Attitude Scale Results of Student Confidence Over Time: Participation in an Integrated Mathematics/Computer Programming Curriculum

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Analyzing the development of attitudes over time is a phenomenon rarely explored. Attitude single-time analyses seem limited in exploring how attitudes develop. In this study, we analyze the longitudinal development of a compound attitude towards mathematics and computer programming practices. Understanding these as social practices, we believe that students may 'grow' into these practices as they participate in them with others. Here we present results from computer programming and mathematics attitude scales of eight Latinx middle school students attending in the AOLME program. Contrastive analysis of the scale domains (i.e., confidence, usefulness, enjoyment, and motivation) yields meaningful shift of students' self-confidence over time.

Keywords: self-confidence, mathematics and computer programming, assigned and nurtured responsibility

El análisis del desarrollo de las actitudes a través del tiempo es un fenómeno raramente explorado. El análisis aislado de las actitudes es limitante al explorar el desarrollo de las actitudes. En este estudio analizamos el desarrollo longitudinal de una actitud compuesta relacionada a las prácticas de la programación de computadoras y las matemáticas. Al entender estas prácticas como prácticas sociales creemos los estudiantes pueden 'crecer' en estás prácticas al participar en éstas con otros. Presentamos resultados de unas escalas sobre actitudes hacia la programación de computadoras y las matemáticas de ocho estudiantes Latinx de escuela media quienes asistieron al proyecto AOLME. Un análisis contrastante de los dominios de la escala (i.e., confianza, utilidad, disfrute, y motivación) señalan cambios significativos longitudinales en la autoconfianza de los estudiantes.

Palabras clave: Autoconfianza, programación de computadoras y matemáticas, responsabilidad asignada y apoyada

Out-of-school time learning programs have provided alternative ways to expand formal education in traditional schools. This range of possibilities allow the generation of learning experiences that stimulate the development of new skills, information, and creativity (Alexander, 2000). Some programs, however, have been conceptualized as remedial approaches for students from underrepresented group to focus on basic skills and social issues (Lauer et al., 2006; Riggs, 2006).

In this paper, we describe over time development of attitudes towards mathematics and computer programming of a group of eight Latinx middle school students who attended the Advancing Out-of-School Learning in Mathematics and Engineering (AOLME) Project. AOLME, similar to "The Fifth Dimension" (Cole & the Distributed Literacy Consortium, 2006) and "La Clase Mágica" (Vásquez, 2003), promotes an informal atmosphere to promote learning of: a) computer programming and related mathematics and linguistic (Spanish and English) practices, and b) supporting social interactions around these practices with adults and experts in these fields. Previous results from such programs confirm that students "can learn when they are invested in the goals of a task [they willfully chose] and motivated to participate in challenging activities that include an educational agenda" (Cole et al., 2006, p. 106). It is not a specific tool or practice in isolation that promotes learning, but the whole ensemble of the local practices; without these characteristics, outcomes are improbable. AOLME emerges from a twofold goal. First, there is a need for middle school students to have greater access to experiences and information about interdisciplinary knowledge (Mooney & Laubach, 2002; Syed & Chemers, 2011) such as science, technology, engineering and mathematics (STEM) fields, so that they can become informed about these fields and consider them as a possibility for their future. In fact, engineering, as a subject, is rarely integrated with science and mathematics. Specifically, computer programming is predominantly absent in the compulsory school curriculum (Celedón-Pattichis et al., 2013). Secondly, Latinx and female students in STEM fields are underrepresented (Chapa & De La Rosa, 2006; Hossain & Robinson, 2012; Rogers, 2009; Syed & Chemers, 2011).

