



University of Nebraska at Omaha  
DigitalCommons@UNO

Biology Faculty Publications

Department of Biology

12-24-2018

# NE STEM 4U afterschool intervention leads to gains in STEM content knowledge for middle school youth

Christine E. Cutucache

*University of Nebraska at Omaha, [ccutucache@unomaha.edu](mailto:ccutucache@unomaha.edu)*

Taylor Boham

*University of Nebraska at Omaha*

Jamie Luhr

*University of Nebraska at Omaha*

Amie Sommers

*University of Nebraska at Omaha*

Nikolaus Stevenson

*University of Nebraska at Omaha*

*See next page for additional authors*

Follow this and additional works at: <https://digitalcommons.unomaha.edu/biofacpub>

 Part of the [Biology Commons](#), and the [Education Commons](#)

## Recommended Citation

Cutucache, Christine E.; Boham, Taylor; Luhr, Jamie; Sommers, Amie; Stevenson, Nikolaus; Sointu, Erkko; Mäkitalo-Siegl, Kati; Kärkkäinen, Sirpa; Valtonen, Teemu; Grandgenett, Neal; and Tapprich, William, "NE STEM 4U afterschool intervention leads to gains in STEM content knowledge for middle school youth" (2018). *Biology Faculty Publications*. 101.

<https://digitalcommons.unomaha.edu/biofacpub/101>

This Article is brought to you for free and open access by the Department of Biology at DigitalCommons@UNO. It has been accepted for inclusion in Biology Faculty Publications by an authorized administrator of DigitalCommons@UNO. For more information, please contact [unodigitalcommons@unomaha.edu](mailto:unodigitalcommons@unomaha.edu).



---

**Authors**

Christine E. Cutucache, Taylor Boham, Jamie Luhr, Amie Sommers, Nikolaus Stevenson, Erkko Sointu, Kati Mäkitalo-Siegl, Sirpa Kärkkäinen, Teemu Valtonen, Neal Grandgenett, and William Tappich



Received: 26 July 2018  
Accepted: 10 December 2018  
First Published: 24 December 2018

\*Corresponding author: Christine Cutucache, Department of Biology, University of Nebraska, Omaha, NE 68182, USA  
E-mail: [ccutucache@unomaha.edu](mailto:ccutucache@unomaha.edu)

Reviewing editor:  
Sammy King Fai Hui, The Education University of Hong Kong, Hong Kong

Additional information is available at the end of the article

## EDUCATIONAL ASSESSMENT & EVALUATION | RESEARCH ARTICLE

# NE STEM 4U afterschool intervention leads to gains in STEM content knowledge for middle school youth

Christine Cutucache<sup>1\*</sup>, Taylor Boham<sup>1</sup>, Jamie Luhr<sup>1</sup>, Amie Sommers<sup>1</sup>, Nikolaus Stevenson<sup>1</sup>, Erikko Sointu<sup>2</sup>, Kati Mäkitalo-Siegl<sup>2</sup>, Sirpa Kärkkäinen<sup>2</sup>, Teemu Valtonen<sup>2</sup>, Neal Grandgenett<sup>3</sup> and William Tappich<sup>1</sup>

**Abstract:** Afterschool interventions in STEM are linked to learning gains during the school day. These opportunities engage and excite students about STEM concepts since they observe a more hands-on, project-oriented approach. Often these opportunities for afterschool interventions are infrequent in nature and leave gaps for students in their maturation and understanding. Herein we describe the first report of an afterschool intervention, named *NE STEM 4U*, targeting socioeconomically disadvantaged middle school youth via a twice weekly, year-long intervention, studied across two years. We assessed the impact of this program on i.) short-term, individual student gains in STEM content knowledge and ii.) delivery of the program in terms of appropriateness for age group and content using the DoS observation tool. We observed statistically significant gains in STEM content knowledge over short-term assessment using a multiple-group, pre-test post-test research design comparing scores in content before and after the intervention. In this report, we highlight the impact of this nascent program in Omaha Public Schools.

**Subjects:** Development Studies, Environment, Social Work, Urban Studies; Social Sciences; Education

**Keywords:** NE STEM 4U; afterschool; STEM; content knowledge; assessment; mentoring

### ABOUT THE AUTHOR

Christine Cutucache The Cutucache Lab studies discipline-based education research (DBER) focusing on content and cognition for students in the sciences. We are interested in student-centered, inquiry-based practices to improve learning outcomes. Active studies include determining the best training for pre-service teachers for robust scientific inquiry in high school science classrooms and learning gains for undergraduates in STEM content areas using various professional development experiences (i.e. using student development theory). Finally, we aim to help students foster critical thinking and metacognition while learning to apply knowledge in the sciences.

### PUBLIC INTEREST STATEMENT

The research presently described in this study is beneficial for the after-school programmer of STEM-related areas, teacher, researcher, etc. The findings provide relevance on capitalizing on out-of-school time via after-school programming by looking at student gains in STEM content knowledge through the NE STEM 4U program. The program utilized DoS observations to validate its involvement in students during out-of-school time. Findings showed that NE STEM 4U can be used as a model organization for positive student learning outcomes as it relates to STEM curriculum.

## 1. Introduction

There exist disparities in the performance of students in science, technology, engineering, and mathematics (STEM) in the United States. Currently, the state of Nebraska reflects these national trends; only 68% of eighth grade Nebraska students are proficient in science, and eighth-grade students from socioeconomically disadvantaged households show proficiencies of only 52% (Nebraska Department of Education, 2017). We are working with the Omaha Public School (OPS) district in the state of Nebraska to address these issues by building on the school day with an afterschool intervention providing hands-on opportunities for youth in STEM content areas, critical thinking skills, and problem-solving skills.

