Primarily Igniting The Passion: STEM In Early Education
Shawna L. Christenson*, Kevin L. Simmonsb, Argyrios D. Vaitsosc

Abstract
Young children have an innate interest in science. They behold the world around them, are natural questioners, and are not content to simply observe the world around them; they must utilize all their senses to make sense of what they perceive. Primary educators can and must capitalize on this interest by immersing students directly into hands-on applications, but also into the collaborative and communicative aspects that make up the 21st century skillset, particularly if the nation is to positively impact underrepresented groups to enter the STEM fields. This paper uses Social Cognitive Career Theory as an approach and offers project-based STEM activities with a focus on aerospace to excite students aged 11 and younger. Creating a science identity early on, particularly for students of color, lower socio-economic status, and female gender, is imperative in order to increase STEM career participation. Additionally, there is a focus on equipping teachers with relevant professional development and ideas to take back to primary classrooms. The authors’ school has an active and successful aerospace program in the form of the Wolverine and Wolfpack CubeSat Development Teams. Teammates in the middle school level have been selected not once but twice by NASA for their CubeSat Launch Initiative (CSLI). One satellite, the WeissSat-I is currently on orbit, while the second, the CapSat-I is in the planning stages. Because of the work of older students, younger students (grade K-5) are exposed to the real work of space. While satellite teams may appear out of reach for school-aged children, there are many other ways to build a science identity and to get students inspired now to be the STEM workers of the future. Engagement suggestions will break down into both student and teacher centered activities. Teachers should take part in learning along with their students by becoming active in professional organizations and continuing professional development (PD).

Keywords: 21st Century Skills, CubeSats, Experiential Learning, Professional Development, Project-Based Learning Science Identity, Social Cognitive Career Theory

Acronyms/Abbreviations
Aerospace, Communications, Engineering, and Science (ACES), Cube-shaped nanosatellite (CubeSat), CubeSat Launch Initiative (CSLI), Professional Development (PD), Project-Based Learning (PBL) Science, Technology, Engineering, Math (STEM), Social Cognitive Career Theory (SCCT), Wolverine/Wolfpack CubeSat Development Team (WCDT).

1. Introduction
STEM careers, while prestigious, highly sought after, and well-paying, have largely been and continue to be predominately filled by white men. Moreover, while there is a demand for employers in these fields, there is urgent concern over the fact that the current labor pool will not serve the STEM job growth needs in the near future [1]. The US Bureau of Labor Statistics finds there are “8.3 million science, technology, engineering, and math jobs...with the expectation that this number will exceed 9 million by 2022” [2]. The lack of participation in and/or willingness to stick with STEM pathways generates concern that the current workforce will be limited with regards to innovation and economic development. Even though there have been interventions to address this need, and scholarship efforts put in place to close the gap, there still remains a disparity for underrepresented groups [3]. In particular, people of color, those from lower socio-economic status, and women continue to struggle to form a personal science identity. These trends for underrepresented groups have been studied from several aspects to determine why students start off interested in the science and math fields but end up not following through with degrees in college, nor pursuing a career once a degree is received. In part, this retention issue is due to a perceived lack of belonging and a lack of a science
identity. Dou, Hazari, Dabney, Sonnert & Sadler [4] note that identity can be attributed to how others see someone, i.e.: “he is a science person” as well as to how one sees self. Afriana, Permanasari, and Firiani [5] suggest, for example, Indonesia’s low science literacy is due in large part to lack of integrated STEM curriculum. They note the revamping of their national curriculum placed a heavy focus on choosing relevant cross-curricular themes that could be implemented into all subject areas. The findings further suggest such STEM-rich curricula must pose relevant questions, define and investigate problems, analyze data, design solutions, and ultimately, communicate those findings.

