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STEMChoice: An Examination of Program Evaluation Data in a STEM-Centered, Inquiry-Based Program

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He is one of two scholarships awarded by NARST (National Association for Research in Science Teaching) to attend the ESERA (European Science Education Research Association) summer research conference in České Budějovice, Czech Republic in August 2016. In addition, he has been named as one of 14 Jhumki Basu Scholars by the NARST's Equity and Ethics Committee in 2014. He is the first and only individual from his native country and Texas Tech University to have received this prestigious award. Furthermore, he was a recipient of the Texas Tech University President's Excellence in Diversity & Equity award in 2014 and was the only graduate student to have received the award, which was granted based on outstanding activities and projects that contribute to a better understanding of equity and diversity issues within Engineering Education.

Additional projects involvement include: Engineering is Elementary (EiE) Project; Computational Thinking/Pedagogy Project; Rocket Project of SystemsGo; World MOON Project; East Lubbock Promise Neighborhood (ELPN) Project; and Robotics. Since 2013 he has served as the president of the Nu Sigma chapter of Kappa Delta Pi: International Honor Society in Education and was the founding president of ASEE Student Chapter at Texas Tech University. He can be reached at ibrahim.yeter@ttu.edu.

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Abstract

On a national scale, there has been a call for improved instruction in science, technology, engineering, and mathematics (STEM) at all educational levels. In addition, claims have been made regarding the lack of a viable STEM workforce in certain critical areas. Consequently, many resources have been devoted to encouraging and motivating students in the secondary levels to pursue a STEM-related career.

This paper is centered on the efforts of an inquiry-based, STEM educational program that uses the conception, design, production, and deployment of rockets as a way to teach and improve students STEM-related workforce skills. The target population included high school students in one state in the southern region of the United States. Program evaluation data were collected via a student questionnaire grounded on two theories: Social Career Cognitive Theory (SCCT) and the Theory of Planned Behavior (TPB).

Based on program data collected during the 2014-2015 academic year, this paper will examine the effectiveness of the program in motivating students to pursue a STEM career, using the theoretical lens of Social Cognitive Career Theory (SCCT). The following research question will be addressed: which factors help predict student intentions to pursue a STEM career upon graduation of high school?

A stepwise multiple regression model was established to predict students' inclination to choose a STEM career. Findings suggest a viable model which accounted for the most amount of variability in students' inclination to pursue a STEM career, $R = .40$, $F (4, 444) =20.885$, $p < .01$. The predictors within this model were focused on teamwork, overall student evaluation of the program, and problem solving.

Introduction

In order for students in the secondary levels to pursue careers in the science, technology, engineering and mathematics (STEM) fields, effective STEM instruction is must be present. However, in the United States, the lack of effective STEM teaching in the secondary level is a glaring issue.[1] For a nation that has increasing STEM workforce demands, the flat response from educational system makes the STEM pedagogical issues increasingly urgent. Despite these problems, there are schools and organizations that utilize problem- and inquiry-based teaching methods that appear to address the problem. One example of such an organization is SystemsGo.

SystemsGo is a non-profit organization headquartered in the southwestern region of the United States, that uses the conceiving, design, production, and deployment of rockets as a way to teach and improve students' STEM-related workforce skills. Annually, 40-50 high schools use this curriculum, allowing students to earn high school science credit. The centerpiece of the curriculum is the inquiry-based, pedagogical approaches that teachers learn and deploy. For an entire academic year, teachers use no lectures. They guide students to develop their projects with questions designed to spark student curiosity and problem solving. These authentic teaching practices are supported in the literature, particularly in comparison studies with traditional approaches[2,3]. This aero-science program develops students' skills in areas of rocket design, development, testing, and innovation. Students learn about the laws of rocket stability, fluid dynamics, and aerodynamics. Students gain hands-on experience in problem solving, teamwork, project management, and effective communication. The program also prepares teachers to use inquiry-based teaching strategies in the classroom. Interestingly, SystemGo encourages interdisciplinary teacher teams that may include someone other than a science teacher. At the culmination of 3 years of participation, students design, build, and launch their own rockets at the White Sands Missile Range. Eighty percent of program participants from the original high school, Fredericksburg High School, have pursued STEM majors or careers.

