



Assessment of the Impact of Summer STEAM Programs on High School Participants' Content Knowledge and Attitude Towards STEAM Careers

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Abstract

For the past five years, the Science and Mathematics Department at Columbia College Chicago, in collaboration with After School Matters (ASM) from the city of Chicago, offers two, six-weeks summer programs for high school and rising high school students interested in the Science, Technology, Engineering, Arts and Mathematics (STEAM) fields. During this period (June through August), 80 students spend six weeks on the college campus participating in one of the two following programs: 1) 30 students participated at the Junior Research Scientists and 2) 50 students participated at the Comed Youth Ambassadors. Both programs were designed by faculty and staff of the department. Students attended classes taught by college faculty and staff; participated in engineering design projects and problem-solving challenges, and attended other STEAM related activities

These summer programs attract high school students from the inner city of Chicago exposing them to STEAM disciplines and careers through rigorous classes, laboratories and real life experiences. At the same time the programs provide them with the full college and career readiness experience. The main goals of this program are to: (1) introduce students to a wide variety of STEAM fields, (2) increase student's engineering mathematics and science knowledge, and (3) facilitate students to learn about different STEAM fields they might be interested in pursuing.

To assess the impact of the program, the participants took a pre and post content knowledge test that included basic electricity and energy questions (the main topics covered in the two programs), and a pre and post survey regarding their attitude towards Mathematics, Science, Engineering and the 21st Century skills. In addition, the authors collected participants' expectations of the program at the beginning of the summer session and their impressions of the program after the intervention.

Data analysis of the pre and post content knowledge test showed a significant gain in both groups, but their attitude toward STEAM careers did not show significant change. In this paper, the author will present the programs and will discuss the impact of the program on the participants in each specific program.

Introduction

Many sources including the National Science Board [1] concur that education in the STEM related fields is the vital importance for the economic development of our nation. Despite our historical record of achievement, the United States now lags behind other nations in these fields at the elementary and secondary levels [2] leading many potential STEM students not to embrace these fields.

In November 2017, the Congressional Research Service [3] also addressed the topic of a shortage (or a looming shortage) of scientists and engineers with consequent effects on areas such as economic growth, job creation, standard of living and national security, also mentioning U.S. students lag those of other nations in STEM knowledge. These statements, with the inclusion of others factors, can lead to fewer and/or less talented U.S. scientists and engineers, a decrease in economic growth, and reduced economic competitiveness [4], [5]

Although the trend in enrollment and pursuing degrees in STEM related field is relatively low, it is possible to see a very low participation of certain minorities (Afro-American, Latino and Women) in these fields. According to Malcom-Piqueux [6] only 9.6% of minority male and 3.0% minority women pursue careers in engineering. Many efforts have been made in the past 40 years to promote more underrepresented minorities to join the STEM workforce showing only small gains [7], [8]

Under the initiative of Dr. Campbell and his colleagues [8], a group of 50 undergrad and grad students from several universities presented several ideas to facilitate access of underrepresented minorities to the STEM field, between them [9].

- Connecting STEM with other disciplines including the humanities and the arts.
- Training to help them better explain science to nonscientists, including family members who may generally be supportive but aren't always familiar with research.
- Learning sooner than well into graduate school about the career paths that becomes available with an advanced STEM degree.
- Ensuring access to “invested mentors,” who show a genuine interest in their careers.

One of the possible ways to reverse this trend is to provide to our students in an early stage (elementary and high school) high quality Out of School time programming focusing in the STEM subjects and potential careers [2] when promoting the integration with the arts, family inclusion, a deep exploration and discovery of the possibilities of the STEM field [8], [9].

Summer time provides an opportunity to facilitate the participation of underrepresented minorities in an exploratory experience of the STEM fields [10]. STEM summer camps and activities facilitate the exposition of students to fields that sometimes are unknown for them, but also contribute to reverse the “summer learning loss” for the participants as well as provide them a frame to learn in a different way, under a different structure [11].

