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Students' Attitudes Toward Science as Predictors of Gains on Student Content Knowledge: Benefits of an After-School Program

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Abstract

High-quality after-school programs devoted to science have the potential to enhance students' science knowledge and attitudes, which may impact their decisions about pursuing science-related careers. Due to the unique nature of these informal learning environments, an understanding of the relationships among aspects of students' content knowledge acquisition and attitudes toward science may aid in the development of effective science-related interventions. We investigated the impact of a semester-long after-school intervention utilizing an inquiry-based infectious diseases curriculum (designed for use after-school) on 63 urban students' content knowledge and aspects of their attitudes towards science. Content knowledge increased 24.6% from pre- to posttest. Multiple regression analyses indicated suggested that the "self-directed effort" subscale of the Simpson-Troost Attitude Questionnaire - Revised best predicted increases in students' science content knowledge. The construct "science is fun for me" served as a suppressor effect. These findings suggest that future after-school programs focusing on aspects of attitudes toward science most closely associated with gains in content knowledge might improve students' enthusiasm and academic preparedness for additional science coursework by improving student attitudes towards their perceptions of their self-directed effort.

Keywords

attitudes; science; curriculum evaluation

Despite a growing need for individuals with both expertise in and a general understanding of science-related fields, many Western countries have observed a decline in student interest in both studying and pursuing careers in scientific subject areas (Osborne, Simon, & Collins, 2003; Owen et al., 2008). The science education community has put forth much effort to understand this decline, and to find ways to promote student pursuit of science coursework and scientific careers. Students' attitudes toward science have received particular consideration because of the breadth of their potential impact on a child's career choice behaviors.

As students progress through school, their levels of interest in science influence their course selections, as well as the career paths they eventually pursue; therefore an early avoidance of, or disinterest in science can have long lasting repercussions (Turner & Ireson, 2010). Research has focused upon late elementary and middle school students, in particular, because student attitudes toward science and interest in science-related careers are established before students enter secondary school, possibly as early as age 11 (DeWitt et al., 2011; Gibson & Chase, 2002; Turner & Ireson, 2010). By eighth grade, students demonstrating an interest in science careers have been found to be more likely to graduate with a four-year undergraduate degree in science than their peers who did not express an interest in science (Tai, Liu, Maltese, & Fan, 2006). Broadly, then, it is important to identify approaches to increase younger students' positive attitudes toward science, and to understand the aspects of these attitudes most closely related to positive student achievement levels. This study investigated whether an activity-based, discovery-oriented after-school program affected students' attitudes toward science and related content knowledge; and if changes in attitudes and content knowledge were related.

Importance of Academic Outcomes for STEM Success

Strong academic outcomes are essential for the successful pursuit of science-related undergraduate degrees and careers. Insufficient preparation, as indicated by low achievement before or during secondary school, can hinder students' abilities to complete the higher-level mathematics and science courses necessary for science-related degree programs (Museus, Palmer, Davis, & Maramba, 2011). In fact, students' academic success in rigorous high school classes, particularly mathematics and other courses that prepare them for college-level work, has been associated with students' success in college-level science-related courses and in college overall (see Adelman, 1999; Cole & Espinoza, 2008; Engberg & Wolniak, 2010; Griffith, 2010; Tornatzkty, Cutler, & Lee, 2002). Underrepresented minority and low income students, particularly, are more likely to have problems related to academic preparedness, and are less likely to have access to high quality science teaching and curricula than are other students (Darling-Hammond, 2010).

Strong academic preparation in high school courses also has been associated with persistence in science-related fields, meaning that students who choose to take lower-level courses are less likely to complete a degree in a science or engineering-related field (Palmer, Maramba, & Dancy, 2011; Museus et al., 2011). Furthermore, students possessing positive attitudes toward science are more likely to maintain science achievement levels, even when they feel less than capable of doing so than their peers without positive attitudes (Liu, Hsieh, Cho, & Schallert, 2006). Thus, improving students' attitudes toward science potentially could result in a cumulative positive effect in which students feel encouraged not only to eventually enter into degree programs in science-related fields, but more importantly to pursue and persevere in the rigorous high school classes that will best prepare them to succeed academically in science undergraduate courses necessary for those programs.

