

Self-efficacy and STEM Career Goals Among Students in a Required Game
Design Class in an Urban Charter Middle School

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Abstract

This study compares self-efficacy scores among students participating in a required web game design class using the Globaloria program as academically underserved students acquire Constructionist Digital Literacy skills, and examines changes in student goals related to STEM careers. Researchers were interested in whether differences in gender, language learner status and years of experience in the program had impact on student self-efficacy and career goals. The data was collected five times during the 2011-12 school year, using an online survey. Students with the most experience in the program showed statistically significant differences in their self-efficacy when compared to other groups with less experience in the program. There were no gender differences among self-efficacy rating averages. However, more girls than boys remained interested in pursuing a STEM career goal over time. The number of students interested in STEM career goals remained higher than expected for an academically underserved population.

Introduction

Students' feelings of STEM self-efficacy are an established factor in academic and career goal setting. The current study examined changes in student reported STEM self-efficacy and the corresponding career goals of students who participate in a required game-design program, Globaloria, in a charter middle school. The student body is comprised of students from the surrounding economically disadvantaged neighborhood and the majority of students are Latino/a.

According to a US Bureau of Labor report, Latino/as employed in professional, scientific and technical fields made up just 7.1% of the workforce in 2011. Looking at both gender and ethnicity presents an even starker picture: the percentage of computing occupations held by Latinas in 2009 was 1.5%. Meanwhile, computing has been identified as one of the fastest growing professions, with a projection of 800,000 positions to be filled by 2018 (Bureau of Labor Statistics, 2012). Other data, from the Integrated Postsecondary Education Data System (IPEDS) Completion Survey (1999-2000) indicates that the most popular majors in which Latino/a students earned bachelor's degrees are in the social sciences, while Latino/a students were less likely to earn undergraduate degrees in biological and life sciences, computer and information sciences, engineering, and the health professions and related sciences. (Llagas & Snyder, 2003). As the professional opportunity gaps widen, the need to reach Latinos, and Latinas in particular, with more targeted and effective opportunities for STEM advancement are clear.

Globaloria is an intervention that aims to introduce students to game design and social media as they become designers and developers themselves. The intervention is

designed to mitigate gaps in opportunity for careers in the STEM field for women and for Latino/as. The program embodies the theoretical instructional design principles of Constructionism and distributed cognition (Harel & Papert, 1991; Salomon, 1997), and is being implemented in middle and high schools serving economically disadvantaged students in several U.S. states. Participating students engage in collaborative game design within a formal, in-school game design class offered for credit and a grade. Students create a game about a socially conscious issue of their own choice. This game also includes some academic content such as math or science. The primary goal from the students' perspective is to create a functioning interactive web game that can teach other students about their chosen social-impact topic by the end of the school year. To complete a game, students participate in several integrated technology-supported activities such as inquiry and collaboration in teams to meet a range of instructional objectives towards achievement of "Constructionist digital literacy" (Reynolds & Harel, 2009).

Researchers were interested in whether differences in gender, English Language Learner status and years of experience in the program showed a relationship to student self-efficacy and career goals. Students responded to a survey of 11 questions on 3 domains of self-efficacy: 1) self-efficacy for STEM learning, 2) self-efficacy for marshalling social resources and 3) self-efficacy for self-regulation.

This research reported here was the second year of data collection using a survey instrument developed based on the work of Bandura (1977, 1994) regarding self-efficacy. During the 2011-12 school year, as well as in 2010-11, we collected survey data the students' self-efficacy regarding STEM-related skills. Data collected from students

regarding their STEM self-efficacy is used to examine connections between the classroom game design experience and the development of efficacy and motivation in this environment.