According to the National Research Council for an Out-of-School Time STEM program to be effective need to provide participants with activities that fulfill the following frame [12].

- 1) Engage young people intellectually, academically, socially and emotionally
- 2) Respond to Young People's Interests, Experiences and Cultural Practices
- 3) Connect STEM Learning in Out-of-School, School, Home and Other Settings

Following the presented framework for the development of an effective OST STEM program, the suggestions of students in the STEM field, and the present need to promote the potential participation of underrepresented minorities in the STEM/STEAM field, the Department of Science and Mathematics - Columbia College Chicago with the support of an external agency, in

this case, After School Matters from the city of Chicago, developed two programs for high school students: the Junior Research Scientists and the ComEd Youth Ambassadors.

Both programs, Junior Research Scientists (JRS) and ComEd Youth Ambassadors (ComEd) are funded by After School Matters of the city of Chicago. After School Matters (ASM) is a non-profit organization that provides life-changing after-school and summer program opportunities to more than 15,000 Chicago high school teens each year, by designing and delivering high quality, hands-on, project-based apprenticeship programs in a variety of content areas, including the arts, communications, leadership, sports, and STEM. ASM provides the logistics necessary to connect high school students from the inner city of Chicago with the academic and artistic programs they offered, facilitating the recruitment of teens, and providing a monetary stipend for the participants in their funded programs.

Implementation of the program in Summer 2017

In Spring 2017, high school teens applied through the ASM application system to participate in the 2017 summer sessions of the JRS and ComEd program. The selection process included a 20 minutes interview to gauge the interest of the candidate to participate in the program. From a pool of more than 300 applicants, the JRS and ComEd instructional teams interviewed more than 100 candidates that selected this program as his/her first choice (among three possible programs they selected to participate this summer). In the interview, the leadership of the program presented the goals, objectives and expectations in great detail. After the interviews, two groups were formed: a group of 32 self-selected JRS participants and a second group of 40 self-selected ComEd participants. It is important to mention that 7 participants also participated in the summer 2016 programs. It is important to note the fact that the participants were “self-selected”, meaning that there was not any requirement from any external agent (teacher or parent) to participate in the enrollment process (there was no need of letter of recommendation or similar adult endorsement). The demographics of the two groups is presented in the Table 1.

Table 1. ComED and JRS Participants’ demographics – Summer 2017

	14	15	16	17	18		African American	Latino	Asian	White	n
Comed	4	8	16	5	7		22	11	4	3	40
JRS	0	5	13	13	1		12	4	8	8	32

The programs run six-weeks, five-days a week for four hours a day having a total of 120 contact hours. Each day, the ComEd program ran from at 9:00 am to 1:00 pm and the JRS program from 1:30 pm to 5:30 pm. The instructional team for the programs were faculty and staff from the Science and Mathematics department. The author of this paper was the instructor in both programs.

General description of the programs

Learning Methodology:

In both programs, JRS and ComEd, the participants worked in a college environment under the instruction and supervision of college professors. The activities were designed following Inquiry and Project Based Learning (PBL) methodologies. The learning process started with a discussion about their previous knowledge and/or experience about the learning content. Then an introduction of necessary knowledge needed was presented for the participants to implement an experiment (or hands-on experience) that will emphasize the specific learning content. To close the topic, the participants discussed the results of the experiment or activity that summarized the learned concept. In the Engineering design part of the session, the teens received all the resources needed to build their own project. They needed to explore how to use the given resources (e.g. the materials to build a robot), and which knowledge they need to acquire in order to produce their design product. In the Scientific Research part, the JRS instructional team supervised the teens in the research process guiding them as needed.

The Junior Research Scientists (JRS):

The Junior Research Scientists (JRS) program has the mission to provide a safe Science Technology Engineering Arts and Mathematics (STEAM) environment for the participants where they can have a first, hands-on experience on what are the characteristics and responsibilities that embodies to be a professional in the STEAM fields. In this environment, they can explore if the STEAM fields can be one of their PASSIONS to pursue in their future education, and in this space, the participants can take risks by delving into subjects that they are not knowledgeable or familiar with.