Despite the seemingly inherent importance of attitudes for knowledge gains, prior research investigating the associations between the two factors have had blended results. Mettas, Karmiotis and Christoforou (2006) analyzed data from the Third International Mathematics and Science Study (TIMSS) for 13-year-olds in Cyprus, and found a significant positive association between students' science self-beliefs and attitudes, and their TIMSS science outcomes. These findings are consistent with Papanastasiou and Zembylas' (2004) analysis of TIMSS data using slightly older students, though their research found inconsistencies regarding the direction and strength of the causal relationship between attitude and achievement on the TIMSS assessment across the three countries included in the study. Similarly, Ozel, Caglak and Erdogan (2013) discovered a mix of outcomes when assessing the impact of student affective factors, such as interest in science, on students' scores in an analysis of 2006 Program for International Student Assessment (PISA) data. Their results suggested that interest had a positive, but weak correlation with science outcomes on the assessment, while other aspects of affect had negative or negligible correlations. An investigation by Gungor, Eryılmaz, and Fakıoglu (2007) also found negligible associations between students' attitudes toward physics and semester course grades in freshman college physics. Authors of these studies offered several reasons for the variations in their results, including a dearth of information on external contextual factors, and the complicated nature of achievement or content knowledge gains as outcome variables (Papanastasiou & Zembylas, 2004; Ozel et al., 2013). It is possible, however, that some of the variation is due to the way the construct of attitudes is measured, and the aspects of student attitudes that the studies captured.

Attitudes toward science

Students' *attitudes toward science* refers specifically to students' emotional conception of science – beliefs, values and feelings – and is a complex, multi-faceted construct (Osborne, Simon, & Collins, 2003). Not all facets are directly related to student attitudes toward school science, or to attitudes that relate to students' decisions regarding future coursework. In their review of the literature, Osborne et al. (2003) identified several constructs that are determinants of student attitudes influencing science-choice behaviors, including (a) student motivation, (b) student self-concept, (c) peer attitudes, (d) classroom environment, (e) perception of school science, and (f) the difficulty of science. Other factors, including gender, socioeconomic status, parental attitudes, curriculum, and cultural attitudes, were less conclusive in their roles as science attitude determinants. Because this prior research suggests that the first six factors are most related to school science, this study employed an instrument to measure students' attitudes that possesses subscales as closely aligned to those factors as possible. The objective was to capture accurately the aspects of attitudes that are associated with academic achievement.

Measuring attitudes towards science

While attitudes toward science frequently are assessed during educational interventions, Blalock et al. (2008) noted that researchers often either create their own instruments or use older measures, and thus many of the attitude surveys in research have not been evaluated with modern, robust techniques to establish empirical evidence of validity. Accordingly, the Simpson-Troost Attitude Questionnaire – Revised, (STAQ-R) is an instrument recently psychometrically evaluated, and found to be a valid measure of middle school students' attitudes toward science (Owen et. al, 2008). Despite its recent reevaluation, very few studies have used the STAQ-R, and many of those using it altered the items to suit the purposes of their investigations. While a study by Nasr and Soltani (2011) of Iranian 17- and 18-year-olds found that one subscale of the slightly modified instrument was a statistically significant predictor of student achievement – "biology is fun for me," a derivative of the STAQ-R's "science is fun for me," – the authors did not provide internal consistencies for the subscale. This omission prevented an accurate evaluation of the instrument's performance. In addition, because prior research indicates that students' science attitudes are established long before high school, there may be differences in the relationship between achievement levels and attitudes toward science in younger students who have not yet made choices about coursework and careers, as compared to their older peers who already have begun making those decisions.

Benefits of After-school Programs

Given the importance of attitudes toward science and the degree to which they may be intertwined with student knowledge gains, any intervention aiming to impact students' preparation for or inclination to pursue science-related careers must attempt to assess the specific aspects of attitude that are related to student learning and achievement. After-school programs are such an intervention, capable of providing academic and social support needed to increase student affect and achievement levels (Lauer et al., 2006; Davies & Peltz, 2012). After-school programs have potential to affect students' in-school science achievement and interest in pursuing science careers. Students participating in high-quality STEM-related after-school programs have shown increased academic outcomes on standardized tests, and a greater likelihood of pursuing a STEM-related career path during post-secondary studies than their peers who did not participate in such programs (Vandall, Reidner & Pierce, 2007; Dabney et al., 2012). However, there are important caveats to these findings. After-school programs are unique learning environments. Student attendance, for example, usually is voluntary and dependent on factors such as transportation and other competing activities (such as sports). Further, teachers in after-school programs are not constrained by state or local requirements, and are able to provide students with hands-on learning experiences or long-term projects that might not be possible during the regular school day (Peterson & Fix, 2007). In any case, effective after-school programs can have many benefits, particularly to students who otherwise may not have access to engaging and active learning opportunities (Basu & Barton, 2007; Ozel et al., 2013; Dabney et al., 2012; see also Apsler, 2009; Durlak, Weissberg, & Pachan, 2010).

