INFLUENCE OF STEM ENRICHMENT ACTIVITIES ON 3RD -5TH GRADE STUDENTS' ENGINEERING IDENTITY

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Abstract

As 21st century skills like problem-solving, creativity, and innovation become central to the world of work, it is essential that students are in environments where they can develop those skills. Integrative STEM education models provide an environment to foster these types of experiences. The earlier we can immerse students in this environment, the more prepared they will be for the world. Outreach targeted at elementary after-school programs is a natural fit. This paper presents a pre-test, post-test quasi-experimental design study to examine the influence of an integrative STEM enrichment program on 3rd through 5th grade students' identity in engineering. The Engineering Identity Development Scale (EIDS) was used to assess students' engineering identity formation in the areas of academic identity and engineering career awareness. Findings showed engineering career subscale scores were significantly higher among students who participated in the after-school STEM enrichment program than those that did not.

Keywords

Integrative STEM, STEM education, engineering education, engineering identity, SCCT

Background

Technological innovation has driven economic growth in the United States for over 50 years. The need for workers with STEM (Science, Technology, Engineering, and Math)-related skills to lay the foundation for such technological innovation is heightened in today's global economy[27]. The number of STEM-related jobs in the U.S. is expected to grow 18% by 2018 compared to 9.8% for non-STEM jobs[15]. The field of engineering and technology education has attempted to address this need for skilled workers throughout its existence and has evolved over time to meet new and emerging workforce demands.

Fear that the U.S. is losing its competitive advantage in the STEM arena, despite attention and funding being allocated in the area, is prompting an increase focus on STEM education[27]. Political discussions and funding efforts have been applied to all levels of education across every state. As a result, we have seen a rise of STEM experts vying for federal dollars and national attention[21]. While much attention has been placed on STEM recently, it is not a new phenomenon. Focus on increasing the number of U.S. students entering STEM fields have been in place for over 40 years, with particular focus on women and minorities. These efforts, however, have not seemed to change the landscape of the U.S. STEM workforce as the deficit of U.S. workers is still prevalent and the problems of inequity and underrepresentation are still widespread[19].

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As the demand continues to rise in STEM fields, the education community continues to look for ways to encourage students to build STEM-related skills. Engineering and technology education is uniquely positioned to provide the framework for integrated STEM education as it focuses on project-based, real-world design problems that require students to pool knowledge from several subject areas[24]. The need for additional integrated STEM-related research, especially as it relates to elementary-aged students, is a driving force for this study.

Purpose

The purpose of this pre-test, post-test quasi-experimental study was to examine the influence of an integrative STEM (Science, Technology, Engineering, and Math) enrichment program on 3rd through 5th grade students' identity in engineering. Integrative STEM education refers to technological/engineering design-based learning approaches that intentionally integrate the concepts and practices of science and/or mathematics education with those of technology and engineering education[24]. An Engineering Adventures unit, developed by the Boston Museum of Science[13], was used as a model for integrative STEM education. The unit was delivered during an after-school program at two elementary schools in Georgia for 45 minutes each day over the course of nine days. The Engineering Identity Development Scale (EIDS) developed by Capobianco et al.[5] was used to assess students' engineering identity formation in the areas of academic identity and engineering career awareness.

Research Questions

1. What is the engineering identity of elementary students?
2. Are there statistically significant differences between 3rd - 5th grade students who participate in an after-school STEM enrichment program and those that are involved in non-STEM after-school programs on the engineering identity subscales of academic identity and engineering career awareness?
3. Are there statistically significant differences between 3rd - 5th grade students who participate in an after-school STEM enrichment program and those that are involved in non-STEM after-school programs on the engineering identity subscales of academic identity and engineering career awareness when the original control group receives treatment?

Theoretical Framework

This study was grounded in social cognitive career theory[16] and builds on prior work in the areas of children's occupational identity development and children's identity development in engineering.

Social Cognitive Career Theory[16] is described as one of the most influential theoretical perspectives in career development and provides a rich explanatory construct for researchers. SCCT was developed to merge common aspects of related developmental theories into an inclusive system that could clarify the process of individual career development. Among the theories that formed SCCT are: social learning[20], personality typology[14], life-span, life-space[26], and general social cognitive theory[4]. SCCT[16] put these theories into the context of careers by focusing on career choice being influenced by beliefs one develops through four major sources:

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(a) personal performance and accomplishments, (b) vicarious learning, (c) social persuasion, and (d) physiological states and reactions.

