High school students are not learning mathematics enough, and as a result, students are underperforming in the subject (NCES, 2019), causing them to enroll in remedial courses during their first year of college. A few reasons that students struggle with mathematics are mathematics anxiety and disengagement due to the complexity of the subject (Perry et al., 2016). Hence, it is vital to seek strategies that enrich the learning experience and improve student engagement in mathematics. Educational robotics has been contended to be an effective learning tool across different subjects as it increases student engagement (Afari & Khine, 2017; Nugent et al., 2010).

Due to the challenges that students face as they learn mathematics and the assertions on the effectiveness of educational robotics as an educational technology tool, it is crucial to conduct the appropriate research that will establish if there is any correlation between the two and shed light on possible auxiliary strategies.

This paper will provide extensive research on how educational robotics used as an educational technology tool improves the learning experience by increasing student engagement in mathematics for high school students. Additionally, it will highlight why educational robotics is key to enhancing the 21st-century skills that are needed in today's world. The guiding question that will lead this study is: Given a group of high school mathematics students attending an afterschool program based on robotics instruction, how would student attitudes, engagement, and mathematics grade scores be affected as compared to similar students not attending an afterschool robotics program?

The persistent decline in mathematics performance of students that transition into college is a phenomenon that continues to be a national concern in the United States (Atuahene & Russell, 2016, p. 12). Some factors that contribute to students struggling with the subject are the lack of engagement and motivation in learning mathematics (Mkhize, 2017; Farooq & Shah,

2008). The lack of engagement can be a result of student perceptions of mathematics as they perceive it as the most challenging and difficult subject (Dodeen et al., 2014).

Research suggests that educational robotics can be used as an educational technology tool to improve learning. According to Papert (1980), mathematics is a subject where students could benefit from through educational robotics because of its hands-on approach. Educational robotics is a problem-solving tool that allows students to learn by engaging in meaningful activities through the construction and programming of robots (Barak & Zadok, 2009). For its engaging nature, educational robotics is likely to assist the struggling students and involve them in the learning process. Additionally, educational robotics enables students to develop 21st-century skills, such as creativity, innovation, critical thinking, problem-solving, decision-making, communication, collaboration, and technology skills (Eguchi, 2014). Supporting students is of importance, particularly for high school students as they prepare for college.

Currently, there is no systematic introduction of robotics in school curricula, and there is still not enough presence of educational robotics in the classrooms (Alimisis, 2013). Subsequently, there is also a lack of quantitative research, empirical data, and reliable experimental designs to support that educational robotics increases learning achievement (Alimisis, 2013; Altin & Pedaste, 2013; Benitti, 2012; Johnson, 2003; Williams et al., 2007). Thus, the significance of this study, because without the proper research that sustains that educational robotics improves student learning and increases student engagement, educational robotics could just be a fashion (Johnson, 2003). If the claims that educational robotics increases mathematics engagement are true, supplemental strategies that align with educational technology principles through the application of constructivism and constructionism practices could be considered for implementation into the mathematics curriculum to support students as they exit

high school. Furthermore, this study could provide additional information to other researchers that are interested in the field of educational technology.

A relationship between the use of educational robotics and increased engagement in mathematics is of importance because according to data from the National Center of Education Statistics (NCES) in 2017, the National Assessment of Educational Progress (NAEP) reported that only 25% percent of students in grade 12th performed at or above proficient levels in mathematics and only 3% performed at or above advanced levels (NCES, 2019). Thus, it is evident that, at a national level, students lack the necessary mathematics skills as they exit high school. Moreover, students who struggle with mathematics often have to enroll in remedial courses in their first year of college.

Remedial courses have the highest failure and withdrawal rates in higher education, and students who take and fail remedial courses are less likely to earn a degree (Acee et al., 2017). Furthermore, research shows that remediation courses can impose negative consequences on first-year college students who are already struggling in the subject (Benken et al., 2015). Acee et al. (2017) identified remedial mathematics as an obstacle for underprepared first-year college students. Often, students who take remedial mathematics courses, fail, and as a result, their attitudes and impressions towards mathematics negatively impact their beliefs about themselves as learners. Therefore, low performance in mathematics in high school could interfere with student success in college.

Factors such as student motivation towards learning, autonomy skills, and anxiety often impact student performance (Guy et al., 2015). Additionally, the low engagement of students in mathematics as they transition from primary to secondary school is also a factor that influences student performance. Low engagement in mathematics can be attributed to a lack of motivation

to learn rather than a lack of cognitive abilities (Mkhize, 2017). Likewise, student attitudes towards mathematics contribute to student academic success and influence student participation (Farooq & Shah, 2008). Thus, the importance of increasing student engagement and attitudes towards mathematics as it could impact student success in the subject.