Purpose

In the current study, we asked whether active, group-based science learning opportunities, delivered after-school, would increase students' content knowledge and inspire attitudinal changes that might raise the likelihood that students will pursue science education pathways and careers. Correspondingly, the evaluation and research plan measured changes in content knowledge, and shifts in students' attitudes towards science. In addition, the five subscales of the Simpson-Troost Attitude Questionnaire – Revised (Owen et al., 2008) were examined to identify which, if any, of the constructs were predictors for fourth and fifth grade students' science knowledge gains during a semester-long after-school science program.

Method

Sample

A cohort (Fall 2012) of 10 teachers from six schools in a large urban public school district volunteered to participate in a semester-long, inquiry-based, microbiology and infectious disease after-school program for fourth and fifth grade students. Two of the 10 teachers were science lab teachers, while the rest were in self-contained classroom settings during the normal school day. All teachers had previous science teaching experience, and every team had at least one teacher who previously had participated in our professional development programs. Teachers conducted the activities with a total of 134 students from their campuses during a three-month period. At all schools, student populations were more than 85% Hispanic and African-American. At five of the six schools, at least 88% of students were considered eligible for free or reduced-price lunches. Teachers assigned an identification number to each student to ensure anonymity. Complete data for both pre and posttest scores were available for 63 students.

Instruments

We administered the 22-item STAQ-R attitudes instrument to students at the start and end of the after-school program (see Owen et al., 2008). The STAQ-R is a shortened and revised version of the Simpson Troost Attitude Questionnaire (see Owen et al., 2008; Simpson & Troost, 1982). In the present study, scales ranged from 1 = Strongly Agree to 5 = Strongly Disagree. The subscales of the STAQ-R and the Cronbach's alpha scores for the posttest attitudinal data are (a) "motivating science class" (6 items assessing students' perceptions of how motivating or interesting they find science class in school, e.g. "We do a lot of fun activities in science class"; $\alpha = 0.67$); (b) "self-directed effort" (4 items assessing students' persistence, e.g. "I always try to do my best in school"; $\alpha = 0.58$); (c) "family models" (4 items assessing students' perceptions of their family's attitudes toward science, e.g. "My mother likes science"; $\alpha = 0.74$); (d) "science is fun for me" (4 items assessing students' enjoyment of science, e.g. "I really like science"; $\alpha = 0.84$); and (e) "peer models" (4 items assessing students' perceptions of their peers attitudes toward science, e.g. "My best friend likes science"; $\alpha = 0.75$; Owen et al., 2008, p. 1081). The Cronbach alphas obtained in the present study for the motivating science class and science is fun for me subscales were lower than the values reported in the Owen et al. (2008) validation study. Pre and post attitudinal scores for each construct were calculated by summing across items and then dividing by the number of items. We calculated gain attitudinal scores by subtracting pretest scores from posttest scores; thus, negative gain values indicated an increase of the trait over time.

A 25-item, multiple-choice assessment (pre-assessment Cronbach's $\alpha = 0.201$; post-assessment $\alpha = 0.829$) created by the curriculum development team to align with the content and objectives of the activities measured students' science content-knowledge gains (see Appendix). Curriculum developers created the test by identifying the most important objectives, vocabulary words and content for students to learn from the activities, and creating items aligned with those components. The development team consisted of four curriculum development and science content experts, two of whom were former K-12 teachers. Elementary science teachers, who have participated as Master Teachers in ongoing science teacher professional development programs assisted in determining the validity of the instrument through expert review. We evaluated the instrument during a month-long pilot of the unit during the spring 2012 semester with 131 demographically comparable 5th grade students, some of whom were from schools that subsequently participated in the Fall 2013 after-school program. It performed adequately as a measure of student content knowledge (posttest $\alpha = 0.824$). This pilot also helped establish validity of the instrument items.