Literature

Self-efficacy is defined as an individual's beliefs in his or her own capabilities to produce designated levels of performance that exercise influence over events that affect their lives. This is an important part of the development of 21st century skills because it is the belief that one has control over one's life. For the purpose of this study, we examine the efficacy beliefs of students engaging in a STEM program, regarding beliefs about their own capabilities in STEM skills including programming, blogging and problem solving in the development process. This set of skills is increasingly being recognized as important as a tool for 21st century success (ISTE, 2012) with some scholars suggesting that self-efficacy is essential for engagement. (Marzano and Pickering, 2010)

Bandura describes four ways that the development of self-efficacy is supported:

- Performance mastery experiences, which many scholars identify as the most important source of support
- Vicarious experiences and social modeling for judging capabilities in comparison with performances of others
- Feedback or verbal persuasion and social influences that one possesses certain capabilities
- Physiological states from which people partly judge their capableness, strength, and vulnerability

Note that one's self-efficacy is a construct that changes readily in response to one's experiences and challenges.

Educational Attainment, STEM Career Aspiration and Self-efficacy

Some research in this literature review focused on the STEM pipeline, and how self-efficacy can play a role in support of bringing students into these careers. Gandara studied data on interventions to bring Latino students specifically into the math and science pipeline. She finds that this will require a broad strategy that begins with preliteracy skills. Her work suggests that we would have to invest from 1.5 to 2 times what we now invest per pupil to begin to even the playing field for Latino students. (Gandara, 2006).

A group of researchers found evidence that high STEM self-efficacy is a stronger predictor of vocational choice for girls than for boys (Larose, Ratelle, Guay, Senécal, & Harvey, 2006). Other studies have found that self-efficacy is positively related to interest and engagement (Schunk & Pajares, 2002); self-efficacy predicts initial engagement and task performance and this success leads to greater intrinsic interest and a greater likelihood of engaging in that task in the future, often at a more challenging level. Watt found that individuals with high self-efficacy enroll in more challenging courses than do individuals with low self-efficacy (Watt, 2006). Highlighting the importance of perceptions of abilities rather than actual abilities for influencing motivation, research shows that interest is more highly related to self-efficacy than actual ability (Bandura, 1991). For all of these reasons, it may be that if participating in Globaloria supports development of self-efficacy, then it may also bring a stronger self-efficacy. For instance, Massey found that the extent to which students have positive experiences in high school

has important implications for intention to pursue postsecondary education (Massey et al., 2003). Self-judged capabilities influence the range of career options seriously considered, the degree of interest shown in them, and the vocational paths that are pursued (Betz & Hackett, 1986; Lent & Hackett, 1987) Researchers have reported that career-related self-efficacy is positively related to career-related outcome expectations among samples of Latino students (Fouad & Smith, 1996; Gushue, 2006), and also that self-efficacy positively influenced academic and career interests in math- and science-related fields among a sample of mainly Hispanic middle school students (Fouad & Smith, 1996), and at the same time, unrealistically low mathematics self-efficacy perceptions may be responsible for avoidance of mathematics-related courses and careers. (Hackett & Betz, 1989).

The development of self-efficacy and its long-term impacts were demonstrated by Jencks and colleagues (1972). In young adults, higher levels of self-efficacy and self-esteem have been found to be associated with better academic performance (Phillips and Gully, 1997). Self-efficacy measures were found to have good internal validity on student success in academic settings (Solberg, O'Brien, Villareal, Kennel, Davis, 1993; Bores-Rangel, Church, Szendre, Reeves, 1990).

Bandura (1989) wrote that '*Self-comparison of improvement in a personalized classroom structure raises perceived capability.*' Bandura identified independent learning within the classroom (p.67), as opposed to other styles of classroom interaction as more supportive of self-efficacy.

Students coming from high-risk backgrounds often have few models for success and many models for failure. As mentioned previously, the school in this case study is using the Globaloria program as a tool to provide a different model and interrupt that cycle. The associations between students' educational experiences and long-term academic and career success are multifaceted and complex; however, the experience with the Globaloria program may be a pathway for moving a young student that has little or no knowledge and experience with game design engineering to a young adult with realistic STEM career aspirations.

Methods and Instrument

Data were collected at 5 points across the year. The survey was administered electronically to all students in (1) August, (2) October, (3) January (4) March and (5) late May. The researcher was present in the classroom and provided a verbal example and instructions for responding to the survey questions using the scale.