A student's ability to form coherent and realistic occupational identities is essential for successful transition into adulthood[18]. Occupational identity development is often cited as occurring during adolescence and early adulthood, but research shows roots of that development beginning in pre-adolescence. During this stage of life, the influence of children's interactions with their environment and the people within those environments help shape who they are[2]. Parents, teachers, and other adults they encounter are included among those that assist in shaping this identity[18,22]. Occupational identity development of this age group has also been shown to be strongly influenced by interactions at school in areas such as guidance counseling, self-perceived ability, peer influence, and school subjects[,22]. These factors should be arranged to positively influence student development, but can be experienced in ways that restrict occupational choices and erect barriers to the development of occupational identity.

The foundation for engineering identity development was built on Gee's[12] work outlining identity as a lens for research in education. Gee[12], defined identity as what is means to be a certain kind of person. He suggested four dimensions of viewing identity and referred to them as interrelated in complex and important ways. Those dimensions explore identity depending on our nature (nature-identity), the positions we occupy in society (institution-identity), the interactions recognized by others (discourse-identity), or by the experiences we have had with certain groups (affinity-identity). Nature-identity (N-Identity) involves forces outside of the control of individuals or society. Being a red-head or an identical twin are examples of this dimension. Institution-identity (I-Identity) considers the process through which identity is authorized by an outside organization. An individual's profession can be considered an I-Identity in that the employer or governing body of that profession determines what it means to be that type of person. Discourse-identity (D-identity) is defined by how others treat, talk about, and interact with an individual. Affinity-identity (A-identity) takes into account an individual's association with a certain affinity group. Those groups have allegiance to, access to, and participate in a specific area of interest. The 4-dimension model presented by Gee[12] allows researchers to develop the idea that identity can be developed and shaped based on the interaction among and between individuals within the varying identity groups.

Theoretical Links to the Present Study

The theories presented support the idea that identity among pre-adolescent learners can be developed through interaction with and exposure to different areas of study through unique experiences and involvement within certain groups. Social Cognitive Career Theory[16] provides evidence that exposure to and comfort-level with STEM-concepts will strongly influence self-efficacy and willingness to continue pursuing a STEM-focused area of study.

Occupational identity development, specifically within the area of engineering is an area that can be impacted using the knowledge provided by SCCT[16]. Elementary students' engineering identity has been linked to their academic identity and engineering career awareness[5]. Studies have shown the development of engineering identity can be influenced by introducing integrated STEM instruction during the regular school day by targeting how elementary children see

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themselves as students, problem solvers, and potential engineers[5,6,30]. This study further examined the role after-school STEM enrichment programs can have on the engineering identity development of elementary students.

Importance of Study

The emergence of a new economy; characterized by customized manufacturing, competitive global business markets, substantial information handling, outsourcing, and fierce competition; is continually changing the landscape of the U.S. workforce and has sparked ongoing discussion on the role of education in preparing students for the 21st century workplace[23]. The need for STEM-prepared youth to fill future roles in the STEM arena as well as the struggles current U.S. educational practices are having in meeting that need is well documented[3,15,21,29].

The role educational systems play in career development and the enhancement of 21st century skills is not limited to preparation students receive in high school. In fact, findings in an ACT[1] report suggest academic achievement attained by the 8th grade has a larger impact on college and career readiness than anything that happens academically in high school. Magnuson & Starr[17] argue, “it is never too early” (p.101) to expose children to careers and that the early years are critical for career development where supportive adults should provide interaction-rich experiences; intentionally incorporating concepts of career awareness, exploration, and planning into children’s experiences as they are making decisions about themselves and the world. Despite evidence showing the need for earlier exposure to STEM, limited opportunities are available for elementary students and teachers to engage in the field of study. Few studies have looked at impacts of elementary STEM education on student achievement or attitudes towards STEM-related careers[8]. Additionally, literature can be found on STEM outreach programs[11], but little data on the effectiveness of such programs is available.

Research Design

A pre-test, post-test quasi-experimental design[7] was used to determine the possible influence of an integrative after-school STEM program on 3rd - 5th grade students’ identity development in engineering. Students enrolled in after-school programs at two different elementary schools were utilized. During the first phase of implementation, one school group served as the control group and participated in the school’s regularly scheduled, non-STEM activities, while the other group participated in a nine-day (45 minutes per day) integrative STEM program. Pre-tests and post-tests were administered to each group of students using the Engineering Identity Development Scale (EIDS) developed by Capobianco et al.[5] to assess students’ engineering identity formation. The EIDS score is made up of two subscales; academic identity and engineering career awareness. Once the first phase was complete, the control group of students participated in the integrative STEM program in a second phase to provide a replication of the treatment and to ensure all students in the study were provided equal access to the integrative STEM program. During the second phase, the original experimental group participated in the school’s regularly scheduled activities, and were given the post-test a second time to check for sustainability of treatment over time, when not engaged in engineering-related activities.