We administered the content assessment to students prior to beginning any activities and again after the completion of the semester's after-school curriculum. Each correct item was coded with a 1, and each incorrect item was coded with a 0. We calculated pre and posttest scores by summing the scores for the 25 items and dividing by 25. We calculated gain scores by subtracting the pre-test score from the posttest score (Cronbach's $\alpha = 0.70$). Teachers administered the STAQ-R at the same time as each content test, providing an assessment of change in student attitudes toward science before and after participating in the program.

Intervention: After-school Program

The Center for Educational Outreach at Baylor College of Medicine developed and disseminated the curriculum for the after-school intervention with support from the National Institute of Allergy and Infectious Diseases (National Institutes of Health). The curriculum consisted of 13 inquiry-based activities designed to increase students' knowledge of microorganisms, the spread of disease and general scientific vocabulary, and also to enhance science skills in areas such as data collection and graphing. The development team designed each activity or lesson to fit within a 45-minute time period and to be appropriate for after-school settings. Set-up for teachers was minimal and students were not required to complete worksheets or other activities that resembled homework. Instead, students worked actively in cooperative groups to solve a problem or question. For example, early in the semester, students explored the question, "What causes magnification?" by observing objects in a clear glass of water (objects looked larger when viewed through the curved sides of the glass), using hand magnifiers to observe pennies, and making their own magnifiers from strips of clear plastic and drops of water.

The set of activities culminated with the use of authentic data collected by Dr. John Snow to determine the source of the 1854 London cholera outbreak. Each group of students was responsible for mapping the locations of cholera victims within a quadrant of London's Soho district. The completed quadrants were assembled to create a complete map of the outbreak. Students were able to pinpoint the greatest concentration of victims near a shared pump on Broad Street. As an optional activity, students used the Google Earth web-based application to find the exact location of the infamous pump in London. All activities from the unit are available to download for free from BioEd Online (www.BioEdOnline.org), a science education website.

Participating teachers attended an orientation session prior to starting the program, in which they were introduced to the lessons, data collection methods and materials needed to teach the curriculum. Program implementation was left largely to the teachers' discretion. They were free to utilize the curriculum as part of pre-existing after-school programs, or to create new after-school programs specifically for the purpose of this evaluation. Additionally, teachers were able to adjust the activities as necessary for time constraints and student comprehension levels, something that all but two of the groups reported doing. Frequency of program meetings also varied among the groups, with four of the six groups meeting only once each week, while the remaining two met twice a week and five times a week, respectively. The purpose of allowing variation in implementation was to gain an understanding of how the curriculum would perform in natural settings. Permitting teachers to use the materials as they would in the real world – without intensive professional development, or stringent implementation guidelines – allows for an assessment of the materials without the confounding effects of either strong professional development or artificially controlled environments. Further, allowing for teacher customization of the lessons provides insights into the robustness of the overall design and instructional approaches. We collected information about how each site implemented the program using a post-evaluation form completed by each teacher or teacher team at the end of the semester-long program. The form asked teachers to report the amount of time devoted to each activity, and whether any activities had been altered or omitted. We also asked participants to comment on student reactions and behaviors, including perceived engagement in the activities, enjoyment of the unit overall, and demonstration of enhanced science skills (e.g. data collection), through the course of the intervention.

Analyses

Correlation coefficients serve as the foundation for the analyses commonly conducted in published research. In fact, Zientek and Thompson (2009) illustrated that given matrix summaries, most analyses within the general linear model can be conducted even without access to the original raw data. The purpose of the present study was not to focus on causal relations or correlations between variables two at a time. We wanted to understand the variability of the dependent variable (i.e., gains in content knowledge) as explained by the predictor variables (i.e., gains in attitudes), as part of a system of variables and wanted to understand the contributions of each predictor in the system. Because Pearson correlation coefficients are limited in explaining the contributions variables two at a time, without considering all the relationships with the system of variables, we conducted multiple regression analyses.

Results

On average, students gained 6.6 points (26.4%) on the 25-item content knowledge assessment (see Table 1) from program beginning to end (Confidence interval = [4.33, 7.59]). The smallest gain score from pre to posttest was a loss of 7 points, and the largest gain was an increase of 17 points. The Q-Q plots appeared approximately normal with a slight deviation on the upper end; no signs of kurtosis and skewness were evidenced; the Kolmogorov-Smirov and Shapiro-Wilk tests of normality were not statistically significant. However, the histogram of the residuals showed some deviation from normality. Plots of the residuals versus the predicted values indicated that the homoscedasticity assumption was not violated (Chen, Ender, Mitchell, & Wells, 2003).