The objectives of the program are to:

- 1) Motivate teens to explore STEAM subjects and potential careers, and have an expanded vision of their possibilities for their academic path
- 2) Facilitate teens to explore what Scientific Research involves and have a hands-on experience working in their own research
- 3) Facilitate teens to explore what Engineering Design, involves and develop a project based in needs and constrains
- 4) Promote teens to develop leadership attitudes and skills to promote themselves and their communities in the STEAM fields and beyond.
- 5) Give the teens a full college experience

During the Summer 2017 session, the program developed two content areas: Solar Energy and Robotics. In the area of Solar Energy the participants explored and learned the following topics:

- 1) Introduction to Energy, 2) Introduction to Electricity, 3) Electrical Circuits and Electricity Laws: Ohm and Kirchoff, 4) Introduction to Solar Energy, 5) The Physics of a Photo-Voltaic Cell, 6) Designing a Photo-Voltaic Array, 7) Introduction to the chemistry of Rechargeable batteries, 8) Introduction to Scientific Research, 9) Design of their own research methodology and 10) Implement their own research and presentation of their findings.

In the area of Robotics, the participants explored and learned the following topics: 1) Introduction to robotics, 2) Moving from the multi-meaning language to a logic single meaning language structure (true or false), 3) The digital and analog world, 4) Introduction to microcontrollers, 5) Building a basic prototype to learn coding affecting the real world, 6) Design the hardware for their own robot, 7) Building the robot and programming it.

Culminating Project or Showcase:

At the end of the session, the Junior Research Scientists team presented the findings of their research as well as the product of their independent engineering design challenge in the “Summer 2017 - Symposium and Final Project Presentations”. The symposium is open to the public and it is taking place in one of the available auditoriums of the Columbia College Chicago. with participation of family members of the participants and professors and students from the Columbia College Chicago. After each presentation, there is a session of Q&A, where the teens can explain specific topics of their work more in detail.

ComEd Youth Ambassadors (ComEd)

In the ComEd Youth Ambassadors program, participants develop a better public understanding of the “Energy Infrastructure Modernization Act” (EMIA). The community engagement team from the Science and Mathematics department at Columbia College Chicago developed the “Smart Grid and You” curriculum. In addition to promoting the contents relevant to the Smart Grid and its impact in the common citizen, the goal of this program is to generate a positive environment in which teens that are inclined but not yet convinced to explore topics on STEM/STEAM. They will have the opportunity to explore STEM/STEAM activities that will encourage them to continue their exploration in these subjects and potential academic careers.

The objectives of the program are to:

- 1) Motivate participants to be more knowledgeable about electricity, the electric grid, the smart grid and learn about the benefits the Smart Grid can bring to their communities.
- 2) Promote participants to communicate the benefits of the Comed efforts to the public at large throughout implementation of outreach activities in the communities
- 3) Develop for the participants a first college experience, working in a college environment and assuming their responsibility of members of a college bound community.
- 4) Improve the participants own and acquire new 21st century skills that will facilitate their future insertion in the highly competitive academic and work places
- 5) Give the teens a full college experience

During the Summer 2017 session, the program developed two content areas: Electricity and Communication. In the area of Electricity, the participants explored and learned the following topics: 1) Fundamentals of electricity where the participants learned the history of Electricity and its development. Participants learned how to measure Voltage, Current, calculate power, design experiments to explore OHM law and Kirchoff laws, 2) The Electric grid, where the participants learned about, generation, transmission and distribution of electrical energy through the conventional grid including the history of its development – the war of the currents – and how to use transformers to minimize losses in transmission). 3) The Modernization of the Electric Grid – The Smart Grid and the devices that make it smart – Smart meters, inclusion of micro-grids, adaptation to usage of alternative energies and more. During this process, participants acquired skills such as soldering, building solar panels, utilizing software to design and assess the energy usage of a house, and build a model of a house from scratch and power it following their design.

