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A formative evaluation of a Southeast High School Integrative science, technology, engineering, and mathematics (STEM) academy

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ABSTRACT

A study was conducted to investigate to what extent an integrative science, technology, engineering, and mathematics (STEM) education program had an impact to high school students in a South East region of the United States of America (US). The program was a brainchild of three teachers in physics, mathematics, and engineering and technology who teamed up to offer an integrative STEM program within their high schools' STEM Academy. The teachers structured their curriculum content in themes of same topics studied in theory (Physics) and practice (Engineering and Technology) using timely Mathematical tools. A cohort of students within the STEM academy signed to participate. This paper presents findings of the student cohort participation through a trilogy lens, and teacher reflections. Twenty students participated in this study. The mean scores for the trilogy levels of engagement for STEM disciplines and STEM careers ranged from 4.10 to 6.21 on a seven-point scale indicating high levels of engagement. Capacity mean scores were 4.30 on Information and 4.35 on Knowledge and for the group. In this category White students had the highest mean scores in both Knowledge and Information. Further, female students were higher on Knowledge. The mean scores ranged from 2.50 to 4.00 on a five-point scale for continuity.

1. Introduction

The National Science Foundation (NSF) began the approach of integrating science, technology, engineering, and mathematics that created the acronym, STEM [14]. The bridging of these discrete disciplines helped to form a new entity that is now labeled as STEM [7]. STEM is highly esteemed in relation to the nation's top priorities and boasts wide support from all levels of the U.S. government. STEM concepts are also embraced in the education community. Therefore, STEM education is an interdisciplinary combination of science, technology, engineering, and mathematics that creates new knowledge [6,7].

The traditional barriers that have been erected between the four disciplines are being removed with the advent of STEM education, which integrates them into one cohesive teaching and learning paradigm. However, an *Integrative STEM education* is any program in which there is an explicit assimilation of concepts and practices from more than one of the STEM disciplines [12]. *Integrative STEM education* is a name that was intentionally chosen to capture more of the educational philosophy than the label of *STEM education* [11]. purposefully formulated an operational definition of *integrative STEM education* as "a technological/engineering design-based learning approach that intentionally integrates the concepts and practices of science and/or mathematics education with the concepts and practices of technology and engineering education" (p. 1).

Experts have suggested that integrative STEM education presents a more relevant approach for educators to expand and increase STEM learning for all students [10,12]. An integrative STEM program aims to offer a rigorous curriculum that deepens STEM learning over time through project- and inquiry-based learning, more instructional time that is devoted to STEM, more resources available to teach STEM, and teachers who are more prepared to teach in the STEM disciplines [9]. Through integrative STEM practices, concepts that are in the National Standards for science, technology, engineering, and mathematics are exercised in unison, allowing students to make connections across disciplines [4]. The potential value of integrative STEM education is a new concept through blending of curriculum designs that include an alignment of the *Standards for Technological Literacy* [4], *Principles and*

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Standards for School Mathematics [15], and *Benchmarks for Science Literacy* [4,16]. Current literature suggests that more research and resources are necessary to fully establish the right platform for best practices that will lead to successful educational outcomes [9,10]. Therefore, integrative STEM education and instructional practices are being explored and have provided opportunities for making STEM learning more concrete and relevant to students [9].

Integrative STEM education programs and K–12 curriculum resources are becoming available through joint efforts of professional organizations within STEM disciplines, departments of education, and commercial educational enterprises [9]. This is consistent with an increasing number of integrative STEM curricula that states and school systems are adopting.

Schools across the nation are developing effective STEM education programs to accomplish successful STEM learning outcomes. Integrative STEM programs have been credited for successes cited in some of the United States' most successful STEM schools and programs [9]. The rationale for this study was based on the need to increase the interest in STEM disciplines and careers. Hence, a formative program evaluation was conceptualized/undertaken. A formative evaluation is a way to detect problems and weaknesses in components in order to revise them. Program evaluations are necessary to help ensure the successful implementation of educational programs which includes the STEM initiative [1,13]. Authors involvement in the formative evaluation started midstream of the implementation of the integrative STEM responding to an invitation from the high school administration's need to find the type of progress in this new venture. The authors collected data concerning the development of and implantation of the integrative STEM to the high school from the three teachers, school administrators, and county administration all information. The process of collecting information included meeting with the three teachers to learn why and how they planned to develop an integrative STEM, meeting with the Principal to learn how an integrative STEM fit in the STEM Academy and the high school curriculum in general, and meeting with the county administrators to learn of the support given to the program. Information collected at this point included original ideas from the teachers and the development of the curriculum, such as topics covered with a timeline of weekly activities; time and class meeting locations (Block times); synchronized teaching of the topics to enable achievement of goals. After this information was collected, the authors developed a timeline for visiting the program to learn of its implementation progress.