Fredricks et al. (2004) defined engagement as a multidimensional construct that is divided into three categories, behavioral, cognitive, and emotional. Though they are independent elements, these categories are intertwined within an individual. They described behavioral engagement as student involvement in academic and social activities, and it is fundamental in preventing students from dropping out and achieving positive academic outcomes. They described emotional engagement as the reaction, negative or positive, that students have towards school, academics, teachers, and classmates, and how this influences their willingness to complete school work. Lastly, they described cognitive engagement as student investment and willingness to apply the necessary effort that it is required to master difficult tasks, and comprehend complex ideas. Based on these assertions, the lack of engagement in mathematics, regardless of its dimension, could have deterring consequences in student attitudes, learning, and achievement.

Mumcu and Aktas (2015) asserted that affective behaviors towards mathematics contribute to student success and that despite the previous knowledge that students have, if they do not like the subject or feel anxious about it, they could become disengaged and not follow the lesson, and as a result, they may not achieve success. Moreover, the value that students ascribe to mathematics is an important indicator of student engagement as it is a strong predictor of whether students will apply themselves to their mathematics courses (Howard et al., 2015).

Farooq and Shah (2008) recognized the teaching method as another factor that impacts student attitudes towards mathematics. The lack of an effective curriculum offered in high school mathematics education could also impact student academic performance (Benken et al., 2015). Additionally, the way students make sense of mathematics significantly impacts their motivation on the subject (Kele & Sharma, 2014).

Kele and Sharma (2014) attributed the learning of mathematics to a learning environment that promotes positive beliefs. They found that students manifested positive views into learning mathematics in a social environment where they can share with other students. Their study concluded that students consider learning mathematics a social process and that students are aware of the importance that mathematics has on their daily activities. Likewise, in their study, Hall and Sink (2015) found that a positive environment positively impacts students learning.

Howard et al. (2015) suggested that to help students succeed, schools have the responsibility of providing resources for students with different skills and aspirations to help them find their place in the world. Additionally, they highlighted the importance of using effective tools while teaching mathematics. Hence, the importance of faculty, administrators, stakeholders on identifying learning strategies and tools that will prepare confident students in mathematics and will help improve their academic achievement in high school.

One tool that creates a positive environment and supports student learning is educational robotics because it uses a hands-on approach that creates engaging activities for students that encourage them to explore ideas through the construction of objects and project integration in a social context (Eguchi, 2014; Mikropoulos & Bellou, 2013). Robinson and Stewardson (2012) affirmed that robotics activities allow educators to incorporate robots as an educational

technology tool to teach construction, programming, geometry concepts, and to develop critical thinking skills and teamwork skills.

Research suggests that educational robotics is an effective learning tool across different subjects, including mathematics, as it develops student skills, triggers student interest, and fosters student creativity and excellence (Alimisis, 2012). Additionally, due to its hands-on approach grounded on constructivism and constructionism theories, educational robotics increases student engagement (Nugent et al., 2010).

Educational robotics aligns with the educational theory of constructivism by Jean Piaget that asserts that students learn better through experiences that allow them to manipulate and construct objects (Piaget, 1973), and the educational theory of constructionism by Seymour Papert that states that students attain knowledge through constructing and making as it allows them to become engaged in the learning process (Papert, 1980). Both educational theories relate to different approaches that are used in educational robotics as an educational technology tool for teaching. Supporting educational robotics with these educational philosophies is of importance because robots alone are just another technology tool (Johnson, 2003). Thus, it is essential to develop the proper curriculum and create optimal learning environments that could lead to student success (Alimisis, 2013). The educational theories of constructivism and constructionism recommend the use of robots for teaching purposes in the classroom because it has the potential to improve student learning as it engages students through the construction of objects in real-world based scenarios (Afari & Khine, 2017; Kubilinskiene et al., 2017).

Educational robotics enables students to understand how and what they have learned and to correlate that knowledge of content to other settings by solving problems through exploration and creation (Somyürek, 2015). By trying to find the solution to a problem from different

approaches, students transfer skills from theory to practice, allowing them to be in a continual process of discovery (Sullivan & Moriarty, 2009).

Educational robotics is an interdisciplinary, project-based learning (PBL) activity where students construct knowledge based on their existing knowledge and own experiences and the constructionism philosophy that asserts that students are more deeply involved in their learning if they build tangible artifacts that they can share with others (Barak & Zadok, 2009).

Educational robotics is a mind tool that allows students to use technology through hands-on activities to solve problems by translating abstract mathematics and science concepts into concrete-real world applications through programming (Mikropoulos & Bellou, 2013). Due to its engaging environment, educational robotics awakens student curiosity and encourages them to develop ideas (Alimisis, 2012). Robots provide students with immediate visualized and tactile feedback that increases the attractiveness of inquiry learning (Altin & Pedaste, 2013). Additionally, robotics activities provide open-ended questions that further the inquiry of the students (Sullivan, 2008).