OPS is the largest and most diverse school district in Nebraska, with an enrollment of around 52,000 students who represent approximately 30% of the state's overall student population. Of these, 72% are minorities and 74% receive free- and reduced-lunch (Nebraska Department of Education, 2017). The proficiency rate for eighth-grade students in this district in science is 50%, and less than 35% when considering only those who receive free- or reduced-lunch (Nebraska Department of Education, 2017). These numbers indicate a clear and immediate need to provide additional, and hands-on, opportunities in STEM for Nebraska students. Consequently, afterschool programming has the unique opportunity to build upon the school day while providing the time and resources for youth to engage in genuine active learning strategies that include experimentation and project design.

Afterschool programs that are well-structured for learning are linked to a number of gains, including improved academic performance, attendance rates, social skills, and even STEM interest (Chittum, Jones, Akalin, & Schram, 2017; Kremer, Maynard, Polanin, Vaughn, & Sarteschi, 2015; Lauer et al., 2006; Roberts et al., 2018; Williams, Brule, Kelley, & Skinner, 2018). Furthermore, students who participate in expanded learning opportunities (ELO) are 20% less likely to drop out of school and 30% less likely to participate in criminal activities than peers who did not participate, and participation in informal STEM activities may increase the performance of students with disabilities in science assessments (Fisher, 2017; Vandell, Reisner, & Pierce, 2007). Existing afterschool programs that provide such opportunities to youth utilize various inquiry-based pedagogical approaches such as Inquiry-Based Learning (IBL). These inquiry-based approaches to learning are generally related to constructivist views on learning, emphasizing several elements such as: 1) prior knowledge of learner, 2) learning from fellow students in social situations, 3) self-regulation of learner (i.e., goal setting, planning and monitoring learning), and 4) meaningful/profession related tasks in learning (Loyens & Rikers, 2011). This highlights practices of active learning and central role of questions and problems generated by learners (Chin & Brown, 2002; Chin & Osborne, 2008). Inquiry-based approaches have been found to improve critical and creative thinking (Casotti, Rieser-Danner, & Knabb, 2008), and higher academic performance (Taraban, Box, Myers, Pollard, & Bowen, 2007; Wilson, Taylor, Kowalski, & Carlson, 2010) regardless of earlier academic success (Lewis & Lewis, 2008)

Inquiry-based approaches (e.g. Inquiry-based learning, problem-based learning, Peer-led team learning) is a student-centered, active learning strategy that engages students in hands-on activities that require them to communicate, conjecture, create, experiment, explore, and solve problems or challenges (Loyens & Rikers, 2011). The goal of IBL is to engage students in the learning process, enhance questioning (critical thinking) and problem-solving, communication, and boost long-term retention of material (Chng, Yew, & Schmidt, 2011; Loyens & Rikers, 2011). Activities performed by students in IBL classrooms, are assumed to reflect a student's knowledge in information search, knowledge related to the content and metacognitive knowledge (Lin, Hmelo, Kinzer, & Secules, 1999). Various levels of student-centeredness (i.e., what kind of a role instructor takes) can be found in the inquiry-based approaches, but just information gathering from literature or internet is not seen as IBL (Bell, Smetana, & Bins, 2005). IBL has been shown to help students at

all levels learn complex concepts, particularly in science and mathematics (Lauer et al., 2006; Love, Hodge, Corritore, & Ernst, 2015). In addition, these inquiry-based approaches have been reported to improve student understanding and retention of STEM information (American Association for the Advancement of Science [AAAS], 2011; Chng et al., 2011; Dahlquist & Cutucache, 2013). Especially, the studies show that students are engaged in inquiry-based activities when the goal is meaningful for them and there is a clear product at the end (Lazonder & Harmsen, 2016). Minner, Levy, & Century, (2009) consider a clear positive trend favoring active inquiry-based approaches: conceptual understanding can be increased with instructional strategies that actively engage students to learning through scientific investigations than those strategies which are based on a more passive view of the student.

Several studies indicate that well-structured afterschool programs improve learning, and that inquiry-based approaches and team (collaborative) learning in formal educational settings also shows similar gains (Lauer et al., 2006; Mäkitalo-Siegl, Kohnle, & Fischer, 2011). Moreover, inquiry-based approaches provide freedom for students, meaning that students can regulate their own learning processes in order to be high-achievers (Mäkitalo-Siegl & Fischer, 2013). However, this indicates that under an inquiry-based model, more instruction and support should be provided for students that demonstrate lower-level problem-solving skills, critical thinking, and metacognition (Mäkitalo-Siegl et al., 2011). In inquiry-based approaches, students are usually working in teams, which can promote learning in social situations. With smaller teams (i.e., smaller groups), question-asking is more possible for students which can guide learning and allow the instructor to appraise students' critical thinking (Baumfield & Mroz, 2002; Chin & Osbourne, 2008). In this research study, we aimed to use inquiry-based active learning strategies in a well-structured afterschool program, NE STEM 4U (Cutucache, Luhr, Nelson, Grandgenett, & Tapprich, 2016; Leas, Nelson, Grandgenett, Tapprich, & Cutucache, 2017), to engage youth from the OPS district in STEM experiments. This study uses a Constructivist theoretical framework (Piaget). As a result, we used a mixed methods research design to include pre- and post-test assessments (quantitative) as well as dimensions of success from outside observers (qualitative). These data were triangulated with a heavier emphasis on quantitative data to assess student learning gains in content knowledge. We gathered data in terms of content knowledge gains, as well as conducted observations.

NE STEM 4U was founded at the University of Nebraska at Omaha (UNO) in 2013 and designed to enhance the knowledge and performance of Nebraska's youth in STEM disciplines by including them in engaging, hands-on lessons through ELO. This program takes place during afterschool hours and targets socioeconomically disadvantaged middle schools from OPS, specifically grades 5–8. Importantly, the program aligns with the principles put forward by the American Association for the Advancement of Science (AAAS, 2011) in its report, *Vision and Change in Undergraduate Biology Education: A Call to Action*, through the use of undergraduates as the primary mentors to K-8 students. Mentors engage youth in age-appropriate active learning experiences that will help them develop STEM knowledge and skills.

