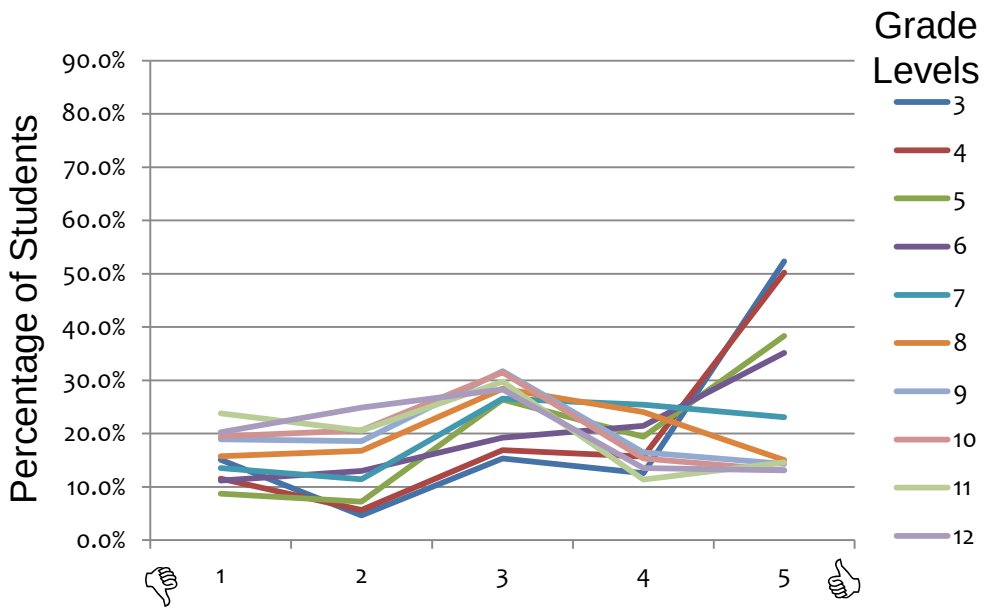
Performing

Females



Caretaking

Males



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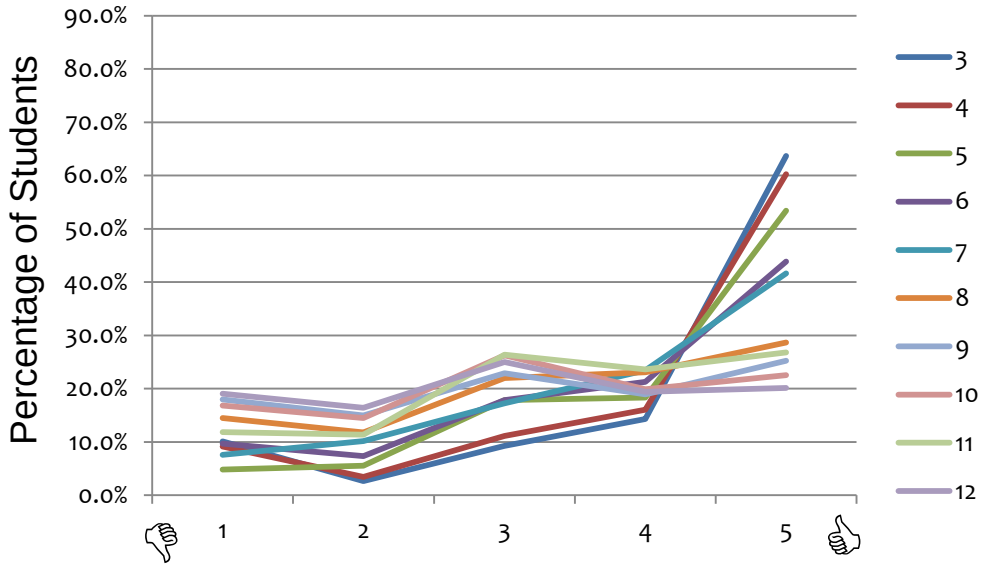
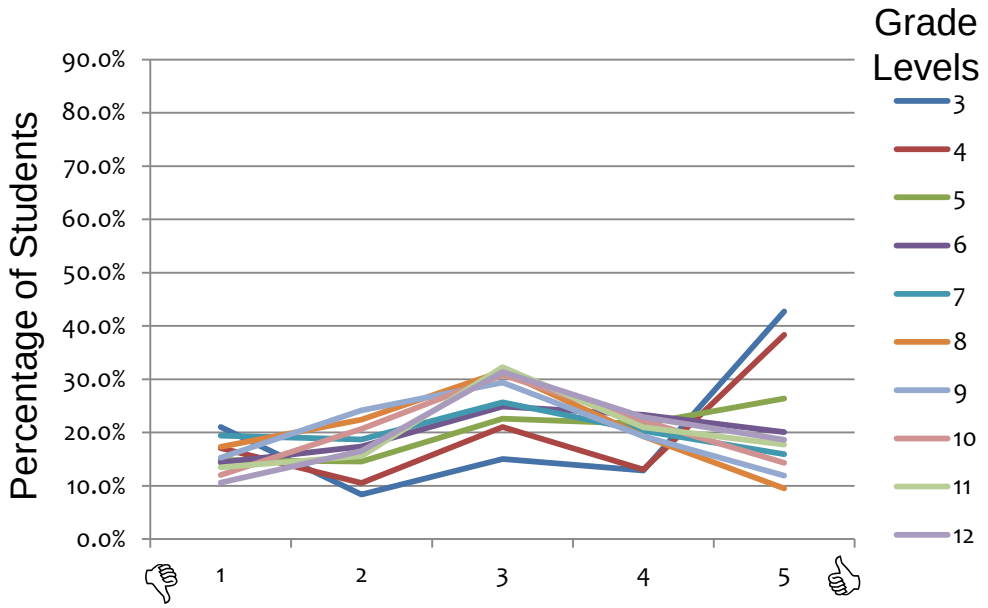
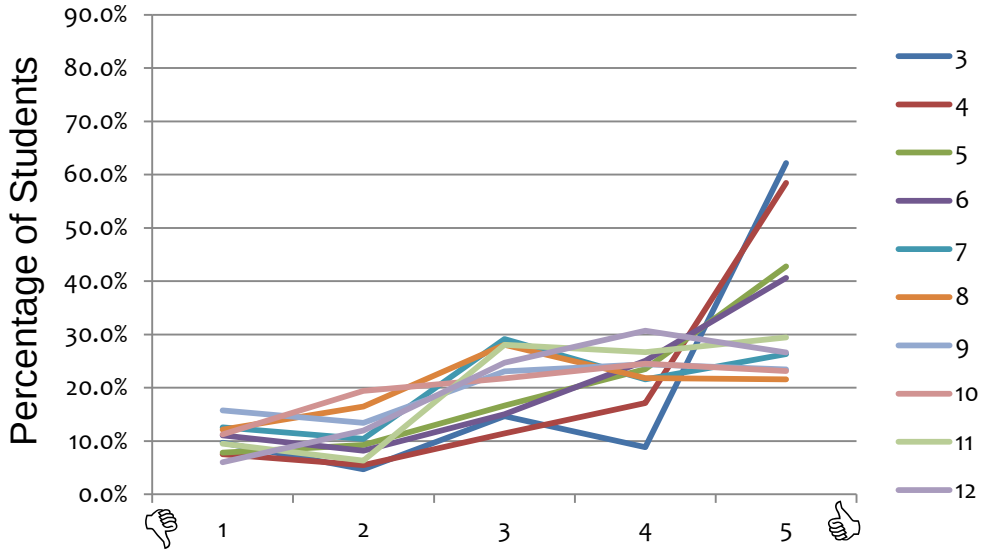