AOLME

AOLME takes place in rural and urban contexts in the U.S. Southwest serving middle school (6-8 grades) students predominantly Latinx who learn Levels 1 and 2 of the curriculum. Each level is covered in approximately 10-12 sessions. The computer programming/mathematics curriculum prepares students to design, program, and implement digital image and video. The curriculum includes pencil-and-paper, modelling, and computer-based tasks using Python programming language and the Raspberry Pi as a main computer platform. Topics covered introduce students to building a basic computer system, using coordinate systems to represent images and videos, moving across number systems (e.g., binary and hexadecimal) to represent, model, and program their images and videos. The final projects require students to develop their own designed images and video. The current goal of AOLME is to work in Levels 1 and 2 with three cohorts of students (approximately 20) at each school. One of the goals is that a group of self-selected middle school students from Cohort 1 and 2 serve as co-facilitators with undergraduate students to prepare the next cohort. Eight students who are the focus of this study belong to the first group of co-facilitators in AOLME. Five of these students attend the rural school. Three of them are female, two of them attend the rural school. Six students are bilingual (Spanish and English), including all female students. Generally, these students reported having had prior interest and good performance in mathematics, while limited knowledge on computer programming before their AOLME experience.

The Project

This study especially focuses on the development of student attitudes towards mathematics and computer programming because we understand that the transformation of attitudes is associated with the learning of new concepts or practices. Accordingly, we view identity development as "the dense interconnections between the intimate and public venues of social practice" (Holland et al., 2003, p. 270). We understand the link between mathematics and computer programming as a social practice into which students "grow" as they participate with others. Nosek, Banaji, and Greenwald (2002), focusing on gender identity/attitude and mathematics identity/attitudes, found that mathematics identity and mathematics attitudes are positively related. They conceptualized mathematics attitude as preference for mathematics, and mathematics identity as the identification of oneself with mathematics. Further, Sfard and Prusak (2005) describe "identity-making as a communicational practice" exposed in a natural real context, where students' identity development can be analyzed. Identity is an evolving construct that influences how students learn and make sense of mathematical concepts. Attitudes are conceptualized as "affective responses that involve positive or negative feelings of moderate intensity" (McLeod, 1992, p. 581). Attitudes are multi-dimensional constructs since they relate to a compound set of beliefs, feelings and behavioral intention towards an object (Fennema & Sherman, 1976; McLeod, 1992), in our case computer programming and related mathematical practices.

Numerous studies have concerned mathematics attitudes using attitude scales. The Fennema and Sherman Mathematics Attitudes Scales (FSMAS) (1976) has been one of the most salient and cited studies and often used as a basis for the development of related versions of scales. The complete FSMAS instrument is composed of nine scales, each with 12 items. The nine scales include: Attitude towards Success in Mathematics; Mathematics as a Male Domain; Mother, Father, and Teacher; Confidence in Learning Mathematics; Mathematics Anxiety; Motivation in

Mathematics; and Usefulness of Mathematics. This 108-item instrument takes 45 minutes to complete. The FSMAS have been modified for different age groups (e.g., Mulhern & Rae, 1998) and for use in different subject areas such as English, physical education, and also for mathematics attitudes. Multiple shortened versions of the scales have also been used in order to quicken the process. Other related scales are, first, the Measurement Properties of Attitude Scales in the National Assessment of Educational Progress (NAEP) Data on Mathematics. The NAEP provides information on the educational progress of students in mathematics and other disciplines. The NAEP assessment also collects information related to student attitudes toward various subjects, including mathematics. Second, Tapia & Marsh (2005) recently developed the Attitudes Toward Mathematics Inventory (ATMI) questionnaire that includes four attitude factors: self-confidence, value, enjoyment, and motivation in mathematics.

