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Assessing the effectiveness of Constructivism and Transformational Leadership on STEM/TEKS through a Construction Summer Experience

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Construction summer experiences in the form of summer camps targeting high school students are becoming more common. These construction summer experiences are critical as they provide high school students the opportunity to learn about construction, career pathways in construction and perhaps motivate them to enroll in one of the nation's university construction programs. Unfortunately, a theoretical framework to develop and implement construction summer experiences did not exist until recently. This study presents the research results of a pilot implementation of a Summer Experience based on Transformational Leadership and Constructivism theories (SumEx-TLC). More specifically, this paper provides the results in Science, Technology, Engineering and Math (STEM), and Texas Essential Knowledge and Skills (TEKS) of a construction transportation infrastructure via summer experience. This one-week hands-on summer experience engaged a small group of minority and economically disadvantaged high school students. During the pilot implementation, data was collected following an exploratory case study with a quasi-experimental design methodology. The pilot study results are encouraging and support the notion of continuing research using similar frameworks with a large-scale implementation.

Key Words: Constructivism, Transformational Leadership, Summer Experience, Construction, Transportation, Infrastructure

Preamble

At least for the last three decades, researchers have documented that in the United States (US), living segregation by race and income is detrimental to the development, well-being, and opportunities of children and their families in the disadvantaged groups (Carr et al., 2008; Duncan et al., 1997; Ellen, 2001; Newman, 2008; Sampson, 2012; Sampson et al., 2002; Sharkey, 2013; Wilson, 2012). Children with economic disadvantage (Poor children) are less likely than their counterparts (never-poor children) to graduate from high school/college and be consistently employed (Ratcliffe, 2015). Thus, the importance of engaging minority and economically disadvantaged high school students in a summer experience provides a pathway to the construction industry. Unfortunately, students, specifically underrepresented minorities in the inner-city High Schools, seldom have the opportunity to learn about existing career opportunities in the construction of transportation infrastructure.

Literature Background

Extensive literature exists on this research project's four main components: Construction of Transportation Infrastructure, Summer Experience, Constructivism Learning Theory, and Transformational Leadership (Figure 1). However, a significant gap exists in the intersection of the four topical areas and, therefore, the need for this research project particularly (in addition to the importance of engaging minority and economically disadvantaged populations). This section intends to summarize the current knowledge of those four components that served as the foundation for the framework to develop Summer Experiences based on Transformational Leadership and Constructivism theories (SumEx-TLC).

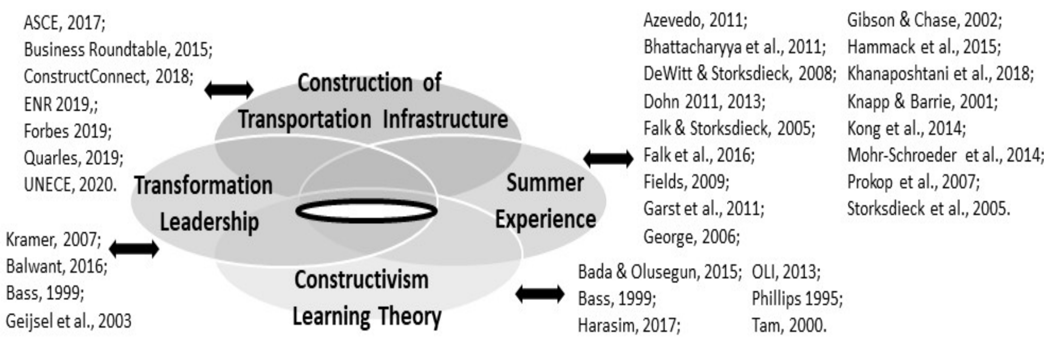

Figure 1. Significant Elements of this Research Project and Sample Literature

Construction of Transportation Infrastructure

Transport infrastructure supports the transport system, including roads/bridges, railways, inland waterways, maritime ports, and airports. The construction of transportation infrastructure is vital because it is the country's backbone and crucial to prosperity and the public's health and welfare (ASCE, 2017).