Similarly, in Taiwan, Liu, Lou, & Shih [6] report that integrating STEM PBL into curricula increases girls’ STEM self-efficacy and professional commitments to future STEM careers. Using social learning theory and social cognitive career theory, the authors observed that women’s preconceived notions of gender roles or identity has an effect on their learning, particularly with regard to what they believe women in STEM fields can achieve. They conclude that women with role models in STEM fields develop enthusiasm and confidence and no longer feel relegated to traditional female stereotypes in STEM careers. Rainey, Dancy, Mikelson, et al [7] point out that women of color are least likely to feel “at home” in the sciences, in part because curricula and pedagogy, in general, privilege white males. Their study looked at the intersection of race and gender to determine if one or the other (or both) were mitigating factors in leaving STEM fields. The conclusion was that a sense of belonging and the formation of a science identity are key factors in retention, but that the underrepresented groups report having few role models with whom to identify, and a lack of peers with whom to engage. While there needs to be a major overhaul in STEM education which addresses these issues, fostering a science identity as early as kindergarten will go a long way towards instilling not only a love of science, but also a desire to enter STEM careers.

Identity formation starts as early as infancy. The world in which children engage is often related to their identities, so stereotypes for gender can be reinforced without thought. Girls wear pink, while boys wear blue. Girls play with dolls while boys play with cars. Moreover, career options are portrayed in books or in the classroom. Girls are stereotypically cast as nurses, teachers, or mothers, while boys are shown as doctors, scientists, and astronauts. It is only recently there has been a focus on depicting underrepresented groups in favourable roles, yet more must be done to develop a healthy science identity in these populations. In early childhood, then, interest development is connected with later educational pursuits [4].

Hachey points out “schools are powerful spaces for identity work” [8] and it is here, where students who might not experience or have reinforced a science identity at home, may be engaged. Educational reform, particularly with a STEM bent, has long been a goal particularly in the United States where student performance in STEM subjects continue to lag behind other countries. According to the National Science Foundation, as of this writing, only five countries perform below the US in science and math (Israel, Greece, Turkey, Chile, Mexico) [9]. Now, more than ever before, there is a movement to embrace the twenty-first century skills that have long been touted as an answer to America’s declining performance. In fact, countries around the world are looking to this approach in order to affect change on their citizens of the future as too many students remain passive learners in the classroom. To mitigate the issue of student passivity, it is essential to engage students early and often in real-world, hands on learning that goes beyond the classroom.

The long-term benefits of these kind of experiences are varied and many. According to the Association of Colleges and Universities, real world academic application in the form of experiential learning helps students both to bridge classroom study and life in the world and to transform inert knowledge into knowledge in-use [4]. Major groups such as the National Education Association and the educational testing giant, Pearson, tout 21st century skills as being the cornerstone for future employability and overall success due to the fact that critical thinking and problem solving make one a more desirable team member. Pearson claims “employees with successful career paths learn to communicate effectively, engage appropriately with others, and [are] self-reliant. Effective career readiness and employability strategies are those that develop the whole learner and include personal and social capabilities; critical thinking and problem-solving skills; and academic and occupational knowledge” [4].

This paper will suggest these key factors for curricula development can be promoted by instilling interpersonal relationships, competence, interest, and identity from the youngest of ages. Additionally, the authors discuss why inspiring children early on in project-based STEM activities leads to citizens who take on STEM careers in the future. They offer activities to inspire the youngest students in their school settings with real, hands-on, experiential learning, in order to increase their science identity and to create a sense of belonging in STEM fields, particularly for students who are underrepresented. Further, the paper will address how educators can get
more involved with relevant professional development that leads to relevant and real-world student engagement.

1.1 Twenty-First Century Skills

Beginning around 2002, and responding to a decline in student performance, the 21st Century Partnership was designed. The National Education Association (NEA) was a founding member and continues to have influence in curriculum development today [10]. They emphasize core courses, learning and teaching skills, and technology with specific focus on critical thinking; creativity; collaboration; communication (also known as the 4Cs); information, media, and technology literacy; flexibility; leadership; initiative; productivity; and social skills.

1.2 The Four Cs

Many of the activities mentioned herein emphasize the critical thinking, creativity, collaboration, and communication elements of the 21st Century Skills although all skills may be implemented depending on delivery.