Multiple Regression

Student gains on the five subscales of the STAQ-R instrument accounted for 19.1% of the variance in gains on student content knowledge test scores, $F(5,57) = 2.70$, $p = .040$. The adjusted R^2 from the SPSS output was lower than desired, which was anticipated given the small sample size (R^2=.191 and Adjusted R^2 = .120). The large beta weight and squared structure coefficient suggest that the gain on the self-directed effort subscale was the best predictor of student content knowledge gains. To further explore the relative importance of the predictor variables, we utilized the *R* package *yhat.* This program produces results from several analyses to determine relative importance of predictor variables (Nimon & Oswald, 2013). The multiple regression, general dominance, relative weights, and Pratt analyses all ordered self-directed effort as the best predictor. The medium-sized beta weights and close to zero squared structure coefficients suggest the possibility that the science is fun for me subscale served as a suppressor. A suppressor variable helps improve explained variance by removing variance that is irrelevant from other predictor variables in the model, thus increasing the predictive power of the other variables. This occurs when the suppressor variable is highly correlated with one or more predictor variables but is not highly correlated with the dependent variable (Nathans, Oswald, & Nimon, 2012; Pedhazur, 1997; Thompson, 2006). The bivariate correlation matrix for all variables provided in Table 1 further supported that science is fun was a suppressor. The science is fun for me subscale was not correlated with the predictor variable, but was highly correlated with two other variables in the model.

Partitioning variance—Variance was partitioned by conducting a commonality analysis in SPSS (Kraha, Turner, Nimon, Zientek, & Henson, 2012; Nimon, 2010; Zientek & Thompson, 2006). The commonality analysis results provided in Table 2 further indicate that students' perceptions of their self-directed effort was the best predictor, but also indicates that almost all of that variable's contribution was unique. Gains on self-directed effort uniquely accounted for 11.91% of the variance in content knowledge gains. The negative commonality results further supports that the science is fun for me subscale served as a suppressor. The two other negative commonality coefficients did not suggest suppressor effects because the coefficients were close to zero (Thompson, 2006).

Program Evaluations

Groups varied in the amount of time taken to complete the activities. While the mean amount of time per activity was 73.36 minutes, there was a range from 55 minutes to 103 minutes. Of the six groups, three missed or skipped two activities, one group missed one, and the remaining two groups completed all 13 activities. Reasons given for skipping activities included a lack of time, extremely low attendance, and a misalignment of the difficulty level (either too easy or too difficult) to the ability level of the students.

In addition to reporting use of activities, teachers rated several aspects of the curriculum by indicating their level of agreement or disagreement with several statements regarding the impact on the students and the efficacy of the materials, based on a 5-point Likert scale (1=strongly disagree, 3=uncertain, 5=strongly agree). Overall, the teachers were very positive about the program outcomes, agreeing or strongly agreeing that the lessons would help motivate the children to pursue other science courses ($M = 4.6$, $SD = 0.5$); and strongly agreeing that the lessons would encourage students to consider careers in health or science ($M = 4.8$, $SD = 0.4$).

Regarding changes in students' content knowledge, teachers agreed that after the use of the activities, their students demonstrated an increase in classroom skills, such as following instructions ($M = 4.3$, SD = 0.5), following safety procedures ($M = 4.6$, $SD = 0.5$), and working collaboratively ($M = 4.6$, $SD = 0.5$). Additionally, the teachers observed an increase in science-specific skills and behaviors, such as constructing graphs and tables from their data ($M = 4.2$, $SD = 0.4$) and using scientific vocabulary in written or spoken communication ($M = 4.40$, $SD = 0.5$).

Discussion

A focus on attitudes that directly impact students' science content knowledge gains will enable educators to better assess the potential of interventions to increase student enrollment in advanced science classes and encourage pursuit of education pathways aimed toward science careers. It also will make it possible to tailor programs specifically to achieve these goals. This is especially applicable within the context of after-school programs, which, being informal learning environments, offer the flexibility to provide students with opportunities to explore topics in-depth and in creative ways that encourage the development of students' interest—or to focus on the development of skills that are covered thoroughly in class (Peterson & Fix, 2007). Accordingly, it is beneficial to understand how to focus after-school programs to increase students' knowledge and attitudes toward science overall. Many underrepresented minority and low-income students do not pursue advanced science courses in high school, and such programs may provide needed skills and motivation to keep these students in the science "pipeline."