While we observe gains from all participants in the program (i.e. both undergraduates and youth in grades 5–8), the purpose of this report was to investigate learning gains among middle school students consistently participating in the afterschool intervention, NE STEM 4U. Programmatic information, including all assessments used with K-16 participants, structure of the program, and pilot feedback from undergraduates can be found by Cutucache et al., 2016, as well as the impact of the program on elementary school youth in Leas et al., 2017. Briefly, undergraduates report gains in 21<sup>st</sup> Century Skills citing the importance of working with faculty mentors and metacognition on the impact of their own teaching on youth. Undergraduates report a strong benefit to their own education and training, STEM content knowledge and organizational skills (Nelson et al., 2017). Moreover, elementary youth participants demonstrated gains in curiosity, inquiry, and scientific thinking (Leas et al., 2017). The program has been serving the OPS district for three school years, and continues to grow and develop new strategies to better serve the student

population. Herein, we report the results of this intervention using pre- and post-test assessments for short-term gains and results of observations using the Dimensions of Success (DoS) tool (Program in Education, Afterschool & Resiliency, 2015) on youth in grades 5–8.

The following are our research questions for this study:

- (1) What content gains are attributed to the NE STEM 4U intervention in grades 5–8?
- (2) What are the strengths and weaknesses of the NE STEM 4U intervention as identified by DoS evaluations?

## 2. Methods

### 2.1. Participants

All subjects described in this report were consented by the University of Nebraska Medical Center/ University of Nebraska at Omaha Institutional Review Board (IRB): Protocol #442–13-EP. All data were collected and analyzed under the IRB-approved protocol. A total of 1,103 youth participated in the NE STEM 4U program from the Fall 2013 through the Spring 2015 school semesters. A total of seven schools from the OPS district were included in the program as selected based on being the lowest performers on standardized test scores in STEM content and the highest percentages of socioeconomically disadvantaged students enrolled (Omaha Public Schools, 2014a). The student population from the seven schools consisted of the following ethnicities: 36.1% Hispanic, 28.3% African American, 24.4% Caucasian, 5.4% Asian American, 4.5% multi-racial, 1.2% American Indian, and 0.1% Pacific Islander (Omaha Public Schools, 2014b). Students who receive free- or reduced-lunch are required to attend afterschool programming, but are able to choose which activity they would like to attend each of the four 6–8 week sessions provided throughout the school year (e.g. STEM, sports, drama club, and reading club).

All youth in the NE STEM 4U program were mentored through this afterschool intervention by UNO undergraduate and graduate students. After training, each mentor committed to a minimum of 3-h per week preparing and teaching lessons (lessons were conducted by two or more mentors). The NE STEM 4U intervention visited each school twice weekly throughout the academic year.

### 2.2. Multiple-group, pre-test and post-test research design

Pre- and post-tests were implemented to determine the impact on student performance in the afterschool program in STEM content areas. A total of 2,993 pre- and post-tests were given among the 1,103 participants between Fall 2013 and Spring 2015 semesters in 8, 6–8 week sessions. The questions on these tests were constructed based on Bloom’s taxonomy, with each test consisting of five questions (i.e. two multiple choice and three short answer questions; Table 1). Mentors at each school presented the students with questions by oral and/or written means. Each question was worth two points (or 20%), allowing a high score of 10 (100%) possible for each pre- and post-test (students earned a “2” for a correct answer, a “1” for a partially correct response, and a “0” for

**Table 1. Example of pre- and post-test, “Rise of the Yeast” Lesson**

Rise of the Yeast Lesson Questions		
1.	What is fermentation? Choose A-D	Multiple Choice
2.	What does is mean when an organism is dormant? Choose A-D	Multiple Choice
3.	Is yeast a unicellular or multicellular organism?	Short Answer
4.	How can we determine when yeast cells are in an active state?	Short Answer
5.	Yeast cells are very common. We can find them in a variety of products that we use on an everyday basis. Please provide an example of yeast being beneficial to humans and yeast being unfavorable.	Short Answer

an incorrect answer). We computed fold change, average fold change, standard error and standard deviation (depending upon sample size), average pre- and post-test scores, and consistency across attendees. The statistical significance was determined by computing p-values using a paired Student's t-test with unequal variances.

### **2.3. Statistical analyses of pre-test and post-tests**

The multiple-group, pre-test post-test research design was used to assess short-term STEM content knowledge gains of youth in grades 5–8. We performed an unpaired Student's t-test assuming unequal variances for this research design. All data were assessed for outliers and only weak outliers were identified; therefore, all data were included in our analyses. In the multiple-group, pre-test post-test research design, we compared gains for individual students on post-tests as compared with pre-tests. Furthermore, we computed average fold change across students that attended NE STEM 4U at least 50% of the provided lessons (intervention group) as compared with those who attended less than 50% (control group). These data were analyzed using the Mann-Whitney test for unpaired data.

### **2.4. Dimensions of success**

The DoS observation tool was used to evaluate the quality of the NE STEM 4U program. The Program in Education, Afterschool, & Resiliency (PEAR) at Harvard University created this observational assessment tool as part of an NSF-sponsored project to assess STEM ELO quality (Program in Education, Afterschool & Resiliency, 2015). This program was approved and began certifying observers at a small scale in 2010 and has grown exponentially since 2013. The Dimensions of Success observation tool focuses on 12 indicators of STEM program quality when not in school. The 12 indicators can be categorized into four areas: the features of the learning environment, activity engagement, STEM knowledge and practices, and youth development in STEM. These four categories present the over-arching themes encompassed by the 12 total indicators of the DoS. The certified personnel use this to gauge the success of the after-school programming. Table 2 provides some qualitative observation examples made with the DoS tool used in this study. An external, unbiased DoS-certified observer used the DoS observation tool to determine the quality of programming of NE STEM 4U. The observer was external to the research team, program, and University and the DoS tool relies upon objective observations provided verbatim of the youth to provide scoring, thereby additionally avoiding bias. Similarly, for additional replicates, two internal researchers certified in DoS conducted a total of four DoS observations. The observation data were similar across all observers, indicating reliability. A total of two DoS evaluations per session per school were conducted. Each observation ranks the program in 12 areas. The rubric allows for each of the 12 dimensions to score between a one (lowest) and four (highest) with averages computed from Fall 2014—Fall 2015. Lessons were revised monthly based on feedback from DoS evaluations in collaboration with the College of Education to ensure quality and alignment with school day curricula in the program.