Through construction-based activities, educational robotics promotes the development of a wide array of skills such as higher-order learning, cognitive, conceptual, problem-solving, math, reading, writing, and computational skills through problem-solving experiences (Castledine & Chalmers, 2011; Eguchi, 2014; Kubilinskiene et al., 2017; Nugent et al., 2010; Xia & Zhong, 2018). Further, research suggests that through educational robotics, students have better long-term content retention, higher motivation, as well as an enhanced social and academic development through social interaction and cooperative learning (Nugent et al., 2010). Additionally, educational robotics promotes joyful learning while furthering student motivation, collaboration, self-confidence, and creativity (Atmatzidou & Demetriadis, 2016). Likewise, the

social environment associated with the collaborative work of robotics provides students with a support network that results in a positive motivation towards learning and a higher sense of self-efficacy (Yuen et al., 2014). Educational robotics allows students to investigate, create, and solve problems, through themselves, through each other, and through their own experiences (Goh & Ali, 2014).

Educational technology tools such as educational robotics is a field that is continuously growing, and it is likely to impact education from P-16 across the curriculum as it creates engaging learning opportunities for students to learn through hands-on activities (Alimisis, 2012; Alimisis et al., 2007). Additionally, educational robotics promotes the development of 21st-century skills.

Now more than ever, technology is omnipresent in our daily lives. Information readily available online, digital lifestyles, human interactions through digital technologies, and rapid technological advancements are a few characteristics that define the 21st century. Because of the dependability that humans have in technology, it is imperative to prepare students with the specific skills that they need to succeed in this information era, these skills are called the 21st-century skills (Chu et al., 2017, Chapter 2).

Some of the 21st-century skills that students need to succeed are higher-order skills such as critical thinking, creative thinking, and problem-solving skills (Sendag & Odabasi, 2009). Likewise, robotics promotes other 21st-century skills, such as cognitive, metacognitive (Blanchard et al., 2010), communication, collaborative, and social (Benitti, 2012), research, logical, and decision-making (Sendag & Odabasi, 2009), interpersonal (Petre & Price, 2004), and algorithmic skills (Afari & Khine, 2017). Because technology is vital to the attainment of 21st-

century skills, educators have started to generate ideas and develop activities to incorporate robotics into the curriculum (Afari & Khine, 2017).

Students across the United States are currently underperforming in mathematics as they exit high school (NCES, 2019), causing them to enroll in mathematics remedial courses as they enter college. The underperformance of students in mathematics is a concern because not only remedial courses have the highest failure rates, but also because students who fail remedial courses, often fall short of completing and earning a degree overall (Acee et al., 2017). Affective behaviors such as mathematics anxiety and a lack of engagement in mathematics (Mumcu & Aktas, 2015; Perry et al., 2016) have been identified as factors that contribute to the underperformance of students. Thus, the importance of education stakeholders to identify engaging tools and strategies that support students as they learn mathematics in high school.

Robotics is a key pedagogy educational technology tool that increases student attention, engagement, and motivation (Afari & Khine, 2017) because it permits students to establish a direct connection between real-world problems through the construction and manipulation of objects and project integration (Mikropoulos & Bellou, 2013). Educational robotics is founded in the constructivist (Piaget, 1973) and constructionism (Papert, 1980) theories. The hands-on approach of educational robotics allows students to explore ideas and increase their creative, cognitive, thinking, and social skills (Xia & Zhong, 2018) across STEM and non-related STEM subjects (Kubilinskiene et al., 2017). Hence, the purpose of this study is to determine if educational robotics affects student attitudes, engagement, and mathematics grades scores on students participating in an afterschool robotics program as compared to similar students not participating in an afterschool robotics program.

Stakeholders in the field of education are cognizant that robotics is a powerful platform for engaging students in the learning process. Additionally, robotics is a powerful tool in developing 21st-century skills. The reason that educational robotics is influential is that planning, assembling, and operating robots challenge student's innovation, stimulates their creativity, and encourages their critical thinking and problem-solving skills. Moreover, because robotics is a social interaction process, it allows students to collaborate and work together as a team while having fun. The natural learning context experiences found in educational robotics provide students the opportunity to transfer learning to authentic scenarios.

The need for supporting students in the mastery of mathematics during their secondary education, the benefits that research claims educational robotics has in enhancing mathematics skills, and the lack of empirical evidence in the field suggest that this study is worthy of being conducted. A positive relationship between robotics and mathematics will school districts, curriculum developers, and education stakeholders to consider using the collected data to explore whether the mathematics curriculum could benefit from the integration of educational robotics. A new learning strategy that uses educational robotics as an educational technology tool could assist in narrowing the deficit in mathematics in students as they exit high school.

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