Integrating computer programming into STEM: an EVT analysis

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Abstract. Drawing on Expectancy-Value model of achievement motivation, this study evaluates the impact of a pilot integrative STEM model that includes computer programming in 156 elementary education students' school science expectancies for success and values. The results revealed that following participation in the 12 sessions-interventions, students reported a significant increase in their values and expectancies for succeeding in Science Education, and a significant decrease in the cost factors associated with studying science.

1 Introduction

In recent years, the relative number of students choosing a career in science, technology, engineering and mathematics (STEM) has drastically decreased [1]. Spain is no stranger to this problem. In the 2014-15 academic years, enrolments in Engineering & Architecture and Science university degrees have dropped by 28.7% and 22.8% with respect to 2004-05, respectively. In addition, there have been registered 15% fewer science graduates than a decade ago [2]. Although many proposals have been made to reverse this situation, students' interest in STEM-related careers remains low and there is a gap in studies that investigate the barriers and factors influencing students' career choice, especially at the elementary level. Accordingly, the aim of this study is to evaluate the impact of a pilot integrated STEM program including computer programming on the School Science Expectancy and Task Values of elementary school students using the Expectancy-Value model of achievement motivation [3].

2 Integrating computational thinking into STEM education: a pilot model

The proposed model conceives STEM education as a complementary overlap across all four disciplines [4]. Briefly, at the start of the unit, students are confronted with a problem that is social and educationally relevant and that is based on school science content. Next, using a coupled-inquiry [5], students research the basic knowledge needed to understand the problem. For data collection, students code different data measurement sensors (i.e. thermometer) using a microcontroller board and visual programming language, thus introducing technology into the STEM model. Afterward, students use the engineering design process [6] to apply the knowledge advanced during the inquiry phase to the design and development of a technological solution that helps in the resolution of the initial problem. Finally, mathematics is essential for the data interpretation during the science phase and for the design aspects of the engineering phase. The unit designed for this pilot study is focused on the physical water quality parameters and on the physical separation techniques of mixtures. Students analyze the quality of water from different rivers, and design and build a water filter to improve its quality.

3 Method

156 participants (50.6% girls), drawn from seven elementary schools in Burgos by means of convenience sampling (from 3rd to 6th course, M_{age} = 9.87, SD_{age} = 1.2), participated in a week-long intensive curriculum enrichment program, attending the STEM project in a formal setting for twelve teaching sessions of approximately one hour each. A 25 items Likert-type EVT scale was administered at the beginning and end of the program. All 25 items were subjected to principal component analysis (PCA) with Promax rotation, revealing the presence of a three-

component solution explaining a total of 51.12% of the variance. There were six Expectancy items (i.e. I am able to do my Science schoolwork well), six Cost items (i.e. I have to sacrifice a lot of free time to be good at Science) and five Values items (i.e. For my planned career, knowledge of school Science will be useful) with strong factor loadings of at least .40 and Cronbach α values ranging from .709 to .770.

4 Results

A Wilcoxon Signed Rank Test revealed a statistically significant increase in Expectancy (z = -3.835, $p < .0001$, r = .22) and Value (z = -2.087, p = .03, r = .12) and a statistically significant decrease in Cost (z = -4.241, $p < .001$, r = .24) dimensions following participation in the STEM program. Thus, at the end of the STEM program, girls and boys reported higher in expectancies for success in Science Education, valued more positively school science, and reported less cost associated with studying science, as measured by the EVT scale. A Mann-Whitney U test revealed no statistically significant difference in EVT results of girls and boys in either pretest (U = 2839, z = -718, p = .473) or posttest (U = 2789.5, z = -893, p = .372). A Kruskall-Wallis test revealed no statistically significant difference in EVT results across 3rd to 6th graders in either pretest,χ^2 (3, n = 156) = 5.535, p = .137, or posttest χ^2 (3, n = 156) = 2.898, p = .408. Thus, the STEM program had similar positive effects on both girls and boys enrolled in 3rd, 4th, 5th and 6th elementary students' that participated in this study.

5 Discussion

Taken together, the results of this study seems to show that the proposed integrative STEM model has improved elementary school students expectancies for success in science, improved their subjective school science values, and reduce the cost related to studying science. Considering previous literature findings suggesting that values and expectancies for success plays an important role in motivational beliefs about enrolment into STEM fields of study [7], [8], these results are of high value for improving physics education in elementary school.

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References

[1] OECD, *Encouraging Student Interest in Science and Technology Studies*. Retrieved from http://www.oecd-ilibrary.org/science-and-technology/encouraging-student-interest-in-science-and-technology-studies_9789264040892-en, 2008.

[2] MECD, *Datos y cifras del Sistema Universitario españo. Curso 2015/2016*. Secretaría General Técnica, 2016.

[3] J. Eccles *et al.*, "Expectancies, values, and academic behaviors," in *Achievement and achievement motivation*, J. Spence, Ed. San Francisco, CA: W. H. Freeman, 1983, pp. 75–146.

[4] R. W. Bybee, *The Case for STEM education*. Arlington: NSTA press, 2013.

[5] L. Martin-Hansen, "Defining Inquiry," *Sci. Teach.*, vol. 69, pp. 34–37, 2002.

[6] R. W. Bybee, "Scientific and Engineering practices in K-12 Classrooms: Understanding a Framweork for K-12 Science Education," *Sci. Teach.*, vol. 78, pp. 34–40, 2011.

[7] J. Song, B. Zuo, F. Wen, and L. Yan, "Math-gender stereotypes and career intentions: an application of expectancy–value theory," *Br. J. Guid. Couns.*, vol. 45, no. 3, pp. 328–340, 2017.

[8] J. Guo, P. D. Parker, H. W. Marsh, and A. J. S. Morin, "Achievement, motivation, and educational choices: A longitudinal study of expectancy and value using a multiplicative perspective," *Dev. Psychol.*, vol. 51, no. 8, pp. 1163–1176, 2015.