1.3 Project-based learning

Project based learning (PBL) is a method of instruction that encompasses a variety of elements including Role-playing, real-world scenarios, blended writing genres, multiple reading genres, authentic assessments, authentic audiences, real-world expertise brought into the classroom, units that assess multiple skills, units that require research and comprehension of multiple subjects, student choice, collaboration, and multiple methods of communication (writing, oral speaking, visual presentations, publishing, etc.) [11].

1.4 Social Cognitive Career Theory

SCCT is a vocational psychology dealing with “career interests, goals, actions, and performance in relation to domain specific self-efficacy, outcome expectations, as well as contextual and background variables” [1]. SCCT shows that students who identify with a certain role, or who “feel” successful in a specific area are more likely to pursue careers in those fields.

2. Methods/Activities

The activities described below are divided into two sections although some overlap is likely to occur. These are not meant to be constrictive, but rather to serve as ideas to help teachers foster a love of STEM in relation to aerospace early on. These kinds of activities can ultimately generate deliverables that can be used for outreach and further engagement, thus promoting a science identity for all students.

2.1 Student centered activities include coloring/activity books, launch parties, STEAM carts, STEM FEST, ACES camp, SciencePalooza, and the Brown Bag Lunch Series.

2.1.1 Coloring and Activity books

Teaching young students about advanced concepts is best done in a format they recognize. The first iteration of the coloring book was distributed as part of a larger event, a launch party (detailed in 2.1.2). The writing teacher collaborated with the art teacher to create the final product with a student spearheading the editing. In this instance, the content was related to the first CubeSat, The WeissSat-1, which was launched December 2018.

![Image](Fig. 1. First middle school CubeSat, WeissSat-1. Image Courtesy Kevin Simmons)

The coloring book included a brief history of the Wolverine CubeSat Development Team, the mission, and goals for the future. A middle school student used an online publishing program to design cartoon content to accompany the text, and the English text was translated into Spanish and Mandarin by students in the world language department. The second version is in the planning stages with the new Wolfpack Team to accompany the creation of the second CubeSat, the CapSat-1. These incoming sixth graders began the work during the school quarantine for COVID and development is ongoing. It will include word puzzles and more to engage young students in aerospace terminology. This activity develops the 21st Century Skills of collaboration, communication, technology, literacy, and more.
reinforced in this activity include communication, collaboration, creativity, and social skills.

2.1.4 STEM FEST

A combination of students in aerospace and public speaking were invited to participate in Palm Beach State University’s STEMFEST, an outreach event for families, which brought together local STEM aficionados and children of all ages. Participating students ranged from 5th-8th grade, with the youngest of those using the aforementioned coloring book to reach out to pre-schoolers. Middle school students shared about CubeSats and explained how their satellite was built and launched into space. This activity encompassed communication, literacy, flexibility, and collaboration with members of the community.

2.1.5 ACES Camp. (Mission patches, CAPCOM)

For five years, ACES camp has educated and ignited the passion of students from around the world in both their regular and international options. For international camps, students from countries such as China and Canada met in person to design space settlements of the future for competitions. Students and teachers collaborated with students from several other countries remotely including Germany, Chile, Peru, and more. In addition to learning space settlement design, students learned orbital mechanics, engaged in mission patch design, learned the importance of communication in a CAPCOM activity simulating an Apollo 13 problem, provided by Space Foundation Teacher Liaisons.

Fig. 3. Student designed WCDT mission patch. Image Courtesy Kevin Simmons

Students also embraced the art of debate and public speaking, and camp culminated with presentations at Kennedy Space Center, the South Florida Science Museum, and the host school. This camp is the starting point for those interested in space settlement...
design competitions, for which several students have participated, including Future Space Scholars Meet and NASA Ames competition hosted at International Space Development Conference. Recently, former ACES campers joined international debate teams for National Space Society’s Space Universalization (SpUn) debates where they argued resolutions pertaining to space exploration and the Lunar Gateway. The camp included almost every aspect of 21st Century Skills due to its integrated approach.