## **3. Results**

A total of 1,103 students in fifth-eighth grades across seven Omaha Public Schools participated in the NE STEM 4U afterschool program from Fall 2013 through Spring 2015. Those participants were given pre- and post-tests to determine changes in content knowledge. The two groups were: students that participated in the NE STEM 4U intervention at least 50% of the provided lessons, and demographically matched students that participated in the program less than 50%. We compared the results of short-term (immediate) performance increases (i.e. before an exercise as compared with immediately after an exercise) through pre- and post-test assessments (Figure 1) and classroom observations using Dimensions of Success (Table 3). With these assessments, our goal was to i.) determine what content gains are attributed to the NE STEM 4U intervention in grades 5–8 and ii.) determine the strengths and weaknesses of the NE STEM 4U intervention as identified by DoS evaluation.

**Table 2. Summary of the specific 12-dimensions for the Dimensions of Success assessment instrument. The Dimensions of Success (DoS) instrument includes four major categories (i.e. Features of the Learning Environment; Activity Engagement; STEM Knowledge and Practices; Youth Development in STEM) with 12-total indicators (i.e. organization, materials, space utilization, participation, purposeful activities, engagement with STEM, STEM content learning, inquiry, reflection, relationships, relevance, and youth voice). This table includes the dimensions of success (DoS) indicators (left) and its respective sub-category from the indicators with supportive observational, qualitative text from observers evaluating the NE STEM 4U program**

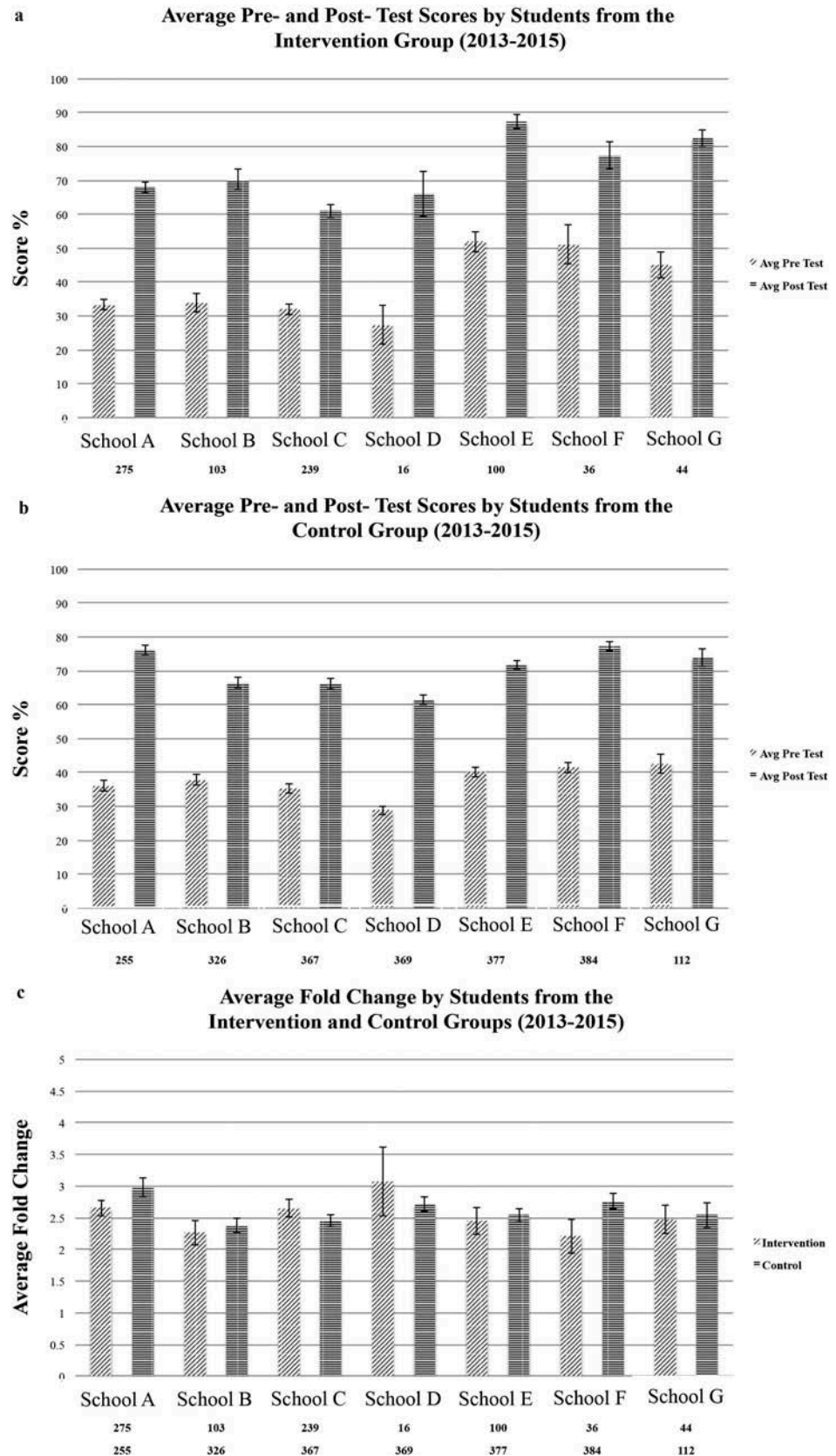
<b>DoS Indicator (Sub-category)</b>	<b>Observation (Direct quotes from observers)</b>
Organization (Features of the Learning Environment)	-All of the materials are ready and there is enough for every student to participate. -The mentors prepared ahead of time and knew where they should stop and start the video.
Materials (Features of the Learning Environment)	- The materials are appropriate for the goal. The different illusions on the screen are age appropriate and appealing. - The students said things like, "It sank! It just dove!" which shows that the materials were appealing to the students.
Participation (Activity Engagement)	-Sometimes useful prompts like: "If you guys want to come sit up in the front and join in on the activity please!" -At times, when students get distracted the mentors bring attention back.
Engagement with STEM (Activity Engagement)	- The lesson was completely hands on, allowing the students to make their own density divers. - The students all have the opportunity to engage in the illusion games. Reacting to the illusions would be a "hands on" approach.
Inquiry (STEM Knowledge & Practices)	-One student said, "I want to see if this will bounce." And so he did his own experiment to see if the polymer was bouncy. -Students are able to ask questions, make their own slime, and to answer difficult questions.
Reflection (STEM Knowledge & Practices)	- The students are able to discuss what they experienced during the illusions. "First of all, it looks like the green and red kind of submerged together. This one seems brighter and this one seems darker." - After the activity is over, the mentor provides a closing discussion over what was learned. The mentors asks questions and the students give responses like, "Cause we were pushing water into the diver which made less space and it has no air."
Youth Voice (Youth Development in STEM)	-Students are always a part of the conversation and are able to share their ideas. -When a student wants to help pick up papers, she is given the opportunity: "Can I pick them up please?" "Yeah of course you can!"
Relationships (Youth Development in STEM)	- The students feel comfortable with the mentors and are not afraid to ask questions. Overall, there is a positive environment. - The relationships between students are positive, and the relationship between the students and facilitators is neither neutral.