Males



Teaching

Females



Research Question

Are youth who have preferences for particular types of learning activities more likely to select STEM-related career choices than youth who have different preferences (accounting for demographic characteristics)?

Logistic Regression Analysis
STEM-related Job = [0, 1] Dichotomous Outcome Variable
(All 21 LR Models include Demographic Background Controls for Gender and Race/Ethnicity)

Comparison of Odds Ratios from Seven Logistic Regression Models of Learning Activity Composite Variables (Each LR model included baseline demographic control variables, gender and race/ethnicity)

Learning Activity **Composite** Variable	Grade Level		
	Elementary	Middle	High
Discover [a]	1.38**	1.99***	1.74***
Make [a]	1.27*	1.60***	1.35***
Collaborate_**REVERSE** [ab]	1.31***	1.30***	1.28***
Compete [a]	0.92	1.04	0.93
Present [a]	1.10	1.16**	0.95
Caretake [a]	0.99	1.03	1.03
Teach [a]	0.93	1.00	1.06

[a] All odds ratios reported above are based on LR models which include demographic background variables for gender and race/ethnicity.

[b] Collaborate_REVERSE is the reverse coded composite variable for the composite variable Collaborate, where a 5 score has been recoded to a 1 score, and vice versa. This status implies that youth with lower scores have greater odds of choosing STEM Jobs, than youth with higher scores.

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Comparison of Prototypical Students

Comparison of Prototypical Elementary School Students

Learning Activity	Neutral (3 / 5) vs Positive (4 / 5)	Neutral (3 / 5) vs Highly Positive (5 / 5)
Discover	38% greater odds	90% greater odds
Make	27% greater odds	61% greater odds

Comparison of Prototypical Middle School Students

Learning Activity	Neutral (3 / 5) vs Positive (4 / 5)	Neutral (3 / 5) vs Highly Positive (5 / 5)
Discover	99% greater odds	296% greater odds
Make	60% greater odds	156% greater odds

Comparison of Prototypical High School Students

Learning Activity	Neutral (3 / 5) vs Positive (4 / 5)	Neutral (3 / 5) vs Highly Positive (5 / 5)
Discover	74% greater odds	203% greater odds
Make	35% greater odds	82% greater odds

Gender Differences?

With respect to aspirations for a STEM-related career, what **gender differences** exist among youth across elementary, middle, and high school?