The program include students and teachers from urban, suburban, and rural schools. The program recruits diverse students, with diversity being defined across a broad spectrum: ethnic, socioeconomic, academic skill, and interest. For example, SystemsGo teams can include students from Advanced Placement physics and students in vocational tracks, like metal shop. The gender makeup of teams ranges all along the continuum from all girls to all boys with most being a combination of the two. The program has a culminating competitions where winning is defined as students' demonstrating their competencies. The composition of participants plus the focus on inquiry-based learning strategies promises exciting evaluation and research opportunities.

SystemsGo charges schools a nominal fee, which is used to buy rocket supplies and provide professional development for teachers. Teachers also get access to the SystemsGo curriculum. Depending on the Texas high school diploma-type that the student is seeking, the course can meet a basic state requirement or be treated as an elective along the career and technical track. A typical class is driven by the students themselves. The work in teams in order to solve project-based problems associated with building small prototype rockets that lead up to building a rocket that can fly at least a mile high. The teachers require that students ask questions, but the teacher answer to the questions is often another question. Lectures, if any, are directed on how to find resources and answers to questions. The purpose of the questioning is to create and enhance an environment of scientific inquiry and student independence.

Purpose

The purpose of this study is to examine the relationship between teamwork, problem solving, and students' overall assessment on students' intentions of pursing a STEM career after graduation from high school via the lens of Social Career Cognitive Theory (SCCT). Using program data collected during the 2014-2015 academic year, the following research question will be addressed: which factors help predict student intentions to pursue a STEM career upon graduation of high school?

Theoretical Framework

This study draws upon Social Cognitive Career Theory (SCCT) and Ajzen's Theory of Planned Behavior (TPB) as its theoretical frame. SCCT has proven potential for explaining students' academic behavior and future career choice. Based on Bandura's social cognitive theory[4], social cognitive career theory stresses the interrelationship among individual, environmental, and behavioral variables that have key impacts on academic and career choice[5]. Additionally, TPB suggests that any behavior, like STEM choice and performance, can be explained by a person's intentions to engage in the behavior. The predictors of a behavior are an evaluation of the behavior, perceived social pressure to perform the behavior (*viz*, teamwork) self-efficacy in relation to the behavior, also known in TPB as behavioral control, and intention to perform the behavior[6]. SCCT, self-efficacy, outcome expectations, and goals operate together with personal characteristics and environmental contexts to help shape academic and career development[7]. While it is claimed that SCCT is comprised of three overlapping models of educational and vocational interest development; choice-making, and performance attainment[8], this study will only focus on the aspect of educational and vocational interest development as shown in Figure 1 below.

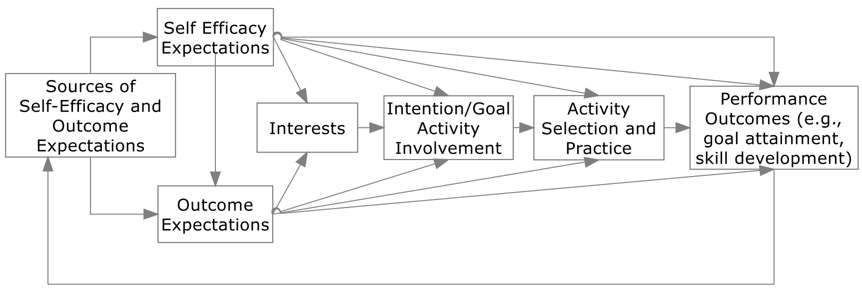

Figure 1. *Model of educational and vocational interest development*

Problem Based Learning

Problem-based learning (PBL) in relation to STEM is an "ill-defined task within a well-defined outcome situated with a contextually rich task requiring students to solve several problems which when considered in their entirety showcase student mastery of several concepts of various STEM subjects."[9] The positive effects of PBL in relation to STEM education have been well-documented in that its use in the classroom has contributed to greater student comprehension and application of concepts than other traditional pedagogical approaches.[10] Students have exhibited higher levels of elaboration, critical thinking and metacognition[11]. Exposure in a PBL classroom has even contributed to changes in student attitudes towards STEM to the point of recognizing its importance.[12] In a meta-analysis which focused on the effects of integrative approaches among STEM subjects on student learning, Becker & Park found that schools that utilized the integration of engineering, math, science, and technology (d=1.76) as well as engineering, science, and technology were likely to help improve student achievement (d=.66-2.95)[13].