In the area of communications, the participants used media to promote an idea: the teens participants designed infographics to communicate in a simple way ideas to the public, also produced several short movies to communicate what they learn in their summer experience. In this process they learned new skills such as using the software “Photoshop” in a proficient way, writing their own script, filming, editing, making voice over, and more.

Culminating Project or Showcase:

The participants in the Summer 2017 participated in the two culminating events: One organized by the electric utility company “ComEd”, and the other was the Summer Symposium and Final project presentations organized by the Columbia College Chicago to showcase the work of all our programs (ComEd Youth Ambassadors and Junior Research Scientists)

In the Summer 2017 session, the ComEd Youth Ambassadors team build a model of two neighborhoods, where each house was designed by each teen and powered by Solar Energy (the teens build the solar panels and designed the electrical circuitry). The general electrical services of the two neighborhoods were supplied by a micro-grid also powered by solar energy. Also the teens displayed several movies they produced during the program, and explained to the public at large the benefits to develop their own micro grid at home.

Evaluation

To assess the impact of the participation of the teens in the six-week summer STEAM program the participants took a content knowledge test and an attitude survey the first day of the program (pre-test) and the last day of the program (post-test). The content knowledge test was designed by the Instructional team following the designed curriculum, using vetted questions from national tests banks [14] and past ACT test. The composed test was assessed for validity and reliability to the curriculum in the spring 2017. The content knowledge test includes 36 multiple choice questions. (The test can be available upon request to the author by email mcaplan@colum.edu)

For the assessment of the participant’s attitude towards STEM and 21st Century skills the survey “Students attitude towards STEM” was used. This survey was developed by The Friday Institute for Educational Innovation, and its validity and reliability had been assessed [13]. The survey includes 39 Likert Scale five-point scale statements where 1 meaning strongly disagree and 5 strongly agree with the statement. To explore each individual subject, the survey included 8 statements regarding Mathematics, 9 statements regarding Science, 9 Statements regarding Engineering and Technology and 13 statements regarding 21st Century skills. To clarify, 21st Century skills refers to a broad set of knowledge, skills, work habits, and character traits that are believed—by educators, school reformers, college professors, employers, and others—to be critically important to success in today’s world. [15]

Data analysis

ComEd Youth Ambassadors content knowledge analysis

From 40 participants enrolled in the program, 37 finished the program. From the 37 participants 34 of them completed both the pre-test and post-test (92%). A paired-samples t-test was conducted to compare if there is a significant change in the content knowledge test of the ComEd Youth Ambassadors program participants. There was a significant difference in the scores of the pre-test ($M=18.03$, $SD=4.35$) and the post-test ($M=22.8$, $SD=5.9$) conditions; $t(33)=6.76 > t_c=2.73$, $p = 0.01$. These results suggest that the six-week intervention has a significant impact in the content knowledge of the teens participating in the ComEd Youth Ambassadors program. In Figure 1, each point in the graph represents the coordinates (Pre-test score, Post-test score) per participant of the Content Knowledge Test. The line indicates the place in the plane where the Pre-test is equal to the Post-test. In the Figure 1 it is possible to observe that the large majority of the points are above the line, showing that the large majority of the participants scored a Post-test higher than the Pre-test.