The development team designed the after-school curriculum in this study to be highly engaging, seeking to increase students' content knowledge, and also their interest in science beyond what they would develop in a traditional classroom setting. All participating teachers indicated a belief that the materials were successful in both respects. The effectiveness of the intervention is also indicated by increases in student science knowledge about microorganisms and disease, as assessed by the content pre and posttest, and reinforced by teacher reports on science-specific skills. Regarding the association between outcome measures, student gains on attitudes towards science, as measured by the STAQ-R, as a whole appeared to be predictive of content knowledge gains, reinforcing our understanding of the intertwined nature of students' attitudes and academic achievement. A closer look at the individual subscales suggests that gain scores on students' attitudes of their self-directed effort and perception of peers models were factors in predicting increased content knowledge in a science after-school program. In addition, the degree to which students found science to be fun was important to the model because of the suppressor effect. That finding suggests that, while the suppressor variable science is fun might not be directly predictive of students' content knowledge gains, the high correlations between the suppressor and student perceptions of peer models and motivating science class improves the predictive power of other variables in the model by eliminating irrelevant variance. Ideally, then, to produce the maximum effect from an after-school intervention, programs should work primarily to target students' attitudes toward their own self-directed effort, with an added emphasis on increasing the positive nature of peer interactions and the overall engagement ("fun") of the curriculum. Further research on the impact of the enjoyment of science activities would be particularly worthwhile, especially because its presence as a suppressor variable is inconsistent with Nasr and Soltani's (2011) results, in which it was the only STAQ-R factor that had a meaningful relationship with biology outcomes. While enjoyment of science plays a different role in the two studies, the fact that it explains variance in both illustrates its importance to programs that have been shown to impact student learning (Ozel et al., 2013). It also indicates that that the effect of students' enjoyment of science activities on achievement may not be as straightforward as prior research would suggest.

Importantly, of the four items making up the self-directed effort subscale of the STAQ-R, only one directly asks about school science: "I try hard to do well in science" (Owen et. al., 2008, p. 1083). The other three items in the self-directed effort subscale reference working hard and persevering in a more general sense, (e.g. "I always try hard, no matter how difficult the work", p. 1083). Because all of the other STAQ-R subscales' items directly ask about students' attitudes in terms of science and science class, it is possible that the self-directed effort subscale is capturing a quality that is not subject specific, but indicative of students' overall desire to achieve. Future work with the individual self-directed effort subscale might investigate the impact of adjusting the items so that all four refer specifically to science instead of general attitudes toward working hard. Other interventions aiming to improve students' attitudes toward science may choose to directly affect this quality alone, and further explore its association to academic success.

As seen in Table 1, gains in student attitudes toward peer models was highly correlated with motivation and science is fun, suggesting that the influence of student perceptions of peer group attitudes about science influence their own motivation and attitudes about science and science class. Gains on family models and motivating science class were not noteworthy predictors of the science achievement in this intervention, which is perhaps unsurprising considering that the intervention was in an after-school program, and thus not directly applicable to science class. In addition, there was very little effort in the after-school program to involve or change families' attitudes toward science. In the case of the family models, it might be beneficial to involve families in the intervention. Parental involvement at the elementary school level is positively associated with student achievement and school success all the way through high school (Barnard, 2004). Thus, the inclusion of a familial aspect to the program could impact both student achievement and attitudes toward science. This is especially important among minority and disadvantaged populations, since parents of those students sometimes are less involved in their children's schools (Wong & Hughes, 2006).

In terms of the motivating science class subscale, the same qualities that make after-school programs beneficial to students – time for inquiry-based exploration, experienced and engaged science teachers – can potentially limit the ability of such programs to affect student attitudes about certain aspects of regular, school day science classes, such as perception of the science classroom and classroom teacher (e.g. "My science teacher makes good plans for us.", (Owen et. al., 2008, p. 1083). Consequently, some items in the motivating science class subscale are potentially irrelevant for this study, because they measure aspects of school science that are likely not affected by students' participation in the after-school science intervention. To adequately capture relevant potential changes in students' attitudes regarding school science after an after-school intervention, it might be necessary to modify the items on the motivating science class subscale accordingly (e.g. "When I see interesting science experiments outside of regular school science, it makes me more interested in what we do in science class." p. 1083), and to remove items unrelated to the intervention (e.g. "I consider our science classroom attractive and comfortable." p. 1083).