Participants

All participants were students in a high school that was affiliated with SystemsGo. Four hundred sixty-six students (n=466) responded to the program questionnaire administered in May 2015. Seventy-nine percent of the students were male and 21% were female. With regards to ethnicity, the three largest groups were Caucasians (52%), Hispanic-Americans (40%), and African-Americans (4%) respectively. Over 80% of the participants were upperclassmen: 37% were seniors, 47% were juniors, 9% were sophomores, and 7% were freshmen. Looking at student standing in the rocket program, 80% of the students were in their first year of the rocket program and 13% were in their second year[14].

Instrumentation

The 2015 version of the Student Questionnaire consisted of 33 questions. Thirteen were demographic questions, seventeen attitudinal items related to the students' experiences and career goals, and three were open-ended questions. A copy of the questionnaire is located in the Appendix. The questionnaire was based on the theoretical frame presented above. While there has been preliminary exploration conducted on the open-ended questions[15], this study focused on the 17 questionnaire attitudinal items which represented variables that were related to intentions to choose a STEM career can be grouped with the following themes: beliefs about the ability to succeed in STEM, STEM success consequences, student social supports, teamwork, project management, and inquiry/project-based learning.[16] Content and construct validity of this instrument were tested by soliciting the input of various stakeholders within SystemsGo. These attitudinal items produced a high reliability coefficient (Cronbach's α=.87)[17]. Exploratory factor analysis was also conducted to support the inclusion of sets of items that loaded well together and eliminate those that did not load well. Based on this analysis, eight items were removed and nine were left for further analysis.

Analysis

Using PASW SPSS (v.18), data were prescreened for missing data, outliers, and normality. First, data were initially checked for missing data using a missing values pattern analysis. Approximately, 2% of the data were missing. Then, using multiple imputation procedures, the missing data were imputed. The variables selected for this study are as follows listed in Table 1.

Table 1. *List of Variables for Preliminary Analysis*

Variable	Variable Label	Function
Q24_1(criterion)	**For me to excel in a STEM career would be**	**Career**
Q40_2	I knew how to help my team stick to deadlines	Teamwork
Q40_14	I believed that my class team worked like an engineering team at a design and production facility	Teamwork
Q40_16	When my team started to drag, I knew what to say to get them back on track	Teamwork
Q40_15Recode	Active Role in Team Briefings	Teamwork
Q39_1Recode	Fantastic Experience	Overall Student Evaluation
Q40_1Recode	Say Wonderful Things	Overall Student Evaluation

Q43_3	When I try to solve multiple complex problems, I placed my data in sequential order	Problem Solving
Q43_1Recode	Getting the facts in complex problems	Problem Solving

Q24_1 represents the criterion variable for students' inclinations toward a STEM career. All other variables function as predictors. Data was then checked for univariate and multivariate normality. For univariate normality, variables with skewness greater than positive or negative 1.5 were adjusted by removing outliers and eventual recoding[18]. To address multivariate normality, variables were tested using Mahalanobis' distance[19]; those cases that were multivariate non-normal were removed from this study. After conducting these normality tests, 449 cases were utilized for multiple regression analysis. The following model was entered into SPSS using the stepwise function: **Career = [Teamwork] + [Overall Student Evaluation] + [Problem Solving]**

Q24_1= [Q40_2+Q40_14+Q40_16+Q40_15Recode] + [Q39_1Recode+Q40_1Recode]+ [Q43_3+Q43_1Recode]

Results

Bivariate correlations with the Career variable (Q24_1) were mostly moderate sizes ranging from a low of .20 (Q43_3) to a high of .30. A list of bivariate correlations is found in Table 2.

Table 2. *Bivariate Correlations*

	Q24_1	Q40_2	Q40_14	Q40_16	Q40_15	Q39_1	Q40_1	Q43_3	Q43_1
Q24_1									
Q40_2	.30								
Q40_14	.23	.53							
Q40_16	.27	.61	.51						
Q40_15 Recode	.29	.63	.44	.67					
Q39_1Recode	.30	.43	.39	.30	.42				
Q40_1Recode	.27	.38	.40	.30	.40	.80			
Q43_3	.20	.28	.25	.35	.30	.19	.17		
Q43_1 Recode	.28	.35	.26	.32	.37	.24	.22	.51	

All correlations were rounded to nearest hundredth. All correlations were statistically significant, p<.01.