Domains and item selection

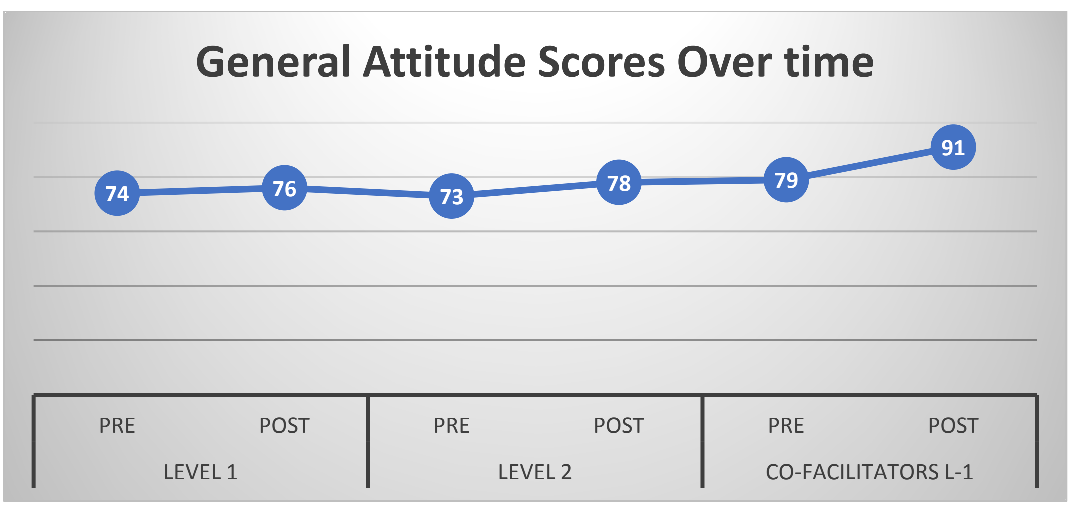
From the NAEP attitude inventory, and mathematics attitude scales from FSMAS (1976), Aiken's (1974) scale, ATMI developed by Tapia & Marsh (2005), we selected domains on the attitude scale that include self-confidence, usefulness, enjoyment, and motivation in mathematics and we adapted and linked it to computer programming as well. "Confidence" refers to students' self-concept on their performance in mathematics and computer programming. Some findings report that during the elementary grades males and females report about equal confidence in their mathematics ability (e.g., Linn & Hyde, 1989). "Usefulness**"** relates to students' beliefs on the value, usefulness, relevance, and worth of mathematics and computer programming in their life now and in the future. International studies have been particularly helpful in clarifying how the belief in the usefulness of mathematics influences achievement and continued study (e.g., Aiken, 1974). "Enjoyment" describes the engagement and pleasure of doing mathematics and computer programming. This category was designed to measure the degree to which students enjoy working with mathematics and in mathematics classes (Aiken, 1974; Tapia & Marsh, 2005). "Motivation" refers to student interest in and desire to pursue studies in mathematics and computer programming. Research suggests that students extrinsically motivated want to study mathematics with the prospect of an immediate and valued reward. Extrinsic and intrinsic motivations are not on a continuum; individuals generally have both as motivators. Extrinsic motivation may enhance performance and persistence when a student has knowledge or examples that future valued rewards are possible (Singh, Granville, & Dika, 2002; Tapia & Marsh, 2005).

The item development and selection derived from the consideration of the four previously mentioned domains and selected scales (i.e., FSMAS, ATMI, and Aiken's). The source of these domain-related items was thoroughly analyzed and items were selected based on their content relevance, level of reliability and discrimination coefficients. Out of a 60-item bank, twelve items were chosen; five of them were chosen and directly included, the rest were adapted. Another group of items was created based on patterns observed in the item bank, and by matching them to the respective domains which they intend to target. Finally, some statements were negatively worded. The total of 20 selected items have been rephrased over time especially in relation to student input and 1/5 of them have been linked to computer programming instead of mathematics. The 20 items have a Likert-scale from 1 to 5 items that gauge the level of agreement in the ranking attitudes related to the four described domains, 5 items linked to each domain. The scales were administered individually at student small groups before and after each Level of the AOLME curriculum. Generally, students took less than 15 minutes to complete the scale. Emphasis on answers as no right or wrong questions was made.