2.1.6 SciencePalooza

For the past four years, middle school students have demonstrated their science research knowledge in a school wide fair; however, recently, the fair expanded to include students in primary and intermediate levels. To ensure student engagement, the primary level teachers build excitement about “SciencePalooza.” Children in Kindergarten were mentored by older students, and became scientists from the first day they entered class.

Fig. 4. 7th grade Chemistry students mentoring Kindergarten students in 2019. Image Courtesy Kevin Simmons.

The classrooms are designed to encourage curiosity in science. The kindergartners even receive their own lab coats and are exposed to daily experiments. The scientific method is posted around the room for reference throughout the year. Even though they are young, the teachers do not treat them as though they are unable to comprehend, which helped students to feel confident in their selected projects. They then used simple science experiments that they did in class and used science journals to record data. The event culminated in a group presentation to parents and “judges.”

Second grade students start the year by discussing what scientists students “do”; they learn about measurement, observation, classification, and how to communicate, findings, etc. Building upon skills from previous years, intermediate are encouraged to do background research on individual topics of interest. Students worked with their Public Speaking teacher to practice oral presentations of their findings.

Middle school students in grades 6-8 enjoyed not only participating in the school-wide science fair, but were happy to mentor younger students by going to their classrooms to help with construction of boards, talk about the scientific process, and to “judge” the young scientists. There is a strong history of science fair success in the middle school grades, so students are motivated to not only choose a topic they enjoy, but to perform to high standards. For the past five years, 90% of these students have placed 1st-4th, and 18% earned trips to the Florida State Science and Engineering Fair, with many choosing aerospace-themed projects. This success demonstrates how science identity formation at an early age leads to science efficacy, and ultimately, a belonging in STEM fields. A school-wide fair incorporates almost all 21st Century Skills including information, media, literacy, creativity, communication, and critical thinking.

Table 1. 6th-8th Grade Student Science Fair Results, The Weiss School, 2014-2020

<table>
<thead>
<tr>
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<tr>
<td>Participated in school fair</td>
<td>0</td>
<td>60*</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td>Invited to Regional Fair</td>
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<td>5</td>
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<td>30</td>
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<td>30</td>
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<tr>
<td>Place 1st-4th at Reg. Fair</td>
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<td>5</td>
<td>17</td>
<td>27</td>
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<td>Finished 1st at Regional Fair</td>
<td>0</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Earned state Sci/Eng Fair Bids</td>
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<td>5</td>
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</tr>
<tr>
<td>Placed at State Fair</td>
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<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3 **</td>
</tr>
<tr>
<td>Grand Champions State Fair</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>**</td>
</tr>
</tbody>
</table>

*All Students in middle school **Cancelled due to COVID-19

2.1.7 Brown Bag Lunch Series

Throughout the year, local professionals from a variety of careers visited the school to share about their vocations. Students spent lunch hours learning about people in their community and participated in Q and A sessions. Brown Bag lunches allowed students to get an idea about what certain jobs entail and how they relate to their neighborhood. Speakers included a surgeon, a flight test engineer, the local mayor, and Congressman Brian Mast. While more were scheduled, Covid-19 restrictions precluded the continuation of the series for last school year. The plan is to reimplement if able for the next year due to high student engagement level. 21st Century Skills addressed include critical thinking, collaboration, communication, technology literacy, and social skills.

2.2 Teacher centered /PD activities include ESTEAM Teacher Camp, Space Foundation Teacher Liaison,
and the American Institute of Aeronautics and Astronautics (AIAA).