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Key Findings

RQ1: Research question one examined the engineering identity of 3rd through 5th grade students. The Engineering Identity Development Scale[5] provided two subscales to determine engineering identity, academic identity and engineering career awareness. The academic identity mean score for all participants during the initial administration of the EIDS was 16.44 (SD=1.61) and the overall engineering career awareness mean score was 24.46 (SD=2.23). In the academic identity subscale, the lowest possible score was 6, while the highest possible score was 18. In the engineering career awareness subscale, scores ranged from 10 to 30. Given those ranges, the academic identity mean score of 16.44 placed in the top 91% of possible responses, while the engineering career awareness subscale falls at approximately the 82% range. It is not surprising that students answered more affirmatively in the area of academic identity, as that has been the case in previous studies[5,6,30].

RQ2: Research question two examined EIDS results after implementing the after-school STEM enrichment unit of instruction to determine if significant differences existed between treatment and control groups. The analysis of variance (ANOVA) showed no statistically significant differences on academic identity subscale scores, F (1, 55)=0.75, p=.389. There was a statistically significant effect, however, on the engineering career awareness subscale, F (1, 55)=20.14, p=.000. Further, Cohen's d effect size value (d=1.19) indicated a high level of practical significance in the area of engineering career awareness. Cohen's d=1.19 indicated mean scores of the treatment group were 1.19 standard deviations higher than those in the control group. That value means there was about an 80% chance that a person picked at random from the treatment group would score higher than one picked at random from the control group.

Findings associated with research question 2 are similar to those reported in other studies using the two-subscale EIDS model. Capobianco et al.[6] and Yoon et al.[30] found no significant group differences on the academic identity subscale, but showed the treatment group scoring significantly higher than the control group in the engineering career awareness area. Although Capobianco et al.[6] and Yoon et al.[30] reported no significant differences in the academic identity subscale, they did not offer explanation as to why this occurred. In my analysis, I would pose that the lack of significance may be due to the fact that students were more familiar with and confident in the areas addressed within the academic identity subscale (doing school work, solving math problems, using computers, working with others, liking school, and making friends).

RQ 3: Research question three aimed to determine if the after-school STEM enrichment unit would produce positive results with the original control group as was found with the original treatment group. I was also interested in determining if the treatment had a lasting effect during periods of time when students were not exposed to STEM-related material. After switching treatment and control groups and conducting the *Engineering Adventures* unit with the original control group, no statistically significant differences were found in either the academic identity, F (1, 55)=.907, p=.345, or engineering career awareness, F (1, 55)=3.43, p=.069 subscales. This finding provided evidence that the treatment had a measurable effect on both groups of students,

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i.e., results from the first group remained over the two-week period of time when they were not engaged in STEM instruction. This finding is encouraging as it provides evidence that even a relatively short (two-week) unit of instruction can influence students' engineering identity development that will not fade immediately after exposure is withdrawn.

Implication for Future Study

This research extended the study of engineering identity development, examined STEM in after-school enrichment programs, provided more data using the EIDS, and provided a glimpse into possible impacts STEM education can have at the elementary school level. Further formal research is suggested in the areas of engineering identity development, after-school STEM programs, and elementary STEM education delivered during the regular school day.

Conclusion

The study adds quantifiable data to support integrative STEM education efforts implemented in after-school elementary programs. Further, we propose that after-school STEM programs may lead to further expansion throughout the regular school day.

Students' engineering identity was positively influenced by participation in the STEM activities in the study and proved to have lasting effects over the time allocated for this research. Both teacher and student participants had positive experiences and the schools involved in the study indicated interest in incorporating STEM education in their after-school programs in the future. Significant differences were present among students who participated in after-school STEM programming in the area of engineering career identity, but that difference dissipated after all students in the study received treatment. This finding indicates that after-school STEM programs can have an effect on the engineering identity of students and shows promise for those trying to impact the level of STEM interest and involvement of elementary students.

As 21st century skills like problem-solving, creativity, and innovation become more and more central to the world of work, it is essential that students are placed in environments where they can practice and develop those skills. Integrated STEM education models provide an ideal environment to foster these types of experiences and will ultimately lead to a workforce that can tackle problems that do not yet exist. The earlier we can immerse students in such an environment, the more prepared they will be for the world in which they will find themselves in after their schooling is complete.

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