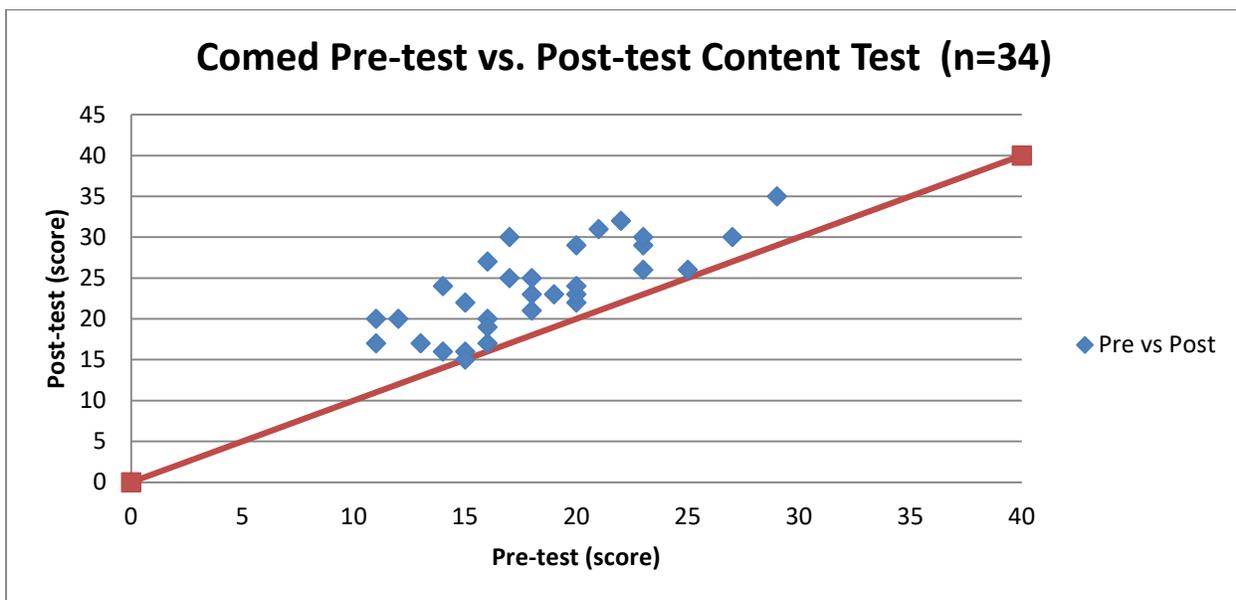


Figure 1. ComEd Youth Ambassadors - Content Knowledge Pre-test versus Post-test. The line in the graph represents score pre-test = score post-test

Junior Research Scientists content knowledge analysis

From 32 participants enrolled in the program, 29 finished the program. From the 29 participants 24 of them completed both the pre-test and post-test (82%). There were three participants that joined the program in the second week and therefore they did not participate in the pre-test session.

A paired-samples t-test was conducted to compare if there is a significant change in the content knowledge of the Junior Research Scientists program participants. There was a significant difference in the scores of the pre-test ($M=24.5$, $SD=6$) and the post-test ($M=29.4$, $SD=5.7$) conditions; $t(23)=5.35 > t_c=2.8$, $p = 0.01$. These results suggest that the six-week intervention has a significant impact in the content knowledge of the teens participating in the Junior Research Scientists program. In Figure 2, each point in the graph represents the coordinates (Pre-test score, Post-test score) per participant of the Content Knowledge Test. The line indicates the place in the plane where the Pre-test is equal to the Post-test. In the Figure 2 it is possible to

observe that the large majority of the points are above the line, showing that the large majority of the participants scored a Post-test higher than the Pre-test.