2.2.1 ESTEAM Teacher Camp

Funded by a grant from the Florida Space Grant Consortium, public school teachers from the authors’ county were invited to attend Equipping Students and Teachers in Engineering, Entrepreneurial, & Aerospace Modalities (ESTEAM) This week long camp along with a Saturday workshop provided PD and suggested ways educators might incorporate activities such as these to increase student science identity. Teachers were encouraged to bring their learned best practices to their schools and to use stipends to either start a STEM club or augment an already existing program. Educators learned about the CubeSat Launch Initiative (CSLI), the importance of a growth mindset, to connect industry with academia by joining professional organizations within their field including Teacher Liaisons, American Institute of Aeronautics and Astronautics, and to reach out to local community businesses and leaders to make change in their classrooms. Participants received a PD book Martians in the Classrooms, CubeSat 101 handbooks, and learned about ways to get involved both in their classrooms and in the community. Participants followed up with how the stipend helped their program and offered insight into what makes experiential PBL difficult. Challenges included how to effectively reach the core group of teachers, how to offer meaningful support throughout the year, and in motivating teachers to share with colleagues.

2.2.2 Space Foundation (SF) Teacher Liaison

Educators from around the world may apply to become Teacher Liaisons. Liaisons employ activities related to space in their classrooms and to develop curriculum that engages students in real world STEM learning. Liaisons connect their school with other organizations, such as school districts, NASA, and more in order to create relationships that foster the “Core 4": Community Outreach, Teacher Education, Space Foundation Connection, and Student Engagement. Once a liaison, educators are eligible to share content, continue PD, and have access to instructional materials for their own classrooms. Teachers may apply annually on the SF website at https://www.discoverinspace.org/education/for-educators/teacher-liaisons/.

2.2.3 American Institute of Aeronautics and Astronautics

The AIAA is a professional organization for individuals that supports the aerospace and aviation industry workforce in multiple ways including networking, advocacy opportunities, and more.

Educators are offered a membership at no cost and receive access to numerous lesson plans, access to educational grants, and other academic support. Opportunities for teachers may exist in their local sections as well. Two authors of this paper, for example, are officers in the AIAA Palm Beach section. More info at https://www.aiaa.org/get-involved/educators.

Table 2. 21st Century Skills in K-5th Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Critical Thinking</th>
<th>Creativity</th>
<th>Collaboration</th>
<th>Communication</th>
<th>Information &amp; Technology</th>
<th>Problem Solving</th>
<th>Leadership</th>
<th>Initiative</th>
<th>Productivity</th>
<th>Social Skills</th>
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<td>✓</td>
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<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tr>
<tr>
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<td>✓</td>
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<td>✓</td>
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<td>✓</td>
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</tr>
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<td>ESTEAM Teacher PD Camp</td>
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</tbody>
</table>

3. Theory

Implementation of the aforementioned activities fits the model for twenty-first century skills with a project-based learning bent. These engaging options have proven to stimulate young students’ interest, and, moreover, excite them for the more advanced options that await them in middle school. To that end, Social Cognitive Frameworks, and Social Cognitive Career Theory (SCCT) suggest that, early on, students begin to formulate an identity that ultimately is reflected in career choices. In addition to providing role models, mentors, and activities that engage young students, it is imperative to continue the formation of science identity for all students in order to bolster the STEM pipeline. Erikson’s theory of childhood psychology suggests that children go through several stages in developing an identity. Particularly of note for this research are the competency and fidelity stages which occur from ages 5-12 [12].

Since students are developing an understanding of what they do well (efficacy) along with a sense of fealty to the identity to which they identify (belonging), it makes sense to augment classrooms to provide hands-on experiences that provide both group and personal science identity formation. Doing so will allow students from all backgrounds to “see” themselves as “STEM people” early on, which will be especially important for underrepresented groups.

Children often begin formulating identity long before they attend school based on their roles and interactions at home [13].
Many current scientists claim curiosity, family encouragement in STEM, and access to STEM media played an important motivating factor in how they viewed themselves as “scientists” [4]; however, many underrepresented populations do not have this luxury. Schools can help to close the gap by providing interactions with teachers, activities that foster situational interests and support mastery as well as provide mentors with whom these students can identify more personally.

The school from which the activities described above were planned has multiple active aerospace teams ranging from interest in high altitude balloons, Ham radio operations, aerospace policy, CubeSats, and lunar rovers. Students also engage in a diverse range of writing contests, design competitions, engineering projects, and public policy efforts that provide authentic STEM reinforcement.