The survey was administered electronically 5 times during the school year: The first, as a pre-test, in mid-August and the last in late May. The final (late May) data collection took place the day after the Globey Awards ceremony, an event recognizing student achievement in Globaloria.

Instructional Context

The research took place in a charter middle school. The parents of the students who attend this school choose to enroll their children in this school instead of the default option. This means that the parents of the students in this school have a potential

difference from parents of children who send their children to a traditional neighborhood school.

- There were several challenges to the implementation of the Globaloria curriculum that stemmed from staff and schedule changes:
- One Globaloria teacher was removed from the faculty mid- school year, shrinking the teaching staff from three teachers to two
- Classes were thus reorganized into larger groups

Approximately 50 of the students had their schedule changed several times in the period between January and March of 2012, which adversely affected the teachers' abilities to know their students and their work. This change impacted the students in their first year of the program (6th graders) more than others since these classes were the most heavily re-organized. The schedule changes mid-year also prevented groups from accomplishing phases of the program, or in some cases caused them to have to scrap work and begin again.

The items used in this survey were derived, in part, from the *Children's Self-efficacy Scale* included in Bandura's *Guide for Constructing Self-efficacy Scales* (2006) and were based on Bandura's work with adolescents. Items 1, 2, 3, and 8 were modified slightly from Bandura's items that were designed to measure *self-regulation for learning*. Items 5, 6, and 7 were modified slightly from Bandura's items that were designed to measure students' self-efficacy for *enlisting social resources*. Items 4, 9, 10, and 11 were written specifically for this study, and are designed to measure students' ability to persist in the face of difficulty when *learning new technology skills* including: editing a wiki,

communicating effectively in a blog, programming in Actionscript, and using the internet to search for information. During the fourth and fifth administrations of the survey, the students taking the survey were provided with a text box after each self-efficacy rating. In the box, students could provide an optional comment explaining their rating. Malerba and Minnigerode conducted validation of the instrument (Malerba & Minnigerode, 2012).

Sample

The survey was administered to 3 main cohorts and 3 smaller cohorts of students who came to the school after the start of middle school. The cohorts are depicted in Table 1.

Table 1 Cohort groups and sample size

Cohort group	N	Percent of overall total
Cohort A3	64	19.8
Cohort B2	84	26.0
Cohort C2	14	4.3
Cohort D1:	123	38.1
Cohort E1:	30	9.3
Cohort F1:	6	1.9

Results

The most significant differences were found between the participants with 3 years of experience (Cohort A) as compared to other groups with less experience. We found that students in their third year of participation in the program **had significantly higher self-efficacy ratings than those who were in their first year at Time 2 and Time 4.**

We also found that students in their second year of the program (Cohort B) had a few significantly higher self –efficacy reports in STEM domains at time 2 and 4.

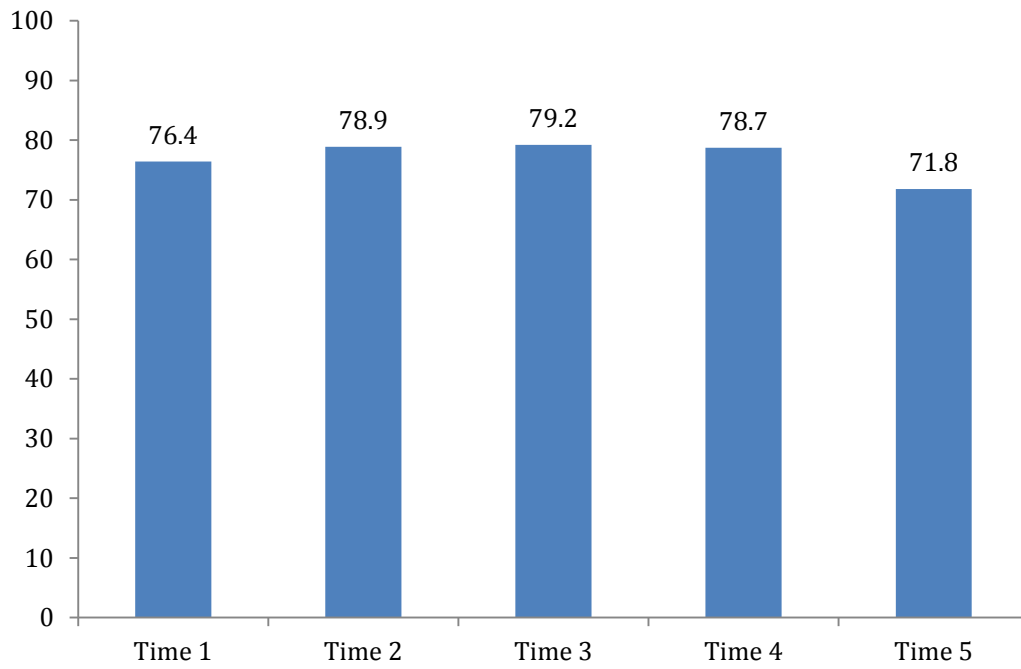
Students in their 3rd year of the program were significantly more confident that they could:

- Remember information presented in class (efficacy for self-regulation for learning)
- Figure out new things about editing the wiki (efficacy for mastery of skills) efficacy for mastery of skills)
- Figure out what to do when stuck on something in Globaloria (time 2 and time 4)
- Help other students who are stuck (efficacy for enlisting social resources for learning)
- Express thoughts clearly on a blog (time 4)(efficacy for mastery of skills)

No significant differences were found for gender and self-efficacy when scores were examined as a whole. In the future, we will analyze further gender differences within grade-group cohorts.

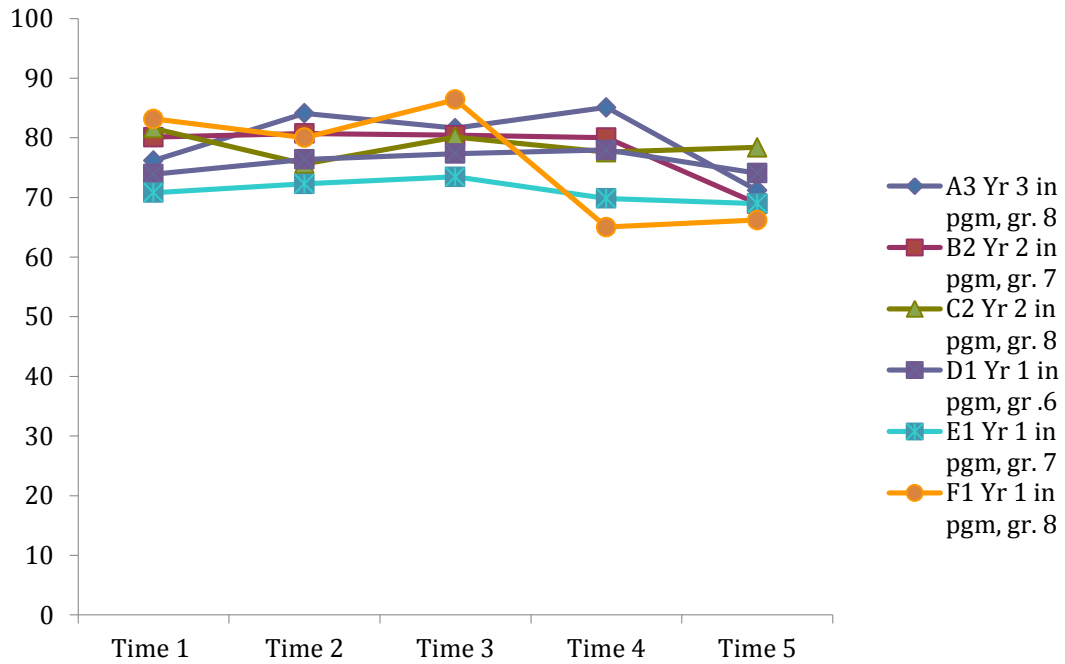
Table 2 below compares the combined average scores for all students at each time point. As a whole, the self-reported scores remained about the same across the year, with the exception of the final time point.