### 3.1. Content gains attributed to the NE STEM 4U intervention

When assessing the impact of short-term, or immediate, changes in student understanding across middle school students, we observed an increase across all schools (Figure 1(a-b)). When comparing performance by students in the intervention before and after the daily activity, we observed significant gains in content knowledge as assessed by pre- and post-tests (n = 813) (Figure 1(a)). The control group, in addition to the intervention, showed a significant increase in short-term content knowledge (Figure 1(b)). Overall, students who participate in the NE STEM 4U program are achieving significantly higher post-tests than pre-tests (Figure 1(a-b)). The average fold changes for each school in both intervention and control groups were greater than 2 (Figure 1(c)). The average pre- and post-test scores for youth in the NE STEM 4U intervention were 37.17% and 69.86%, respectively, as compared with 37.45% and 70.34%, respectively, in the control (non-intervention)



**Figure 1. Results of pre-test and post-test scores for 2013–2015. (a and b) Average score of intervention and control groups for 2013–2015, respectively. All differences between pre- and post-tests were statistically significant ( $p < 0.005$ ). (c) Average fold change of intervention versus control groups. Sample size of each cohort is reported as the number below each school's scores, with fold change including both pre- and post-tests, respectively.**



**Table 3. Dimensions of Success (DoS) tool used to assess the NE STEM 4U program. Average score of observations on a scale of 1 (lowest) to 4 (highest). A total of n = 52 observations were conducted and are reported here**

	Fall 2014	Spring 2015	Fall 2015	All Semesters
Category	Average	Average	Average	Average
	n = 15	n = 19	n = 18	n = 52
Organization	2.9	3.2	3.2	3.1
Materials	3.1	3.5	3.5	3.4
Space Utilization	3.2	3.5	3.9	3.5
Participation	3.0	3.2	3.0	3.1
Purposeful Activities	2.6	3.0	3.0	2.9
Engagement with STEM	2.9	3.0	2.8	2.9
STEM Content Learning	2.9	2.9	2.8	2.9
Inquiry	2.5	3.0	2.8	2.8
Reflection	2.3	2.9	2.6	2.6
Relationships	3.2	3.6	3.4	3.4
Relevance	2.0	2.4	2.3	2.2
Youth Voice	2.3	3.0	2.7	2.7

group. All differences between pre- and post-test scores for both the control and intervention groups were statistically significant (Figure 1,  $p < 0.005$ ).

Furthermore, we conducted a Mann-Whitney test to determine content knowledge gains between pre-test and post-test for students in the NE STEM 4U intervention (i.e. true experimental group) compared with that of the control (i.e. students age-, gender-, race-, and grade-matched non-NE STEM 4U intervention participants). This test showed a significant difference between the intervention and control post-test scores of School A ( $U = 27,949.0$ ,  $T = 74,816.0$ ,  $P < 0.001$ ) and School B ( $U = 1983.0$ ,  $T = 3935.0$ ,  $P = 0.0050$ ). There was also a significant difference between the intervention and control groups for pre- and post-test scores at School C ( $U = 39,646.0$ ,  $T = 68,326.0$ ,  $P = 0.042$  and  $U = 39,268.0$ ,  $T = 67,948.0$ ,  $P = 0.027$ , respectively) and School E ( $U = 14,779.0$ ,  $T = 27,971.0$ ,  $P < 0.001$  and  $U = 12,231.0$ ,  $T = 30,519.0$ ,  $P < 0.001$ , respectively).