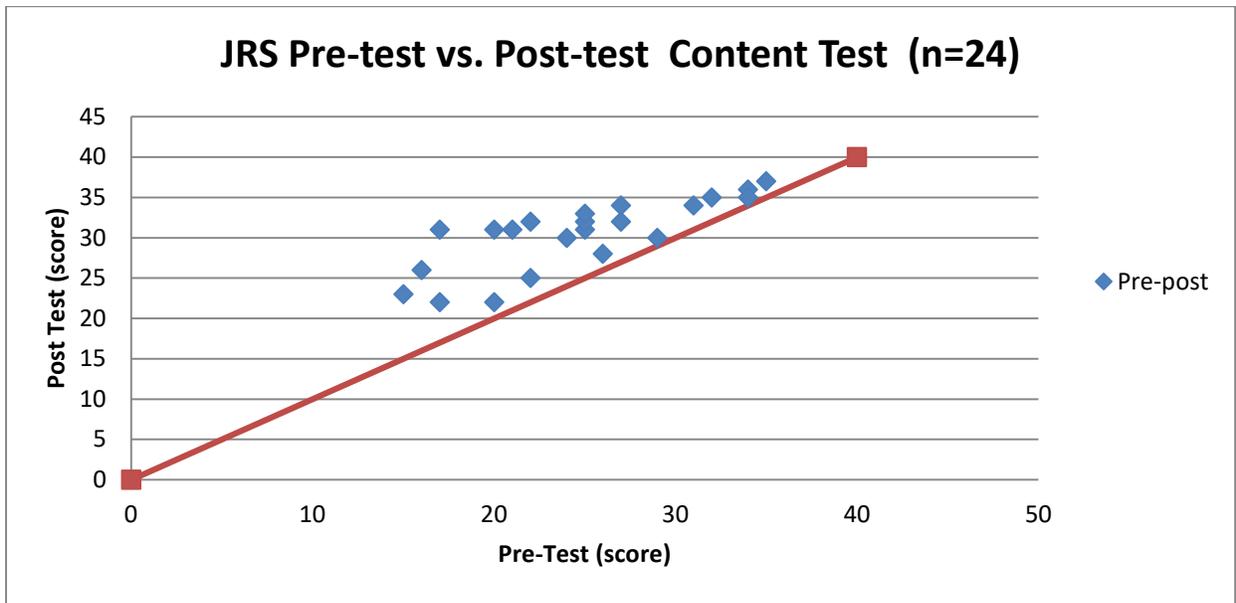


Figure 2. Junior Research Scientists - Content Knowledge Pre-test versus Post-test. The line in the graph represents score pre-test = score post-test

Content knowledge analysis summary

As mentioned before the Content Knowledge Test include 36 questions. The maximum score in this test is 36. From the results of the gain between the pre-test and post-test it is possible to see that in both groups the average gain was approximately five points of a maximum of 36 points. There is a difference in the means of the pre-test between the groups. The mean of the pre-test for the JRS team was 24.5 when the mean for the pre-test for the ComEd team was 18.03, five points difference between the groups.

It can be explained for the way that the program was presented through the recruitment procedure. The JRS program was presented as a research program, when the ComEd was presented as an exploratory program. From the enrollment roster it is possible to see that the teens from the JRS team are enrolled mostly in Chicago Public High School with selective enrollment (the best schools in the city) when the members from the ComEd team are enrolled in their majority in neighborhood Chicago Public High Schools. Also it is possible to see that all the participants had a positive change in their content knowledge. In all the cases, the post-test was higher than the pre-test.

ComEd Youth Ambassadors and Junior Research Scientists - Attitude towards STEM and 21st Century skills analysis

From the 40 initial participants in the program, 30 ComEd Youth Ambassadors teens completed a valid paired pre-survey and post-survey regarding the participant's attitude towards STEM and 21st Century skills. From the analysis of these surveys it is possible to see that there is not significant change in any of the four areas surveyed: Mathematics, Science, Engineering and 21st Century skills as shown in the Table 2

Regarding the Junior Research Scientists, after reviewing the data from 22 valid paired pre-survey and post-survey regarding the participant's attitude towards STEM and 21st Century skills, it is possible to see that there is not significant change in any of the four areas surveyed: Mathematics, Science, Engineering and 21st Century skills as shown in the Table 3

Note: all the statements (positive and negative) in the survey were assessed in a 1 to 5 Likert scale. After converting the negative assessments, the value of 5 represents a positive attitude towards the statement, and the value of 1 represents a negative attitude towards the statement

Table 2. Survey Analysis for the ComEd Youth Ambassadors Program (n=34)