Considering SCCT suggests exposure to real science early on aids in science identity formation, it makes sense for educators to implement activities like those described above to positively impact the STEM pipeline and encourage more diversity in the fields.

4. Results

Results from the numerous activities plotted against student age indicates that very young students (as early as 5-years old) are both interested and benefit from the listed authentic STEM experiences.

Moreover, when engaged in science-based activities, younger students are much more likely to create a science identity that follows them into their later academic years. Students who have participated in these activities along with the bigger work of spacecraft design in their middle school years report a reinforced passion for STEM while at the same time a feeling of frustration over not having access to similar activities in their secondary education pursuits. If student STEM interest is not reinforced at all academic levels, that interest can wane, and can ultimately affect career choice.

4. Results

Graph 1. Average student age vs K-5th Activity rigor

<table>
<thead>
<tr>
<th>STUDENT LEARNING OPPORTUNITY ID</th>
<th>Min Age</th>
<th>Max Age</th>
<th>Rigor (1-6)</th>
</tr>
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<tbody>
<tr>
<td>Coloring Book Activity (WCDT History) A</td>
<td>5</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Launch Party (Stomp Rockets) B</td>
<td>6</td>
<td>10</td>
<td>1.5</td>
</tr>
<tr>
<td>Brown Bag Lunches With Speakers C</td>
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<td>14</td>
<td>2</td>
</tr>
<tr>
<td>STEM Fest (Community Outreach) D</td>
<td>9</td>
<td>14</td>
<td>2.5</td>
</tr>
<tr>
<td>Museum STEAM Carts E</td>
<td>10</td>
<td>14</td>
<td>2.8</td>
</tr>
<tr>
<td>Science Palooza (K-2nd) F</td>
<td>5</td>
<td>11</td>
<td>3.5</td>
</tr>
<tr>
<td>SciTech Conf.-AIAA (present) G</td>
<td>10</td>
<td>14</td>
<td>3.8</td>
</tr>
<tr>
<td>ACES CAMP (Orbital Mech. Debate) H</td>
<td>8</td>
<td>15</td>
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<tr>
<td>Science Palooza (3rd-5th) I</td>
<td>8</td>
<td>11</td>
<td>5</td>
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Table 3. K-5th Activity Age Ranges and Rigor
5. Discussion
The future of the STEM workforce is in jeopardy, yet it is one of the most important segments of society when it comes to viable and rewarding employment, its impact on technological and scientific advancements, and future innovations that can benefit society. While there is a shortage of young people in general entering STEM fields, students of color, lower socioeconomic status, and women (and any combination of these) are even more scarce. Numbers of students interested in STEM decreases as they enter high school and even more so in secondary education; and once in college, there are fewer students who actually finish STEM careers, choosing instead to transfer out. These findings are significant in that educators can and should play a vital role in identity formation for elementary students who might not be positively impacted elsewhere. Students report when they have opportunities to engage in science practices, they are more likely to feel recognized as a scientist by their peers, their role models, society, and, most importantly, themselves [13].

Offering PD on SCCT and identity theory would help educators and school officials to understand the extent to which they can enable students to feel like they “belong” in STEM. A simple ranking survey to assess how students identify (e.g., a science person, a sports, person, an arts person, etc.) would help educators understand their class/groups, and could provide opportunities to expand student possibilities.

6. Conclusions
Educators should not overlook the importance of early childhood as a strong base to scaffold science identity. While there are many factors that affect students and whether they “see” themselves in a particular field, providing role models who look like students in all subgroups will help solve the STEM pipeline issue. Students who view themselves as, and who feel recognized by others as a “scientist”, report that science experiences in the classroom and beyond and role models who look like they do are primary factors for underrepresented minority students. Likewise, science identity formation contributes to a positive perception of the classroom climate overall [14], particularly when engaged in research experiences that lead to science self-efficacy. Teachers who work closely to align themselves with professional organizations and STEM industry-related professionals will create realistic learning experiences for their students and will more easily meet the requirements to create 21st century students.

Acknowledgements
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