Investigating Gender Differences Across Grade Ranges

Frequency Distribution

Grade Level	Gender			
	Male		Female	
	n	Percent	n	Percent
Elementary	1265	51.0	1215	49.0
Middle	1306	52.4	1186	47.6
High	1043	48.4	1110	51.6

Logistic Regression Analysis
STEM-related Job = [0, 1] Dichotomous Outcome Variable
(All 3 LR Models include Demographic Background Controls for Race/Ethnicity)

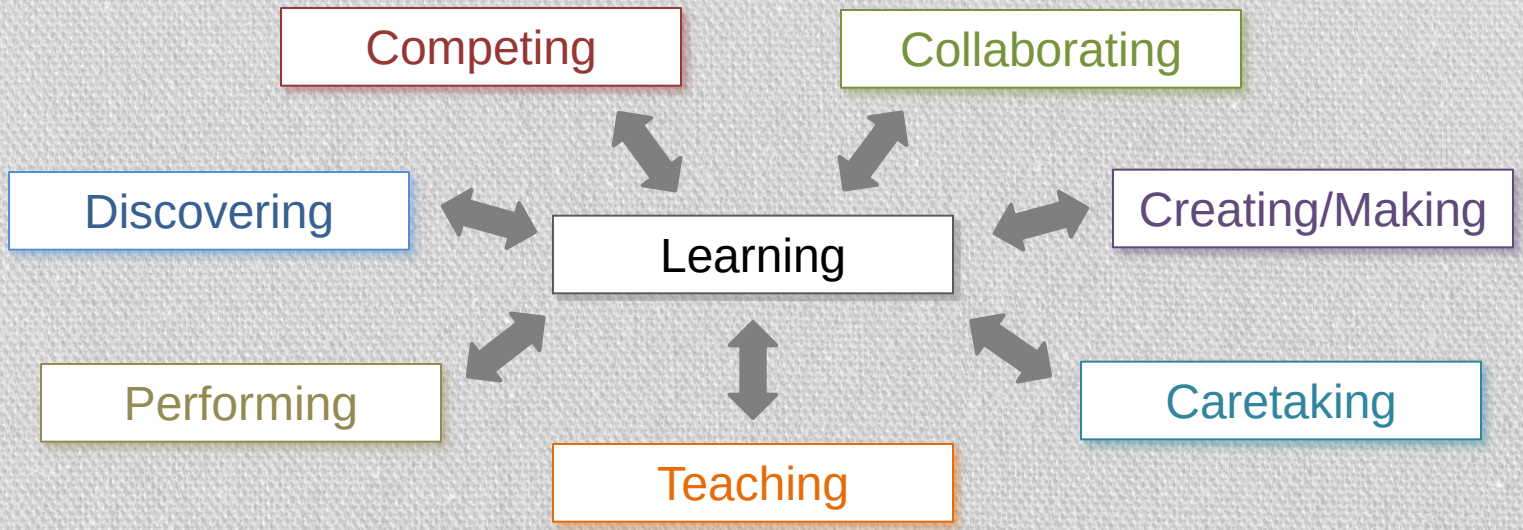
Grade Level	Odds Ratio
Elementary	3.0***
Middle	4.3***
High	4.1***

These results suggest that among Elementary School children, **a prototypical MALE** has **3.0 times greater odds** of choosing a STEM-related career **than a prototypical FEMALE**.

Among Middle School children, **MALES have 4.3 times greater odds than FEMALES** of choosing a STEM-related career.

Among High School children, **MALES have 4.1 times greater odds than FEMALES** of choosing a STEM-related career.

FOCIS



Elements and Characteristics

What elements characterize each of these types of learning activities?

Degrees of Intensity

What is the LOWEST level (non-inclusion) for each activity?
What is the HIGHEST level for each activity?

We gratefully acknowledge the support of these organizations

NOYCE FOUNDATION

NSF

S. D. BECHTEL, JR. FOUNDATION
STEPHEN BECHTEL FUND

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I gratefully acknowledge their contributions

Thank you

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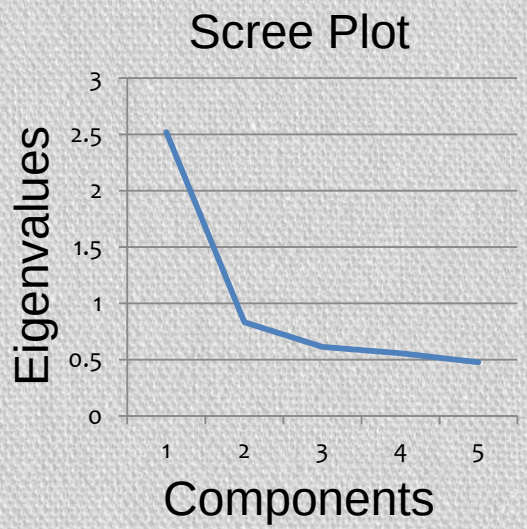
SUPPLEMENTARY SLIDES

Principal Component Analysis extracted a single component from the five "**Discovering**"-related questions.



Created a composite variable equal to the average value of the five original survey questions to create a composite variable named "**Discover**" which has a value that varies between [1 to 5] and is treated as continuous in this analysis.

The same process was carried out for the other six types of learning activities.