		Mathematics	Science	Engineering	21 st Century
Pre-Survey	Mean	3.73	4.16	4.26	4.35
	S.D.	0.83	0.69	0.69	0.55
Post-Survey	Mean	3.80	4.21	4.04	4.24
	S.D.	0.88	0.85	0.99	0.65

Table 3 – Survey Analysis for the Junior Research Scientists Program (n=22)

		Mathematics	Science	Engineering	21 st Century
Pre-Survey	Mean	4.10	4.28	4.26	4.30
	S.D.	0.73	0.7	0.52	0.47
Post-Survey	Mean	4.14	4.28	4.04	4.29
	S.D.	0.73	0.79	0.83	0.5

The summary of the data collected presented in Table 2 and Table 3, supports the hypothesis that the participants (self-selected) had a positive attitude towards STEM and the 21st Century skills when they enrolled in the program, and this positive attitude continued after the implementation of the program. A paired-samples t-test was conducted to compare if there is a significant change in the Attitude towards STEM of the ComEd Youth Ambassadors and Junior Research Scientists program participants. The results for both groups indicate that there was not a significant change in their attitude towards STEM.

Given that there is not significant change in the mean of attitude of the participants, but a slight increasing in the standard deviation for each of the subjects, this can suggest that the participants, in the post-survey have being more critical about their choices than in the pre-survey.

Outcomes of the programs:

After the six-week program and based in the artifacts and presentations developed by the participants, and the constant conversations between the instructional team and the participants, the formative assessment from the instructional team concludes that in the majority of the cases the participants:

- 1) Gained knowledge in the area of Solar Energy, Robotics and Electricity
- 2) Developed a better understanding of the STEAM fields and careers: The instructional team observed during the six-week intervention how the participants in the both programs started to ask more questions about different STEAM fields, and showed interest in explore by themselves different opportunities to continue their path of discovery in these fields (e.g. asking us for letters of recommendation to join other programs led by different universities, enrolling in the fall session of the program, etc) All the data that supports this outcome is anecdotal
- 3) Acquired skills
 - a) Learning skills that will be useful for them at college time,
 - b) A sense of responsibility, emphasizing that the success of their own work resides in their own investment and dedication,
 - c) Leadership skills and team management
- 4) Participants have a change in their behavior and attitude towards learning understanding that learning is more than pass a test, is the path to develop their own personality, exploring their strong capacities as well as improving those that they are not so strong.

It is important to note that is the believe of the instructional team implementing both programs, that the success to accomplish the outcomes mentioned above relies in the fact that the instructors became mentors, developing a strong personal relation between each participant and the mentor/s. The teens are in need of strong role models that also are available and reachable. The connection developed during the six-week program led, for many of the participants, to continue connected with the program and the mentors, and in this way to continue having access to STEAM experiences.

Conclusion

From the data presented above, it is clear that the six-week summer intervention accomplished its main objective: motivate underrepresented minority high school students to explore the STEAM fields and potential careers. Even though Columbia College Chicago is not offering careers in STEAM, the Comed and JRS program's alumni, whom now are university students pursuing STEAM degrees in prestigious universities such as Carnegie Mellon, MIT, University of Michigan and others, continue participating in the program in their summer break mentoring the new cadre of high school students, shows the long term impact of the project.

The evidence shows that the program has a positive impact in the content knowledge of the participants and maintain a positive attitude towards STEAM and STEAM related fields and careers. Participants also developed leadership capabilities and feeling of belonging, supported by returning participants contributions in our programs after the period of these programs

Programs like those presented in this manuscript have the power to impact the lives of many youth people, that by reason of social pressure or other motives, they do not believe that they are capable to be successful STEAM professionals.

The struggle to motivate and recruit young minority students to join the STEAM field can be addressed by developing a set of interrelated local programs (the accent in LOCAL) based in local or regional universities. These programs can provide an Out of School Time pathways where self-selected students will have the opportunity to be exposed to the STEAM fields and potential careers lead by committed professionals in the field.

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