### 3.2. Results of classroom observations using the dimensions of success tool

A total of 52 observations were conducted across the school sites occurring at least twice for every session of the NE STEM 4U program beginning in Fall 2014 (when the tool was available). The average scores are included as results of these observations and organized by category in Table 3. The DoS observation tool was used for objective qualitative and quantitative analyses of the NE STEM 4U program. The NE STEM 4U program scored highest, on average, in five major areas: organization, materials, space utilization, participation, and relationships (average scores of 3.1, 3.4, 3.5, 3.1, 3.4, respectively). Conversely, we observed from this tool the main areas of weakness of relevance (avg. 2.2) followed by reflection and youth voice (avg. 2.6 and 2.7, respectively). It is interesting to note for the Fall 2014 through the Spring 2015 year, there was an increase of average scores in each dimension over the course of the school year (Fall 2014–2.74; Spring 2015–3.1; Fall 2015–3.0).

## 4. Discussion

This report describes a nascent intervention in Omaha, Nebraska in the Omaha Public Schools district called NE STEM 4U. This intervention is an outreach program to capitalize on the out of school time hours for youth in grades 5–8 in an effort to provide hands-on opportunities for

youth to engage in STEM concepts and strengthen their content knowledge. Secondary objectives of the program include the development of critical thinking and problem-solving skills by the youth (to be discussed in a future report). Moreover, undergraduates serve as the major mentors in this intervention and we describe the impact on this cohort in a separate paper (Nelson et al., 2017).

Specifically, we examined two research questions: i.) what content gains are attributed to the NE STEM 4U intervention in grades 5–8? And ii.) what are the strengths and weakness of the NE STEM 4U intervention as identified by DoS evaluations? We observed student gains (both in control and intervention groups) from pre-test to post-test as expected. As observed in Figure 1(c), the fold change between control and intervention did not show statistical significance based on orders of magnitude. (For example, a student who scores a 50% and 100% on the pre- and post-tests respectively will achieve a fold change of 2. However, a student who scores a 10% and 30% on the pre- and post-tests, respectively, will show a higher fold change of three than that of the student who achieved overall higher scores. Because fold change measures magnitude without regard to the application of the STEM discipline, our next research objective will be to have students demonstrate their application of the information.) Briefly, we aim to identify whether students can demonstrate the ability to think and act in a scientific way, as active learning should foster these types of processes. Future research questions will include whether students in the intervention can follow the scientific method more accurately than those in the control group, and, when given a problem, if those in the intervention stay on-task and persevere longer than those in the control group.

When considering content knowledge alone, the average fold change when compared between intervention and control groups show that on average, a student in either group is performing better on the post-tests. However, we observed statistical significance between the control and intervention group as a result of Mann-Whitney testing in Schools A and B post-tests in addition to Schools C and E pre- and post-test scores.

Additionally, we conducted external evaluations of the program using DoS and observed the program was most effective in an organization, appropriate materials for the age group and lesson, space utilization was conducive to the activity, student participation was encouraged, and youth-mentor relationships were built. In regards to the increase of DoS evaluation scores over the semester, we believe the new mentors are able to gain a better understanding of the NE STEM 4U program, the schools, and the students (K-8) during the first semester. These new mentors along with previous mentors are then able to apply these understandings in future semesters and at different schools. Moreover, this program is expanding to additional cities in the 2017–2018 year, to determine reliability potential as a national model.

#### **4.1. Global impact**

Data regarding middle school students' STEM learning gains are relatively limited (Williams et al., 2018). Presently, more research needs to be conducted to better understand the role that afterschool programs play in STEM content learning for middle school students during out-of-school time. However, some new findings have provided important information for researchers looking to capitalize on this out-of-school time. Chittum et al. (2017) found that afterschool programs can halt the decline of motivational beliefs on science that typically occur in the middle school years. These findings indicate that afterschool programming is one way to help students maintain their motivation toward science during a critical time (Chittum et al., 2017). Afterschool programming that includes science in learning gardens ("SciLG") has provided additional insight on programming and the influence that it has on student engagement being more productive and that their perceptions of themselves change to that of being able to contribute and be valuable to the science community (Williams et al., 2018). Programming for middle school students during non-traditional learning time was also found to be beneficial during the summer months. Most importantly, hands-on activities and related opportunities for

students that are not traditionally available in a school setting are valuable components to the learning experience (Roberts et al., 2018). Since the approach described herein could be implemented in any out-of-school time setting, not dependent upon location, we suggest this program for implementation in other sites.

#### 4.2. Limitations

There are a few limitations to this study, including the method in which the pre- and post-tests were administered to students. Tests were administered based on students' needs as well as provided school materials. Specifically, some mentors would state the questions orally as well as have the questions visually represented, and others only had them visually or orally represented. Consequently, this may affect student understanding of a question (based on different learning styles). Time constraints were another limitation. After school bussing schedules, parents picking their children up early, etc., meant some students left the lesson before the post-test was administered, thus not receiving the full benefit of the program. Consequently, data was lost in regard to that student's learning gains. Finally, in an effort to control for the impact of having several mentors, we used a large sample size to mitigate the mentor-specific impact, but it remains a challenge to fully control for this variable.

#### 4.3. Summary

This pilot of a new intervention called NE STEM 4U suggests this model as an effective program to lead to content gains in STEM areas by socioeconomically disadvantaged youth in grades 5–8. This study indicates that the NE STEM 4U program might be an effective national model to be implemented in metropolitan cities to engage youth. Moreover, the secondary outcomes of such a program include 21<sup>st</sup> century learning skills and career preparation skills including critical thinking and problem-solving skills. We suggest that this program is helpful in improving proficiencies in STEM content by youth, though more data are necessary to determine frequency with which youth must attend for the program to be most beneficial as well as the need to determine if students that participate in the intervention can indeed “think like scientists”, including tenacity when an experiment failed, as compared with their peers in the control group.