Table 2 Self-efficacy across the year



Cohort group means vary somewhat across time. The group with the most upward change was Cohort A, which is comprised of 8th grade students with 3 years of experience in the program. See Table 3 below for a comparison of the self-efficacy scores for each Cohort group.

Table 3 Self-efficacy Means Across Year



Low self-efficacy scores at the last time point are most likely related to the end-of-year competition, the Globey Awards competition. In the competition, most students are not recognized for their work while a few are singled out as outstanding. The last data collection was done immediately after the award ceremony and temporarily depressed the scores. It might be necessary to disregard that data in discussions of the program’s impact during the year.

English Language Learners Compared to Not English Language Learners

A significant proportion of EAPrep students speak English as a second language. Some of these students are classified as English Language Learners, or ELL, students by the district. When we compared students who were classified as English Language Learners (ELL) and students who speak English as a first language, we found significant differences during Time 2 (October), and to a lesser extent at Time 4. The areas with significant difference between the ELL and non-ELL groups at Time 2 (October) included:

- Self-confidence for helping other students
- Remember information presented in class
- Self-confidence for figuring out new things on the wiki
- Figure out what to do when you get stuck on something doing Flash programming in Globaloria class

At Time 2 and Time 4:

- Self- confidence for participating in class discussions

At 3 time points and overall. Change was significant in a negative direction.

- Self-expression through blogging

Note that, as mentioned previously, the negative responses may be attributed to the fact that students were not required by teachers to blog frequently.

See Table 4 for comparison of the average ratings for significant differences.

Table 4 Comparison of Significant differences in Self-efficacy for Not ELL vs ELL

	Time 2	Time 3	Time 4	Average chg from T1 to Final
Remember information presented in class?	Not ELL 80.2↑ ELL 72.4↓			
Figure out new things about editing the wiki	Not ELL 78.9↑ ELL 71.5↓			
Help other students who are stuck on something in Globaloria	Not ELL 80.4↑ ELL 71.9↓			
Participate in class discussions in Globaloria class? ↓	Not ELL 82.1↑ ELL 69.2		Not ELL 81.9↑ ELL 70.9↓	
Share your thoughts on a blog clearly?	Not ELL 81.1↑ ELL 72.2↓	Not ELL 82.9↑ ELL 73.6↓	Not ELL 80.0↑ ELL 70.8↓	12.4 -24.2↓
Figure out what to do when you get stuck on something doing Flash programming in Globaloria class?	Not ELL 76.6↑ ELL 68.3↓			