Limitations

The student participant population consisted mostly of underrepresented minority, and low-income youth. Thus, it may not be possible to make inferences about the relationships among science attitude scales and content knowledge with other student populations. Further, the project examined a particular set of life science topics and activities related to microorganisms, infectious diseases and epidemiology, with an emphasis on hands-on and problem-solving activities. Student attitudes and science learning scores might behave differently with other topics and types of activities. Additionally, the sample size was relatively small, which limits generalizability of the results. The voluntary nature of after-school programs means that attrition will be a problem regardless of the particular intervention, thus reducing the sample size and leading to issues of student self-selection. As a possible counter to such problems, future studies should collect data from a larger sample of students. Finally, although the measures used in this study are intended to act as a measure of potential long-term decision-making, this was not longitudinal research. Future work should ideally explore the long-term predictive nature of the STAQ-R in order to understand the factors of attitude that impact student choice behaviors. Although limitations existed, the findings provide potential direction for future studies seeking to assess factors that might influence students' interest in science and likelihood of pursuing additional science courses and careers paths.

Conclusion

Though there is still much to be understood about the relationship between student attitudes toward science and science knowledge gains, this study highlighted several areas worthy of exploration. For this study, the most important aspects of the science intervention associated with content knowledge gains were that the after-school program increased students' perceptions of their own willingness to work hard on difficult topics. More broadly, then, the importance of gains in students' perceived self-directed effort, peer models, and science is fun for me constructs in predicting gains in science-content knowledge may have utility in the planning, delivery and evaluation of after-school programs aimed at disadvantaged students.

To better gauge actual career goals, future studies might join the attitude survey and achievement measure with an instrument assessing students' future plans. Though fourth and fifth grade students might be too young to have fully formed ideas about potential areas of study, this step might add another level of insight into the relationship between attitudes and pursuit of science-related careers. Further, with a better understanding of the aspects of science interventions that potentially can increase students' achievement levels and long-term attitudes toward science, designers of after-school programs will be able to tailor them specifically to students' needs, and perhaps encourage students to pursue careers in science when they might not have before.

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Appendix. Content Test Items

Of the microbes listed below, which kind is considered by many biologists to be non-living?

- **a.** Viruses
- **b.** Protists
- **c.** Bacteria
- **d.** Fungi

Dr. John Snow of 19th century England was instrumental in the development of which medical specialty?

- **a.** Cardiology
- **b.** Gastroenterology
- **c.** Epidemiology
- **d.** Pulmonology

Yeast is an example of what kind of microorganism?

- **a.** Protist
- **b.** Bacteria
- **c.** Microbe
- **d.** Fungi

In what ways are food and microbes related?

- **a.** Microbes spoil food.
- **b.** Microbes enhance the flavor of some foods.
- **c.** Microbes help produce some foods through fermentation.
- **d.** All of the above.

Which statement is true?

- **a.** Bacteria can be beneficial or harmful.
- **b.** There are more microbes within the human body than the body has cells.
- **c.** Only a small percentage of the millions of kinds of microbes cause disease.
- **d.** All statements are true.

Which personal habit is not an effective way of passing on an infection to another person?

- **a.** Coughing or sneezing into a hand and then touching someone
- **b.** Washing hands frequently
- **c.** Not washing hands after going to the bathroom and touching someone
- **d.** Kissing

Which of the following conditions did not contribute to the cholera epidemic in London in 1854?

- **a.** Spoiled meat
- **b.** Crowding of people into small areas
- **c.** Human wastes mixing with drinking water
- **d.** Warm temperatures

Why do you use agar (or potato slices) in a Petri dish when you want to grow certain kinds of microbes?

- **a.** Provides a soft surface for placing the microbes.
- **b.** Provides food for the microbes.
- **c.** Prevents the microbes from spreading outside the Petri dish.
- **d.** Helps to identify the microbes.

A room is 20 feet by 25 feet in size and holds 50 people. What is the population density of the room in square feet?

- **a.** 1 person by 25 square feet
- **b.** 1 person by 20 square feet
- **c.** 1 person by 50 square feet
- **d.** 1 person by 10 square feet

The bluish growth on old bread is caused by

- **a.** bacteria.
- **b.** fungi.
- **c.** protists.
- **d.** viruses.

Influenza, hepatitis, and Ebola are diseases caused by what kind of microbe?