#### Acknowledgements

Thanks to the Nebraska Children's Learning Center Network and Beyond School Bells, particularly Jeff Cole and Julie Sigmon, for assisting in DoS training opportunities for our staff. The authors acknowledge The Sherwood Foundation (C.C., N.G., and W.T.), UNO's Office of Research and Creative Activity (T.B.), Nebraska Research Initiatives (W.T. and C.C.), and the Nebraska University Foundation (C.C.) for funding of this project. Thanks to Collective for Youth staff for helping to make these opportunities possible to youth at a citywide level. Thanks especially to Megan Addison, Gwyn Williams, and Nicole Everingham. Thanks also to all youth participants, the Omaha Public Schools afterschool site directors, and the administrative leadership at Omaha Public Schools, including Dr. Chris Schaben. The authors declare no conflict of interest.

#### Funding

This work was supported by the The Sherwood Foundation [2614].

#### Author details

Christine Cutucache<sup>1</sup>  
E-mail: [ccutucache@unomaha.edu](mailto:ccutucache@unomaha.edu)  
ORCID ID: <http://orcid.org/0000-0001-5091-0713>  
Taylor Boham<sup>1</sup>  
E-mail: [tboham@unomaha.edu](mailto:tboham@unomaha.edu)  
Jamie Luhr<sup>1</sup>  
E-mail: [jknehans@unomaha.edu](mailto:jknehans@unomaha.edu)  
Amie Sommers<sup>1</sup>  
E-mail: [asommers@huskers.unl.edu](mailto:asommers@huskers.unl.edu)  
Nikolaus Stevenson<sup>1</sup>  
E-mail: [nstevenson@unomaha.edu](mailto:nstevenson@unomaha.edu)  
Erkko Sointu<sup>2</sup>

E-mail: [erkko.sointu@uef.fi](mailto:erkko.sointu@uef.fi)

Kati Mäkitalo-Siegl<sup>2</sup>

E-mail: [kati.makitalo-siegl@uef.fi](mailto:kati.makitalo-siegl@uef.fi)

Sirpa Kärkkäinen<sup>2</sup>

E-mail: [sirpa.karkkainen@uef.fi](mailto:sirpa.karkkainen@uef.fi)

Teemu Valtonen<sup>2</sup>

E-mail: [teemu.valtonen@uef.fi](mailto:teemu.valtonen@uef.fi)

Neal Grandgenett<sup>3</sup>

E-mail: [ngrandgenett@unomaha.edu](mailto:ngrandgenett@unomaha.edu)

William Tappich<sup>1</sup>

E-mail: [wtappich@unomaha.edu](mailto:wtappich@unomaha.edu)

<sup>1</sup> Department of Biology, University of Nebraska, Omaha, NE 68182, USA.

<sup>2</sup> Department of Teacher Education, University of Eastern Finland, Joensuu 80100, Finland.

<sup>3</sup> Department of Teacher Education, University of Nebraska at Omaha, Omaha, NE 68182, USA.

#### Citation information

Cite this article as: NE STEM 4U afterschool intervention leads to gains in STEM content knowledge for middle school youth, Christine Cutucache, Taylor Boham, Jamie Luhr, Amie Sommers, Nikolaus Stevenson, Erkko Sointu, Kati Mäkitalo-Siegl, Sirpa Kärkkäinen, Teemu Valtonen, Neal Grandgenett & William Tappich, *Cogent Education* (2018), 5: 1558915.

#### References

[AAAS] American Association for the Advancement of Science (2011). Vision and change in undergraduate biology education: a call to action. *Final report of a national conference organized by AAAS with support from the National Science Foundation*, Washington,