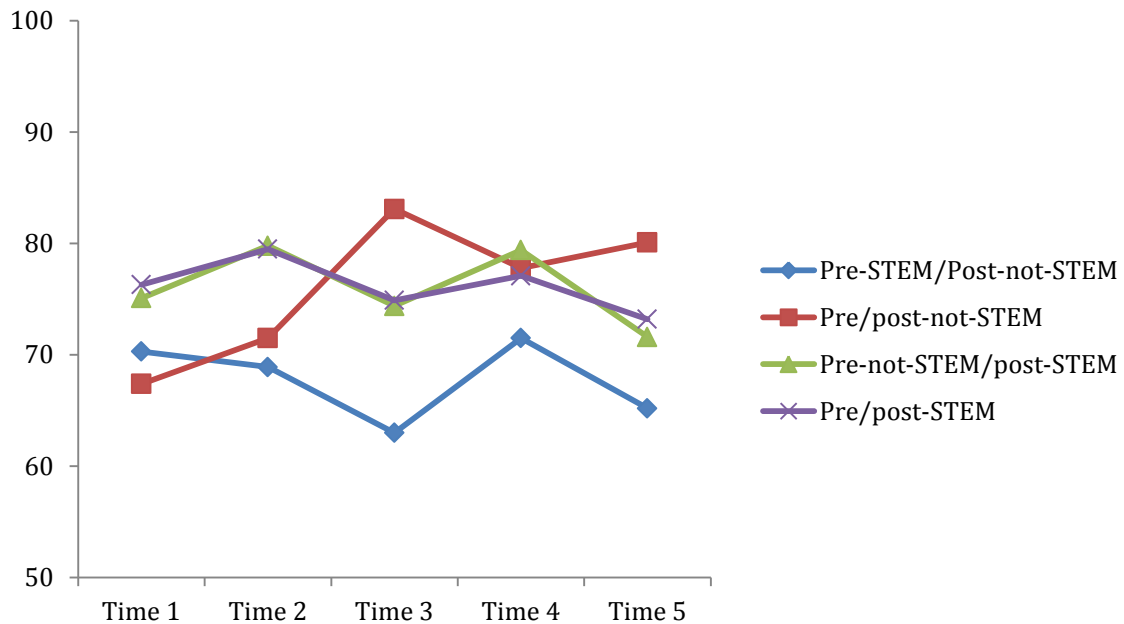
STEM Career Interest

We collected data about student career goals throughout the year. Students were asked via survey the following question: ‘What is the career that are you pursuing?’ The students’ responses were then coded as STEM goals or non-STEM goals. Please see a paper entitled *STEM Career Goals Among Globaloria Students at East Austin College Prep Academy* (2012), available online, for a very detailed discussion of student responses.

STEM Career Interest Comparisons

Among students who were in their first year of the program (D1, E1, F1) and started the year with a STEM career goal, the students who had a STEM career goal at the end of the year (shown in purple in Figure 1) had higher self-efficacy at the beginning of the year and continued to have higher self-efficacy across the year than those who started with a STEM-goal that changed to not-STEM (shown in blue in Figure 1). Those who changed to a STEM-goal (shown in green in Figure 1) had self-efficacy levels nearly identical to the pre/post STEM group.

Figure 1 Self-efficacy in First Year Students With and Without STEM Career Goals



We found a consistent pattern: those students who ended the year reporting no interest in a STEM career tended to report lower self-efficacy than those who ended the year reporting an interest in a STEM career goal. More research is in process to determine if higher self-efficacy in the STEM areas continues to align with a career interest in STEM.

Students with STEM interests at both pre and post tend to have higher confidence on average than those without STEM interests at pre and post. The first group reported that they can:

- Help other students who are stuck and
- Figure things out while working in Flash

STEM Career Interest and Gender

Researchers examined differences in student STEM interest or change in STEM interest across gender. There were a larger percentage of girls than boys that had STEM career goals at pre and post, or that maintained an interest in a STEM career across the year.

Conversely, there were more boys than girls who reported a STEM-career goal pre-program and then a non-STEM goal at year-end. Possible reasons for this difference could be that the collaborative, project-based nature of the Globaloria curriculum provides opportunities to experience success in STEM-related projects but also provides some frustration. Another possible partial explanation could be that the vicarious modeling of success in STEM available from teachers and experts who are available to the students at EAPrep may be providing more helpful in terms of support for girls than boys. In addition, it is very likely that social and cultural factors are also contributing to boys reporting fewer STEM career goals.

Table 5 STEM Interest Percentages Among Students

	Male (n = 131)		Female (n = 143)	
	N	Percentage	N	Percentage
Group 0 = STEM interest at pre, non- STEM at post	17	13.0%	8	5.6%
Group 1 = Non-STEM interests at pre and post	46	35.1%	46	32.2%
Group 3 = Non-STEM interests at pre, STEM interest at post	41	31.3%	44	30.8%
Group 4 = STEM interests at pre and post	27	20.6%	45	31.5%

Difference in STEM self-efficacy among students with and without STEM career interest
 Students who begin the year with an interest in STEM but who later lost interest in STEM careers (0) as a group have significantly lower confidence that they can *contribute to class discussions* and lower confidence that they can *figure out what to do when stuck*

on something in Flash than students who began the year with a non-STEM career goal and then later gained an interest in STEM careers (3).