- **a.** Virus
- **b.** Bacteria
- **c.** Protist
- **d.** Fungi

Infectious diseases spread more quickly today than 100 years ago because

- **a.** scientists have created many new diseases in their laboratories.
- **b.** airplanes speed travel from place to place.
- **c.** fresh food crops are infected with microorganisms.
- **d.** of modern sanitation.

As a result of Dr. Snow's investigation of the cholera epidemic in London in 1854 – this happened.

- **a.** Restaurants in the Soho district were closed by health officials.
- **b.** The Broad Street public water pump handle was removed.
- **c.** A new hospital opened in Soho.
- **d.** The city banned stockyards in the Soho district.

The disease known as Acquired Immune Deficiency Syndrome, or AIDS, is the result of which kind of microorganism invading the body?

- **a.** Virus
- **b.** Bacteria
- **c.** Protist
- **d.** Fungi

About how many bacteria can be found in the human gastrointestinal (GI) tract?

- **a.** 10 billion
- **b.** 100 billion
- **c.** 1,000 billion
- **d.** 100,000 billion

Which of the following foods is not made with the help of microbes?

- **a.** Ice cream
- **b.** Yogurt
- **c.** Bread
- **d.** Cheese

Bread and carbonated beverages such as root beer depend on what microbe-based process?

- **a.** Carbonation
- **b.** Fermentation
- **c.** Pasteurization
- **d.** Petrification

Which infectious disease is no longer a problem today?

- **A** Influenza
- **b** Cholera
- **c** Tuberculosis
- **d** Small pox

What is a germ?

- **a.** Infectious disease
- **b.** Microbe
- **c.** Microbe that causes disease
- **d.** Moisture particles sprayed during coughing or sneezing

In order for bacteria to grow, they need

- **a.** a source of energy.
- **b.** source of young viruses.
- **c.** specialized equipment.
- **d.** someone to cough or sneeze.

Which of the following objects makes something appear larger?

- **a.** Glass
- **b.** Slide
- **c.** Swab
- **d.** Lens

One of the most common microbes used in food production is a

- **a.** fungus.
- **b.** protist.
- **c.** virus.
- **d.** micron.

Microorganisms are often measured in

- **a.** decimeters.
- **b.** centimeters.

c. millimeters.

d. microns.

A way to protect yourself from some diseases is called

a. polarization.

b. vaccination.

c. constipation.

d. fertilization.

Microbes are an important part of the environment because they

a. break down waste.

b. cause the water cycle.

c. protect the ozone layer.

d. block global warming.

Table 1

Descriptive Statistics, Confidence Intervals For The Mean, and Bivariate Correlations Between Gain Scores On Student Content Knowledge and Gains and STAQ-R Subscales and

			95% CI					
Gains	**Mean**	**SD**	**[LL, UP]**	**gtotal**	**Gself**	**Gmot**	**gpeer**	**gfun**
gtotal	0.264	0.217	[0.210, 0.316]					
gself	0.012	0.296	[−0.060, 0.083]	*−.364*				
gmot	−.0.090	0.469	[−0.204, 0.026]	.012	.230			
gpeer	0.008	0.814	[−0.186, 0.210]	−.165	.188	*.357*		
gfun	0.056	0.716	[−0.119, 0.238]	.058	.092	*.405*	*.609*	
gfam	−.0.206	0.844	[−0.424, −0.004]	−.086	.050	.159	*.359*	*.346*

Note. n = 63. Gtotal can range from 0 to 1. Correlations that are statistically significant at the .01 or .05 level are italicized. gtotal = gains on student content-knowledge; gself = gains on self-directed effort; gmot = gains on motivating science class; gpeer = gains on peer models; gfun = gains on science is fun for me; gfam = gains on family models; CI = Confidence interval; LL = Lower Limit; UP = Upper Limit.

Table 2

Multiple Regression and Commonality Results for STAQ-R Subscale Gains as Predictors of Student Content Knowledge Gains

STAQ-R Gains	β	r_s^2	Unique	Common	Total
Self-Directed Effort	−.358	0.692	11.91%	1.30%	13.21%
Motivating Science Class	.103	0.001	0.84%	−0.83%	0.01%
Peer Models	−.244	0.143	3.46%	−0.72%	2.73%
Science Is Fun for Me	.223	0.017	2.83%	−2.50%	0.33%
Family Models	−.074	0.039	0.46%	0.28%	0.74%

Note. $n = 63$; R^2=.191; Adjusted $R^2 = .12$; β = beta weights; r_s^2 = squared structure coefficients; CI = Confidence Interval.