- DC. 2009, July 15–17. Retrieved from <http://visionandchange.org/files/2013/11/aaas-VISchange-web1113.pdf>
- [OPS] Omaha Public School. (2014a). Retrieved from <http://district.ops.org/DEPARTMENTS/GeneralFinanceandAdministrativeServices/Research.aspx>
- [OPS] Omaha Public School. (2014b). Retrieved from <http://district.ops.org/Portals/0/RESEARCH/Docs/Statistical%20Reports/MembershipEthnicity/2014-15%20Official%20Fall%20Membership.pdf>
- Baumfield, V., & Mroz, M. (2002). Investigating pupils' questions in the primary classroom. *Educational Research*, 44(2), 129–140. doi:10.1080/00131880110107388
- Bell, R. L., Smetana, L., & Binn, I. (2005). Simplifying inquiry instruction. *The Science Teacher*, 72(7), 30–33.
- Casotti, G., Rieser-Danner, L., & Knabb, M. T. (2008). Successful implementation of inquiry-based physiology laboratories in undergraduate major and non-major courses. *Advances in Physiology Education*, 32(4), 286–296. doi:10.1152/advan.00100.2007
- Chin, C., & Brown, D. E. (2002). Student-generated questions: A meaningful aspect of learning in science. *International Journal of Science Education*, 24(5), 521–549. doi:10.1080/09500690110095249
- Chin, C., & Osborne, J. (2008). Students' questions: A potential resource for teaching and learning science. *Studies in Science Education*, 44(1), 1–39. doi:10.1080/03057260701828101
- Chittum, J. R., Jones, B. D., Akalin, S., & Schram, Á. B. (2017). The effects of an afterschool STEM program on students' motivation and engagement. *International Journal of STEM Education*, 4(1), 11. doi:10.1186/s40594-017-0065-4
- Chng, E., Yew, E. H., & Schmidt, H. G. (2011). Effects of tutor-related behaviors on the process of problem-based learning. *Advances in Health Science Education Theory Practices*, 16(1), 491–503. doi:10.1007/s10459-011-9282-7
- Cutucache, C. E., Luhr, J. L., Nelson, K. L., Grandgenett, N. F., & Tapprich, W. E. (2016). NE STEM 4U: An out-of-school time academic program to improve achievement of socioeconomically disadvantaged youth in STEM areas. *International Journal of STEM Education*, 3(6), 1–7. doi:10.1186/s40594-016-0037-0
- Dahlquist, L. M., & Cutucache, C. E. (2013). Effectiveness of PBL in a large, undergraduate classroom setting. *Cider Online*. Retrieved from <http://www.cider.vt.edu/conference/proceedings/2014ConferenceProceedings.pdf>
- Fisher, K. (2017). The correlation between extracurricular STEM activities and students with disabilities. In *Proceedings of the Interdisciplinary STEM Teaching and Learning Conference*, 1(1), 56–72.
- Kremer, K. P., Maynard, B. R., Polanin, J. R., Vaughn, M. G., & Sarteschi, C. M. (2015). Effects of after-school programs with at-risk youth on attendance and externalizing behaviors: A systematic review and meta-analysis. *Journal of Youth Adolescence*, 44(3), 616–636. doi:10.1007/s10964-014-0226-4
- Lauer, P. A., Akiba, M., Wilkerson, S. B., Apthorp, H. S., Snow, D., & Martin-Glenn, M. L. (2006). Out-of-school time programs: A meta-analysis of effects for at-risk students. *Review of Educational Research*, 76, 275–313. doi:10.3102/00346543076002275
- Lazonder, A. W., & Harmsen, R. (2016). Meta-analysis of inquiry-based learning: Findings of guidance. *Review of Educational Research*, 86(3), 1–38. doi:10.3102/0034654315627366
- Leas, H., Nelson, K., Grandgenett, N., Tapprich, W., & Cutucache, C. (2017). Fostering curiosity, inquiry, and scientific thinking in elementary school students: Impact of the NE STEM 4U intervention. *Journal of Youth Development*, 12(2), 103–120. doi:10.5195/JYD.2017.474
- Lewis, S. E., & Lewis, J. E. (2008). Seeking effectiveness and equity in a large college chemistry course: An HLM investigation of peer-led guided inquiry. *Journal of Research in Science Teaching*, 45(7), 794–811. doi:10.1002/tea.v45:7
- Lin, X., Hmelo, C., Kinzer, C. K., & Secules, T. J. (1999). Designing technology to support reflection. *Educational Technology Research and Development*, 47, 43–62. doi:10.1007/BF02299633
- Love, B., Hodge, A., Corritore, C., & Ernst, D. C. (2015). Inquiry-based learning and the flipped classroom model. *Primus: Problems, Resources & Issues In Mathematics Undergraduate Studies*, 25(8), 745–762. doi:10.1080/10511970.2015.1046005
- Loyens, S. M., & Rikers, R. M. J. P. (2011). Instruction based on inquiry. In R. E. Mayer & P. A. Alexander (Eds.), *Handbook of research on learning and instruction* (pp. 361–381). New York, NY: Routledge.
- Mäkitalo-Siegl, K., & Fischer, F. (2013). Help seeking in computer-supported collaborative science learning environments. In S. A. Karabenick & M. Puustinen (Eds.), *Advances in help-seeking research and applications: The role of emerging technologies* (pp. 99–120). Charlotte, NC: Information Age Publishing.
- Mäkitalo-Siegl, K., Kohnle, C., & Fischer, F. (2011). Computer-supported collaborative inquiry learning and classroom scripts: Effects on help-seeking processes and learning outcomes. *Learning and Instruction*, 21(2), 257–266. doi:10.1016/j.learninstruc.2010.07.001
- Minner, D. D., Levy, A. J., & Century, J. (2009). Inquiry-based science instruction—What is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of Research in Science Teaching*, 47(4), 474–496. doi:10.1002/tea.20347
- Nebraska Department of Education. (2017). *2016-2017 State of the Schools Report - A report on nebraska public schools*. Retrieved from <http://nep.education.ne.gov/>
- Nelson, K., Sabel, J., Forbes, C., Grandgenett, N., Tapprich, W., & Cutucache, C. (2017). How do undergraduate STEM mentors reflect upon their mentoring experiences in an outreach program engaging K-8 youth? *International Journal of STEM Education*, 4, 3. doi:10.1186/s40594-017-0057-4
- Program in Education, Afterschool & Resiliency. (2015). *Dimensions of success*. Retrieved from <http://www.pearweb.org/tools/dos.html>
- Roberts, T., Jackson, C., Mohr-Schroeder, M. J., Bush, S. B., Maiorca, C., Cavalcanti, M., ... Cremeans, C. (2018). Students' perceptions of STEM learning after participating in a summer informal learning experience. *International Journal of STEM Education*, 5(1), 35. doi:10.1186/s40594-018-0133-4
- Taraban, R., Box, C., Myers, R., Pollard, R., & Bowen, C. W. (2007). Effects of active-learning experiences on achievement, attitudes, and behaviors in high school biology. *Journal of Research in Science Teaching*, 44(7), 960–979. doi:10.1002/(ISSN)1098-2736
- Vandell, D. L., Reisner, E. R., & Pierce, K. M. (2007). *Outcomes linked to high-quality afterschool programs: Longitudinal findings from the study of promising afterschool programs*. Irvine, CA: University of California, Irvine.

Williams, D. R., Brule, H., Kelley, S. S., & Skinner, E. A. (2018). Science in the Learning Gardens (SciLG): A study of students' motivation, achievement, and science identity in low-income middle schools. *International Journal of STEM Education*, 5(1), 8. doi:10.1186/s40594-018-0104-9

Wilson, C. D., Taylor, J. A., Kowalski, S. M., & Carlson, J. (2010). The relative effects and equity of inquiry-based and commonplace science teaching on students' knowledge, reasoning, and argumentation. *Journal of Research in Science Teaching*, 47(3), 276–301.



© 2019 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:

Share — copy and redistribute the material in any medium or format. Adapt — remix, transform, and build upon the material for any purpose, even commercially.

The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.

You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

No additional restrictions

You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.



**Cogent Education (ISSN: 2331-186X) is published by Cogent OA, part of Taylor & Francis Group.**

**Publishing with Cogent OA ensures:**

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

**Submit your manuscript to a Cogent OA journal at [www.CogentOA.com](http://www.CogentOA.com)**