There is a trend for bigger declines in self-efficacy among those with STEM interests at pre and post (4) than those who had no interest at pre or post (1). This could possibly be explained by a trend toward over confidence against the interested group (4) at time 1.

There appears to be a direct relationship between self-efficacy and maintaining a STEM career goal across the whole year, for students in their first year of the program. Meanwhile, the students without a STEM-related career goal at any time during the year (pre/post without STEM) showed the most increases in self-efficacy on average across the year.

The group of students who changed from a STEM goal to a non-STEM goal showed declines, on average, in self -efficacy from Time 1 to Time 3, and then a rebound. This was true for the group who reported STEM goals at both pre and post program. These groups showed a sharp decline, on average, at the last Time point. Since the results from the last time point seem to go against previously observed patterns, it is difficult to establish if there is a trend for self-efficacy decreases to precede a change in career goals.

Discussion

Results of students' self-efficacy ratings within a year re-emphasizes that self-efficacy is a fluid and changing rather than fixed construct. In addition, the instrument has been

refined in response to the issues mentioned above. The following findings merit discussion.

Data for student self-efficacy assessment collected from the cohorts for Times 1-4 during the 2011-12 school year, or August through March, showed moderate increases in response averages. All groups, on average, reported lower self-efficacy at the end of the year. The students in their first year of the program reported less change in self-efficacy on average than those who had more years of experience with Globaloria. As mentioned previously, there were many changes in the teaching faculty and class period during this year, and students in the first year of the program were most impacted by these changes.

The most significant positive change in self-efficacy occurred among students with the most experience in the program. It is possible that longer exposure to Globaloria is more effective in this learning context. Also, significant differences between cohorts were found in the groups with either two or three years of experience in the program. One possible explanation for this may be the importance of mastery or successful experiences in support of the development of self-efficacy. Students with more years in the program have had an opportunity to experience success within the game design and development process, and also have other vicarious modeling experiences, watching their peers and others experience success. The more experienced cohort groups reported significantly more confidence in their ability to figure things out about editing the wiki, helping other students who are stuck on something, and figuring out what to do for themselves when stuck while programming in Flash. At Time 4, the group with 3 years of experience reported self-efficacy that was significantly higher than the group of 7th graders in their first year of the program across all measures.

There are reliability issues with the data collected at the final time point. The final time point data was unexpectedly low for all groups except for C2 (8th graders with 2 years of experience in the program). There can be many reasons for this, but one hypothesis is that the end of year game competition, the Globey Awards, tends to require large amounts of the very limited resource of teacher time and attention to be focused on a small number of students. It is also interesting to note that the students in the group which did **not** show unexpectedly low ratings, the C2 cohort, included several winners of the Globeys competition. Those students who went unrecognized at the awards possibly felt that their work fell short and thus their self-confidence about their STEM abilities was undermined. The busy and distracted nature of the end of the year and survey fatigue effects might also contribute to an explanation of these findings.

When looking at data excluding those collected at the final Time Point, the groups generally show self-efficacy scores that grow slightly higher at each time point, on average, across the year. The exception is the group F1, eighth graders in their first year of the program. These students showed decreases in STEM self-efficacy ratings. Note that this group included a small number of students.

STEM career goals and STEM self-efficacy

Analysis of STEM career goals with self-efficacy results is limited by a large number of other potential influences and factors. This being said, the current discussion is meant as a starting point to begin to observe some of the patterns in STEM career goals as well as the relationship between self-efficacy and STEM career interest. These data suggest that a lower starting self-efficacy and/or a lack of growth in self-efficacy may contribute to a change from a STEM to non-STEM career goals.

In addition to numerical responses at two time points, students were given the opportunity to enter text to further explain their ratings. In these optional responses, we found both positive and negative remarks about students' self-perceptions. A preliminary analysis of the comments showed that boys tended to respond with less confidence while girls tended to emphasize the positive in these responses.

Career Goals and Self-efficacy

Analysis of data reveals what appears to be a direct relationship between self-efficacy and the maintenance of a STEM career goal across the year among students in their first year of the program. Note that further analysis that should be done with this data to explore relationships among other cohort groups. There is a trend for bigger declines in self-efficacy among those with STEM interests at pre and post than those who had no interest at pre or post. A trend toward over confidence against the STEM career interest group at Time 1 might explain this result.