Summer Experiences

Summer experiences are implemented in multiple settings such as summer camps, professional shadowing during summer, summer field trips, and summer museum visits, among others. Several researchers have argued that this type of setting promotes experiential learning (Azevedo, 2011; Knapp & Barrie, 2001; Prokop et al., 2007). In a pedagogical sense, such learning experiences contribute to active learning and interest development in Science, Technology, Engineering, and Mathematics (STEM), while also increasing their understanding of the topic (DeWitt & Storksdieck, 2008; Garst et al., 2011).

It is also documented that individual career choices are based on interests, perceptions, attitudes, and values (Hammack et al., 2015), and K-12 is where they are established (Bhattacharyya et al., 2011; George, 2006). Historically, summer experiences (or summer camps/summer academy boot camps) have been conducted to assess student perception change in fields relating to STEM (Hammack et al., 2015; Bhattacharyya et al., 2011; Mohr-Schroeder et al., 2014), career interest in the science and engineering fields (Kong et al., 2014), and others. Summer experiences in Construction Management have also shown a positive impact (Table 1).

Table 1. Construction Summer Experiences

Summer Experience	Institution	Key finding	Reference
Women in CM Summer Institute	Colorado State Univ.	Increased participants perceived knowledge of construction management	Mehany (2019)
Building Construction Summer Camp	Auburn University	Increased the participant's recognition of the professionals that manage construction projects	Redden (2018)
City of Minecraft	Kansas State University	The top 10% of the participant's responses indicated that they learned about civil eng. and construction	Loughmiller (2018)
Visualization, Informatimatics, Technology Automation, and Learning	Florida International University	Participants were made aware that technology could be applied to construction to solve problems in interesting ways.	Carrasquillo (2017)
Construction Management Academies	Texas A&M University	Made a positive impact on participant's career choice	Escamilla (2017)
Construction Summer Camp	California State University	Hands-on learning was an effective tool in promoting STEM and construction management to the participants.	Gaedicke (2016)

Constructivism learning theory

Constructivism learning theory postulates that the experiences and reflection of those experiences by the people impact their understanding and knowledge of the world (Harasim, 2017) (Figure 2).

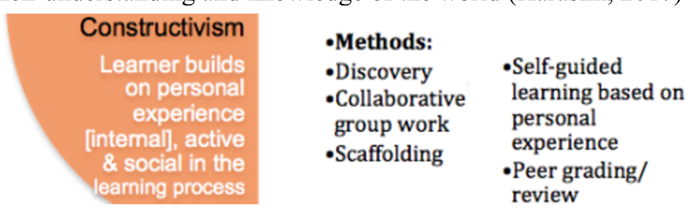

Figure 2. Learning Perspective and Instructional Methods for Constructivism Theory (OLI, 2013)

The constructivism theory was selected as the hands-on activities allowed the participating high school students to discover and collaborate in a self-guided learning environment (Figure 2). The constructivist learning theory was applied in this research because of its applicability to education (especially K-12), the ability of the pedagogy to recalibrate the student's existing perceptions values, and understanding of how things operate and promote an active learning environment (Phillips 1995; Tam, 2000) that stimulates the students (Bada & Olusegun, 2015).

Transformational Leadership

Transformational leadership involves "inspiring followers to commit to a shared vision and goals for an organization or unit, challenging them to be innovative problem solvers and developing followers' leadership capacity via coaching, mentoring, and provision of both challenge and support" (Kramer, 2007). Transformational leadership has broad potential applicability to higher education, and the leadership style is positively associated with students' motivation, satisfaction, perceptions of instructor credibility, academic performance, affective learning, and cognitive learning (Balwant, 2016). The transformational leadership components that were implemented in this summer experience are idealized influence, inspirational motivation, intellectual stimulation, and individual consideration (Bass, 1999). It was expected that this would bring positive change, engage students, and overlap with active learning resulting in the constructivist learning theory.