2. Theoretical/conceptual framework

The literature was sought for an appropriate evaluation model to undergird this study on the Integrative STEM Academy at Southeast High School. After careful examination, the Discrepancy Model designed by Malcolm Provus in 1969, was deemed appropriate for this study. Provus defined evaluation as the process of agreeing upon program standards, and using discrepancy between outcomes and standards to evaluate the program. hence, the discrepancy model evaluates whether there is a significant difference between the program outcomes (Integrative STEM Academy at Southeast High School) and the outcomes from a standard program (generally from highly successful STEM programs). The standards used to measure the success of the Integrative STEM Academy were the engagement, capacity, and continuity (ECC) trilogy. The concepts of engagement, capacity, and continuity are known in STEM education as the ECC trilogy.

The trilogy is a new theory originally used to frame evaluation designs that contribute to the knowledge base regarding what improvements are necessary to ensure students' continued success in STEM disciplines. In their review on students success in STEM disciplines [5], identified a pattern of three broad-based themes that emerged as factors for success in STEM disciplines; those themes were engagement, capacity, and continuity, which quickly became referred to as the ECC trilogy. These three characteristics broadly reflect the nature of successful STEM education programs. Engagement is referred to as interest, motivation, and attitude of students in the STEM disciplines. While capacity refers to achievement, knowledge, and skills toward the STEM disciplines. Continuity refers to the support systems such as access to extracurricular activities, dual enrollment, SAT/ACT, and mentorship. The underlying assumptions of engagement, capacity, and continuity are based on common trends that show the three factors operate interdependently and are required for student success in STEM fields. Therefore, any criteria used to develop an effective and successful integrative STEM Academy will be based on the trilogy factors. The degree to which the three factors are present in the integrative STEM Academy will reflect the Academy's effectiveness and success. The criteria are as follows: STEM programs must provide engagement in STEM disciplines for participating students; STEM programs must increase capacity in STEM disciplines for participating students; and STEM programs must provide continuity in STEM disciplines for participating students [5].

If the Academy reflects a high degree of engagement, capacity, and continuity outcomes, it means the discrepancies are relatively small and the Academy is more consistent with national STEM programs that are highly successful. This will help the Southeast High School Integrative STEM Academy to be measured against highly successful national STEM schools and programs and to develop a STEM Academy that possesses nationally recognized STEM qualities.

In this study, the STEM criteria were compared with the outcome information obtained from the Southeast High School Integrative STEM program to help identify discrepancies in the implementation of the program. Alignment with the national standards for STEM disciplines in science, mathematics, and engineering, and technology [4] is central to the development of the Southeast High School integrative STEM program. The need for an effective STEM integration program at Southeast High School is underscored by the fact that there is implementation of a STEM program at the feeder middle schools for Southeast High School from the sixth-up to the ninth-grade level through a program titled the Advanced Manufacturing and Prototyping Integrated to Unlock Potential (AMP-IT-UP) in the Southeast County School System. Therefore, an effective implementation of an integrative STEM Academy is necessary to extend STEM learning in Grades 10–12 at Southeast High School. The discrepancy model can be and is often used as a formative assessment to determine whether to revise or end a program.

2.1. Integrative STEM curriculum

The integrative STEM program was implemented in August of the 2012–2013 school year. The integrative STEM Academy at Southeast High School has the characteristics of a typical inclusive program that focuses on the disciplines with no prequisites requirements. Any student in the broader school population can gain access to opportunities presented by the program to develop STEM competencies. STEM disciplines are taught in a coordinated effort by teachers following the state's performance standards for STEM disciplines. Three teachers (mathematics, science, and engineering and technology) were assigned to teach a maximum of 60 students using this integrative STEM curriculum. For example, using a contextual setting to design and test a *catapult* allows application of standards from each of the State's three STEM fields (science, mathematics, and engineering). A science standard from the State's