Using the stepwise method, four regression models were established to predict students' inclination to choose a STEM career, as seen in Table 3. Model 1 uses Q40_2 from Teamwork as a sole predictors. Model 2 uses Q40_2 and Q40_15 from Teamwork as predictors. Model 3 uses Q40_2 and Q40_15 from Teamwork as well as Q39_1 from Overall Student Evaluation as predictors. Model 4 uses those three variables in addition to Q43_1 from Problem Solving as predictors. While all four models were statistically significant as shown in Table 3, the best regression model was Model 4, which accounted for the most amount of variability in students' inclination to pursue a STEM career, $R = .40$, $F(4, 444) = 20.885$, $p < .01$. In that model, three of the four predictors were significant, $p < .05$. Only Q40_15 (Active Role in Team Briefings) was nonsignificant (β = .09).

Table 3. *Summary of Regression Analysis for Variables Predicting Student Intentions to Pursue STEM Career (N=448)*

	Model 1			Model 2			Model 3			**Model 4**		
Variable	*B*	*SE B*	*β*	*B*	*SE B*	*β*	*B*	*SE B*	*β*	***B***	***SE B***	***β***
Q40_2	.35	.05	.30**	.22	.06	.20**	.17	.06	.15**	**.13**	**.07**	**.12***
Q40_15				.20	.06	.17**	.14	.07	.12*	**.10**	**.07**	**.09**
Q39_1							.30	.08	.19**	**.29**	**.08**	**.18****
Q43_1										**2.27**	**.07**	**.17****
R		.30			.33			.37			**.40**	
R^2		.09			.11			.14			**.16**	
F		45.47**			27.41**			23.32**			**20.89****	

*p < .05. **p < .01.

Discussion

The purpose of this initial examination was to use a combination of SCCT and TPB in order to explain student inclination toward a STEM career. Though three of the four predictors are significant in this model, the results not only suggest that the presence of collaborative learning combined with authentic problems is needed in the contemporary STEM classrooms[20,21] but confirm earlier studies that showed that students who participated in problem-based learning felt that it helped them become independent learners[22] and reported a greater sense of personal growth[23]. Such findings are a positive indication that this program is effective in terms of affecting student interest to make the experience more personal to them[24]. This type of interest development is aided through the establishment of a positive group environment that supplies the students with authentic, applied tasks to complete in order to achieve the goal of building a rocket. From this model, a student's intentions to pursue a STEM career after high school are predicted based on three aspects: a) the students' actual outlook on the experience in the program, b) ability to effectively work in a team under real deadlines, and c) their ability to solve complex problems.

Future Research

In learning more about the students in SystemsGo in relation to SCCT, I feel that a structural equation model would be useful to see because it would help to explain the program data from a broader perspective via the construction of latent constructs multiple dependent variables and indirect effects.[25,26].

Note

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Appendix

The Rocket Program- AY15post © 2015 Hansel Burley
Student Participant Information Sheet—SystemsGo Evaluation
Project Title: Evaluation of SystemsGo Project. AY 15
Investigator: Hansel Burley, Texas Tech University

Purpose: Congratulations on your participation in your school's rocket program. Your high school's program is designed to increase students' interest in science, technology, engineering, and mathematics (STEM). The sponsor of your school's program is a non-profit organization called SystemsGo. This group provides the curriculum to your program. This program needs your help in making these types of programs better. We only need that you answer a few questions from our online questionnaire. This online questionnaire is one part of an evaluation of SystemsGo. They are interested in learning how well rocket programs increase students' interest in STEM careers. This questionnaire is designed to help them understand the program's effectiveness. We are inviting you to help SystemsGo by answering questions about the program and your career interests. I'm writing you as part of the evaluation team from Texas Tech University. I hope you will participate in this short survey. Your participation is completely voluntary. You may quit at any time. Procedures: If you choose to participate in this evaluation, your responses are completely anonymous. Your teacher will give you a link to the survey, and it will be on the SystemsGo website. Answer the survey on your class computer. It should take about 10-15 minutes to complete. You may skip any question that you do not want to answer. That's it. Again, there are no names collected, so be as honest and thoughtful as you can. Any written results will focus on all rocket program students. We will not release any information that can identify you.

Risks: Because this questionnaire is anonymous, there are no risks to you. We also cannot imagine how any of the questions can cause you any discomfort. Additionally, your choice not to participate in answering the questions will not affect you or your status in your rocket program in any way. Compensation and Benefits. There is no reward for taking the survey. However, many consider improving STEM as the most important task for American education. Your answering a few questions will help in that effort. It also will help SystemsGo, and it will help your local program. Contact: If you have any questions or concerns about this project contact Hansel Burley at 806.834.5135 or hansel.burley@ttu.edu. If you have questions about your rights as a research volunteer, you may direct them to the Human Research Protection Program (HRPP), Office of the Vice President for Research, Texas Tech University, Lubbock, Texas, 79409, 806.742.2064. This is project number 504365. Again, the survey can be finished very quickly, so push to the end if you can. Some questions are similar to each other. That's by design--read carefully. Thank you again!