Summer Experience Brief Description

The hands-on pilot Construction of Transportation Infrastructure - Summer Experience focused on the construction of infrastructure for the three types of transportation (Land, Air, and Water), had its content directly linked with the Texas Essential Knowledge and Skills (TEKS) in Science, Technology, Engineering and Math (STEM) as well as marketable "Soft" Skills, and in the process, made it unique for Texans. Furthermore, the Construction of Transportation Infrastructure - Summer Experience was grounded on the newly developed Transformational Leadership and Constructivism theories (SumEx-TLC) framework. The hands-on pilot summer experience involved all-day one-week interaction (Monday – Friday) among the researchers and economically disadvantaged and minority high school students. The students had four sessions each day from Monday through Thursday and five sessions on Friday of one hour and 30 minutes. Each session focused on one STEM-TEKS or Marketable "Soft" skill that was contextualized in the construction of the different transportation infrastructure types. Detailed information about the summer experience can be found in the paper published at the ASC 2021 conference titled "Framework for a Summer Experience based on Transformational Leadership and Constructivism " (Langar, S., & Sulbaran, T., 2021).

Research Methodology

The research methodology used in this project was an exploratory mixed research as it allowed the researchers to create knowledge and understanding as well as set a standard for acceptable teaching practices for summer experiences by gaining an understanding through exposure to the particular phenomenon of implementing the summer experience. The theoretical framework is presented in the paper titled "Framework for a Summer Experience based on Transformational Leadership and Constructivism (SumEx-TLC)" in the ASC 2021 Proceedings. The pilot deployment, data collection, data analysis, and lessons learned and presented in this paper (Figure 3).

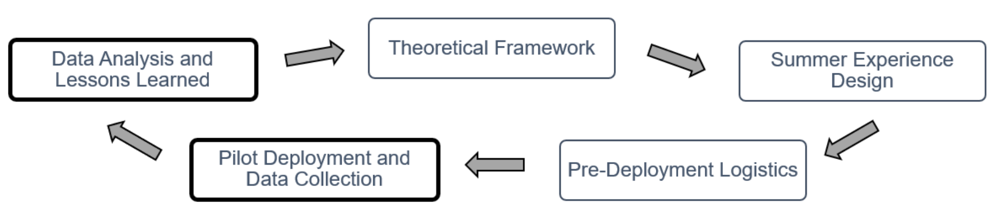

Figure 3. Summer Experience Cycle

Collection and Assessment

The data collection and assessment of SumEx-TLC presented in this study measured the impact on economically disadvantaged high school students' knowledge and perceptions of STEM/TEKS. Assessments and data collection were conducted at the beginning of the summer experience (Pre-assessment), daily in the afternoon (formative), and post-assessment (summative) at the end of the summer experience. All assessments were designed to maintain the student respondents' confidentiality, were conducted online using Qualtrics, and were approved by the Institutional Review Board (IRB) at the University of Texas at San Antonio. Most of the questions were multiple-choice, and responses to the questions were in the form of a five-point Likert scale that assesses the KPI. All data was collected and stored on Qualtrics. After the surveys were deactivated, all responses were downloaded from the Qualtrics to a secured University Computer for Data Analysis to evaluate the KPI's. Data collected during the pilot implementation from the nine participating students were subjected to descriptive and inferential statistical analysis using SPSS and Jupiter Notebooks. For the descriptive statistics, distribution tables and graphs were created and discussed in the subsequent section. For the inferential statistics, an independent sample t-test was performed

Results

The results from the data collected related to STEM and TEKS are presented below in the following topical areas:

- Science: Use of physics law (TEKS 112.39) to design infrastructure such as bridges
- Technology: Develop 3D Models (TEK 126.43) to communicate transportation infrastructure concepts
- Math: Apply geometry concepts (TEKS 111.41) to quantify materials needed to construct transportation infrastructure

Science - Physics - Newton's Laws - TEKS 112.39

The students' responses regarding knowledge of Newton's Laws (physics) after the summer experience were higher than the responses before the summer experience (Figure 4). The Newton's Laws mean value before the summer experience was 3.67 (between "Average" and "Somewhat Above Average"), and the mean value after the summer experience was 4.38 (between "Somewhat Above Average" and "Far Above Average), (Table 2). This improvement is encouraging and indicates a positive perception change among participating students post-summer camp.