Gender and Career Choice

The female students remained interested in STEM careers across the year at a higher rate than males. This patterns matches self-efficacy rates across the year. There are several factors that may contribute to this pattern. Since participation in Globaloria is required, it may be that girls become interested in a course that they would not have had confidence to try, and ultimately experience as enjoyable and rewarding. The unexpected success they experience may lead them to an interest in pursuing other STEM opportunities. Another possibility is that social or vicarious modeling of success in STEM available to the students, for example by the Globaloria teachers and experts, may be more helpful for girls than boys, as literature suggests. The resulting support for self-efficacy in STEM

may therefore influence girls to stay interested in the STEM field through middle school years to a larger degree than it influences boys. Yet another contributing reason could be that the collaborative project based nature of the Globaloria curriculum provides opportunities to experience success in STEM-related projects, but may also provides some frustration for those who have not yet developed collaboration or communication skills prior to the course. It is possible that boys have less developed communication and collaboration skills, and thus experience this frustration to a higher degree than girls. Lastly, it is very likely that social and cultural influences are factors that contribute to boys reporting fewer STEM career goals. More literature review and further study will focus on understanding the very complex relationship among these factors. As these students enter high school, it will become even more important to ensure that they are supported in their interest and self-efficacy.

Students who did not report a STEM-related career goal at any time during the year (pre/post) showed increases in self-efficacy across the year. This finding seems counterintuitive given literature that cites connection between interest and self-efficacy (Lent, Brown and Hackett, 1994). However, it could be that students with no expectations for their performance in the STEM area might be less likely to experience frustration and conversely remain confident in their abilities.

Conclusion

The students who participated in the Globaloria program at EAPrep reported high levels of interest in STEM careers. This is significant because these levels were much higher than what is expected for Latino/as in light of the Postsecondary Education Completion Survey and Bureau of Labor Statistics data cited here. Students with longer participation

in the Globaloria program reported higher self-efficacy ratings than those new to the program. Students who were English Language Learners reported significantly lower self-efficacy early in the program year, but these differences were not present at the end of the program year. The findings are preliminary and data collection and analysis will continue.

Suggestions for further research

Future research should more deeply examine the relationship between self-efficacy and career goals to further illuminate what is driving the change in the relationship between STEM self-efficacy and STEM career goals. Specifically, does a decrease in feelings of self-confidence lead students to change their career goal from a STEM goal to something in another field? This examination should look at the experiences of students of each cohort group, of English Language Learners, and of both gender groups. Further analysis of gender differences within grade-group cohorts should look for potentially significant differences in STEM self-efficacy, and career goals, as the differences in gender within cohorts was not explored here.

Future research should also analyze the responses given in open-ended text box responses to gain a better understanding of the reasons behind the responses of students in the open-ended survey questions, and to explore student experience through interviews as a supplement to data collection.

Limitations

The survey questions were written at the beginning of 2010-11. It should be noted that the changing nature of implementation of the curriculum meant that questions that were relevant during 2010-11 did not necessarily reflect the implementation during 2011-12. Since students were asked questions about activities that were not a daily part of their Globaloria experience, for example: blogging and class discussions, students responded negatively in those areas. This is documented by the responses some students gave after

their ratings, in open-ended text boxes on the survey, which included statements such as ‘we don’t blog in class’.

During this study, (2011-12) students entered responses on a scale of 1-100 to rate their self-efficacy on 11 questions. This approach proved to be cumbersome and can be seen as a limitation of this study. Changes to the instrument were also made in response to perceived challenges, and during the 2012-13 year, students give their responses on a scale with 10 points, from Not Confident At All to Completely Confident.

As mentioned in the Instructional Context section, changes in schedule and staffing along with large class sizes that resulted from the changes were limitations of the study in that they weakened the implementation of the program. In addition, over-surveying may also be considered a limitation.

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