Q42 Get your school ID number from your teacher. Please enter your 4-digit school ID number here. It must be exactly 4 characters.

Q1 Please indicate your ethnicity (Mark all that apply)

- Asian American
- Black/African American
- Hispanic American
- Native American
- International
- White/European American

Q46 Please indicate your gender

- Male
- Female

Q2 What are your educational aspirations?

- High school
- Some college
- Associate's Degree
- Bachelor's Degree
- Master's Degree
- Doctoral Degree
- Medical Degree
- Law Degree

Q9 What is your standing at school?

- Freshman
- Sophomore
- Junior
- Senior

Q11 Have you earned any college credit? How much?

- 0 hrs.
- 1-9 hrs.
- 10-21 hrs.
- 22+ hrs

Q12 Have you taken a physics course prior to the rocket program course?

- ❍ Yes
- ❍ No

Q13 Will you get credit for physics by taking the rocket program course?

- ❍ Yes
- ❍ No

Q14 What type of 6 or 9 week grades do you get in science courses?

- ❍ All A’s
- ❍ A’s and B’s (about equal)
- ❍ Mostly B’s
- ❍ B’s and C’s (about equal)
- ❍ Mostly C’s
- ❍ Usually less than C’s

Q34 Highest level of education of my mother or female guardian

- ❍ Less than high school
- ❍ High school diploma
- ❍ Some college
- ❍ Associate's degree
- ❍ Bachelor's degree
- ❍ Master's degree
- ❍ Doctoral degree
- ❍ Medical degree
- ❍ Law degree
- ❍ No female guardian

Q17 Highest level of education of my father or male guardian?

- Less than high school
- High school diploma
- Some college
- Associate’s degree
- Bachelor's degree
- Master's degree
- Doctorate degree
- Medical degree
- Law degree
- No male guardian

Q16 Please (Choose one) I am:

- First year rocket program student
- Second year rocket program student
- Third year rocket program student
- Fourth year rocket program student

Q35 What was your rocket team's goal for your rocket?

- CoET (Concepts of Engineering and Technology) Design project
- Tsiolkovsky: Rocket with a 1 lb payload, flying one mile high
- Oberth: Rocket that reaches transonic speed
- Goddard: Rocket that reaches 80,000-100,000 ft

Q47 Please indicate your school's University Interscholastic League (UIL) ranking

- 1A
- 2A
- 3A
- 4A
- 5A
- 6A

Q5 Using the slide bar, please indicate your degree of interest, right now

______ Interest in attending college

Q21 Please indicate your degree of agreement with the following statements:

______ I know an adult who is a scientist, technologist, engineer, or mathematician.

Q24 Using the scale below, please complete the following statement:

______ For me to excel in a STEM career would be

Q32 Using the scale below, please complete the following statement:

______ If the rocket did not fly as expected (or my project failed), I would want to know why

Q35 Using the scale below, please indicate your degree of agreement with the following statements:

______ Using what I have learned from the rocket program, I am certain I will build things that have a lasting effect on society.

Q40 Using the scale, please indicate your degree of agreement with the following statements:

______ In my rocket program classroom, we learned from things going wrong. (10)
______ In my rocket program classroom, I knew how to help my team stick to deadlines. (2)
______ I believed that my class team worked like an engineering team at a design and production facility. (14)
______ I took an active role in team briefings (15)
______ When my team started to drag, I knew what to say to get them back on track. (16)
______ After being in this program, I know for sure that I can figure out complex problems. (17)

Q43 When I try to solve multiple complex problems,

______ I focused on getting the facts (1)
______ I tended to guess at answers (2)
______ I placed my data in sequential order (3)

Q43 Using the scale below, please complete the following statements:

______ If needed, I know for sure I can do the research for a design brief. (2)

Q39 This was a fantastic experience.

______ What do you think right now?

Q40 When I tell people about the program, I will say wonderful things about it

____

Q51 Tell us more about your experience. What did you like best about your rocket program experience?

Q37 If you had three times the money, what changes would you make in the program?

Q44 Describe two or three (or more) STEM topics you learned. Think in terms of science and math concepts or engineering principles.