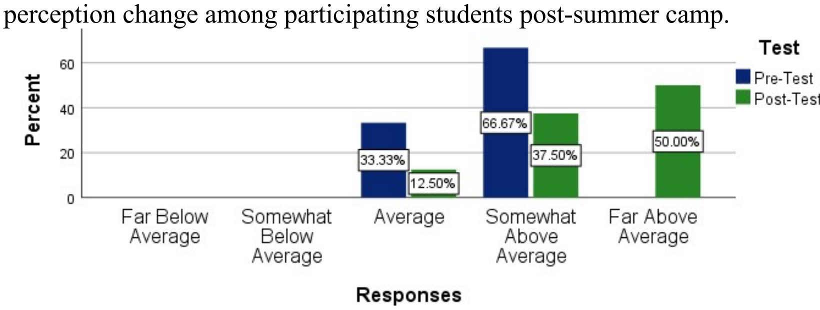

Figure 4. Physics Law/ Forces (STEM TEKS 112.39) - Pre and Post-Test

Table 2. Mean responses for Physics Law/ Forces (STEM TEKS 112.39)

Test	N	Mean	Std. Deviation	Std. Error Mean
Pre-Test	9	3.67	.500	.167
Post-Test	8	4.38	.744	.263

Additionally, 62.5% of the participants indicated that the summer experience impact on their knowledge of Newton's Law was "A great deal" (Figure 5).

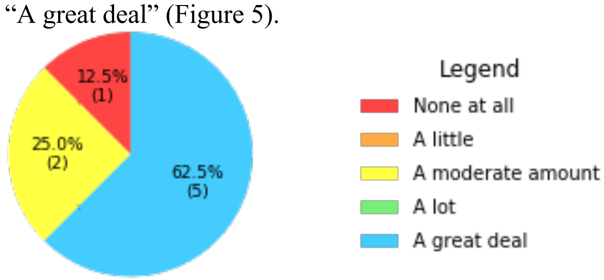

Figure 5. Impact of the Summer Experience on Physics Law (Forces) Knowledge (STEM TEKS 112.39)

Technology - 3D Modeling - TEKS 112.46

The students' responses regarding knowledge in developing 3-D Models after the summer experience were higher than those before the summer (Figure 6). 3-D modeling mean value before the summer experience was 3.44 (between "Average" and "Somewhat Above Average"), and the mean value after the summer experience was 4.63 (between "Somewhat Above Average" and "Far Above Average) – Table 3. This improvement is very encouraging, especially compared to the science component, among the participating students post-summer camp.

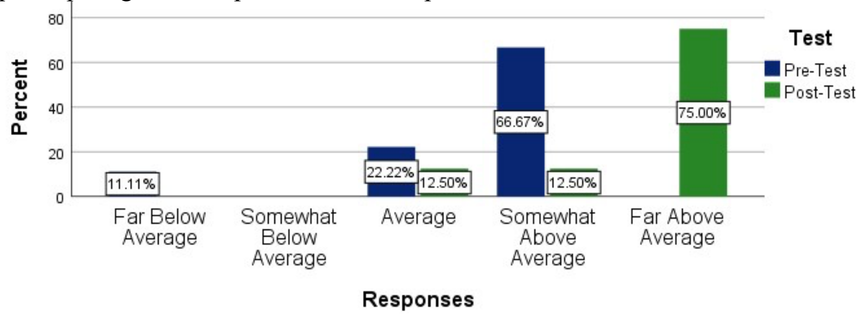

Figure 6. 3D Modeling (STEM TEKS 112.46) - Pre and Post-Test

Table 3. Mean responses for 3D Modeling (STEM TEKS 112.46)

Test	N	Mean	Std. Deviation	Std. Error Mean
Pre-Test	9	3.44	1.014	.338
Post-Test	8	4.63	.744	.263

Additionally, 75% of the participants indicated that the summer experience impacts their knowledge of 3-D modeling as "A lot" or "A great deal" (Figure 7).