Results

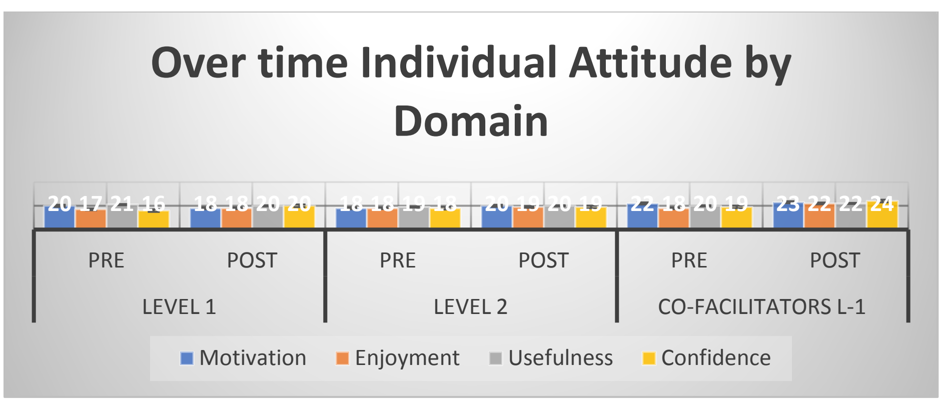
Based on the premise that student attitudes and identities are never fixed (Holland et al., 2003), we developed a contrastive analysis of the results from of the scale domains (i.e., confidence, usefulness, enjoyment, and motivation) completed by at each student at each level. Results yielded an overall meaningful increase of productive attitude towards mathematics and computer programming of the group of students. Figure 1 depicts a difference of almost 20 points between results from the average general scores of the scale administered the first (74/100) time during early Spring 2017 semester and the last time (91/100) during late Spring 2018 semester. Greater changes were observed when students participated as co-facilitators. Closer attention to specific results by domain provided a more insightful analysis of the significance of student participation as co-facilitators.

Figure 1 *Over time average general mathematics-computer programming attitude scores*



When analyzing results of average scores by level and domain, we realized a trade of attitudes over time. For example (see Fig. 2), initially the group of students generally identified mathematics and computer programming as useful (21/25) and motivated (20/25) to learn and work in these areas. Nevertheless, their reported levels of self-confidence (16/25) and enjoyment (17/25) on mathematics and computer programming were rather low in comparison with the prior domains. Post Level 1 and during later participation in the AOLME project, a shift gaining greater levels of self-confidence in mathematics and computer programming is observed over time. In fact, during the last reported attitude, self-confidence is the highest domain (24/25). We believe that the process of teaching other students what they had previously learned affected their level of self-confidence in mathematics and computer programming. During focus interviews, these students asserted that they needed to start thinking as "teachers" since they were trying to help the new students understand the ideas in a fun and productive way. Another relevant spike in the reported attitudes is the group's motivation to do and learn mathematics and computer programming. As portrayed in Figure 2, higher (22/25 and 23/25) levels of motivation were reported as this group of students took up the role of co-facilitators. The level of responsibility bestowed upon them worked as a catalyst of motivation and commitment to work which in turn boosted their confidence, enjoyment and understanding of usefulness of mathematics and computer programming.

Figure 2 *Over time individual average mathematics-computer programming attitude scores by domain*



Although some of the students are still wondering about their future careers, they all seem to agree that their school mathematics grades and participation have increased. They argue that their participation in AOLME helped them see applications of mathematics in a context that they value and view as challenging. Such combination supports their stronger sense of confidence in mathematics skills, their interest in mathematics, which in turn have renovated their perspective of learning and doing mathematics in the classroom. Further, they argue to be motivated to face challenging mathematics because they have figured out that if they work hard, they will make it. These efforts are deemed worthwhile as these are deemed as useful and enjoyable.

Conclusion

The process of gaining more responsibility was coupled with the process of being provided greater support within a challenging situation. Assigned responsibility within a challenging context, we think, might not have been enough. Such responsibility needed to be nurtured and co-developed with others. For this, the co-facilitators attended the professional development, which was a review of what they had learned and combined with related pedagogical approaches. Later on, they also co-taught the lessons to the students together with the college undergraduate students mostly with a computer engineering background. The scaffolded support in a challenging situation to gain greater levels of responsibility represents an important combination that we urge to notice as essential in the process of gaining greater levels of self-confidence and which we want to explore further. We understand that the development of self-confidence is a social process that evolves through the interaction of meaningful support and challenges between individuals and an environment that believes in students and supports them through these challenges while striving for their independence. Links between these levels of confidence reported by students in AOLME and how they report transferring such attitudes and perspectives of usefulness of mathematics into their school mathematics classroom are worth exploring further.

Acknowledgement: We thank the students and facilitators who have participated in AOLME. They are the reason and synergy of this project. We also acknowledge the support by the National Science Foundation under NSF ITEST Award #: 1613637, Broadening Participation of Latina/o Students in Engineering Using an Integrated Mathematics, Engineering and Computing Curriculum in Authentic, Out-of-School Environments. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the NSF.

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