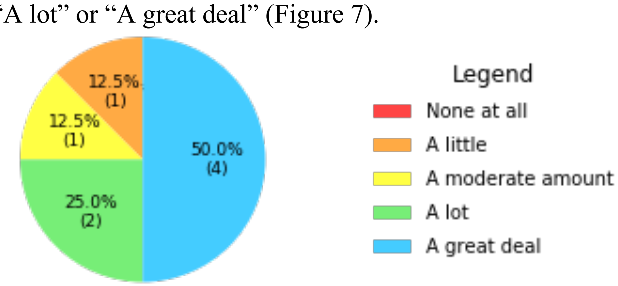

Figure 7. Impact of the Summer Experience on 3D Modeling Knowledge (STEM TEKS 112.46)

Math - Geometry - TEKS 111.41

The students' responses regarding knowledge of geometry after the summer experience were higher than those before the summer experience (Figure 8). The geometry knowledge mean value before the summer experience was 3.00 (around "Average"), and the mean value after the summer experience was 4.38 (between "Somewhat Above Average" and "Far Above Average") - Table 4. This improvement is encouraging, but it should be noted that the perception change was similar to that for the science component but lesser than the technology component among the participating students post-summer camp.

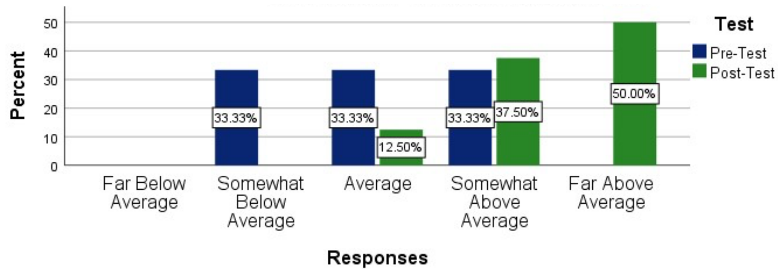

Figure 8. Geometry (STEM TEKS 111.41) - Pre and Post-Test

Table 4. Mean responses for Geometry Knowledge (STEM TEKS 111.41)

Test	N	Mean	Std. Deviation	Std. Error Mean
Pre-Test	9	3.00	.866	.289
Post-Test	8	4.38	.744	.263

Additionally, 75% of the participants indicated that the summer experience impacted their knowledge of geometry as "A lot" or "A great deal" (Figure 9).

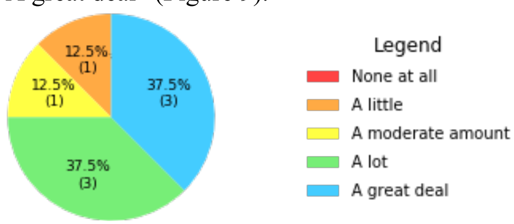

Figure 9. Impact of the Summer Experience on STEM TEKS 111.41 - Geometry Knowledge

Summary, Limitations, and Future Work

This one-week hands-on pilot summer experience implementation on a construction transportation infrastructure was very informative and encouraging. The mean score in all of the STEM topical areas increased (scale of 1 to 5): science from 3.67 to 4.38, technology from 3.44 to 4.63, and math from 3.00 to 4.38. The students also indicated that the summer experience's impact was "A lot" or "A great deal" on all STEM topics: 62.5% on science, 75% on technology, and math. Although the study was pilot in nature and had a limited number of participants, these positive results are significant as they support further research on this topic. Therefore, it is anticipated another summer experience cycle will be executed as indicated in Figure 3.

Lessons learned are that (1) grounding summer experiences in a theoretical framework is possible, (2) further deployments of the summer experience are needed to extrapolate results, (3) minority and economically disadvantaged high school students fully engaged in the experience, (4) explicitly linking construction with STEM is beneficial, and (5) exploring another construction context will enrich research process.

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