Science for all: Boosting the science motivation of elementary school students with utility value intervention

Da-Jung Diane Shin, Minhye Lee, Jung Eun Ha, Jin Hyun Park, Hyun Seon Ahn, Elena Son, Yoonkyung Chung, Mimi Bong

Department of Education and bMRI (Brain and Motivation Research Institute), Korea University, Seoul, Republic of Korea
College of Education, Hankuk University of Foreign Studies, Seoul, Republic of Korea
Graduate School of Education, Inha University, Incheon, Republic of Korea

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ABSTRACT
The need for students to learn science, technology, engineering, and mathematics (STEM) has increased steadily, while student motivation in this area continues to fall behind. We investigated the effects of science utility value intervention in increasing the science motivation (i.e., interest in science, appreciation of the role of science in future careers, and intention to engage in science-related activities) of Korean 5th and 6th graders. The usefulness of science for attaining the personal and communal goals inherent to various non-STEM careers was emphasized and internalized through classroom activities including postcard writing. At the end of the semester, students in the experimental group (n = 219) perceived greater personal and communal utility in science than those from the control group (n = 197). This enhanced perception of science utility led to greater interest, a higher likelihood of cognitively connecting science to future careers, and the willingness to engage in scientific activities.

1. Introduction
Technological advances have made science, technology, engineering, and mathematics (STEM) literacy a critical determinant of a country’s economic competitiveness (U.S. Department of Education, Office of Innovation and Improvement, 2016). Unfortunately, students’ motivation to engage in STEM subjects remains low and begins to decline in the upper grades of elementary schools (Jacobs, Lanza, Osgood, Eccles, & Wigfield, 2002; Patrick & Mantzicopoulos, 2015). Many initiatives for early STEM education have thus been proposed to address this problem, but evidence attesting to their efficacy is scarce.

According to the expectancy-value theory (EVT; Eccles & Wigfield, 2002), one route to increase STEM motivation is helping students understand the usefulness of STEM in the achievement of personally important goals. Relating science to individual and social goals, such as career aspirations, interpersonal connections, and altruism, has proven to facilitate continued interest (Brown, Smith, Thoman, Allen, & Muragishi, 2015) and choice behaviors in science (Harackiewicz, Rozek, Hulleman, & Hyde, 2012). In the present study, we tested the effects of an intervention highlighting both the personal and communal utility value of science in various careers on the science motivation and career interest of elementary school students.

1.1. Why target students’ perception of utility value?
EVT posits that expectations for success and subjective task value are important predictors of student motivation (Eccles & Wigfield, 2002; Wigfield & Eccles, 1992). Task value can be divided into four different types: attainment value (the importance of a task for an individual’s self-schema), intrinsic value (task enjoyment), utility value (the usefulness of a task for an individual’s short-term and long-term goals), and cost (the negative aspects of task engagement). With the exception of cost, an increase in task value contributes to an increase in task engagement and choice intentions.

Augmenting perceptions of utility is particularly effective in enhancing student motivation and performance (e.g., Hulleman & Harackiewicz, 2009; Hulleman, Kosovich, Barron, & Daniel, 2017). Of the four task value constructs, utility value is considered the most extrinsic in nature and is thus relatively amenable to external manipulation (Eccles & Wigfield, 2002; Rozek, Hyde, Svboda, Hulleman, & Harackiewicz, 2015). Students perceive high utility in science when they recognize the instrumental merits of the subject beyond the classroom, i.e., in terms of their personal goals or other aspects of their lives (Eccles & Wigfield, 2002; Hulleman et al., 2017). Discovering these connections improves STEM motivation by provoking stronger...
interest (Brown et al., 2015; Gaspard, Dicke, Flunger, Brison et al., 2015; Hulleman, Godes, Hendricks, & Harackiewicz, 2010) and greater choice behaviors in STEM (Harackiewicz et al., 2012).

Utility value can be either personal (the usefulness of a task for an individual’s present and future life) or communal (the usefulness of a task for an individual’s social goals, such as building interpersonal relationships and helping others; Brown et al., 2015). Intervention and experimental studies alike have demonstrated that emphasizing the communal utility inherent in STEM, such as the usefulness of STEM careers in serving the community, develops interest in STEM among students (Brown et al., 2015; Weisgram & Bigler, 2006). For instance, college students exposed to a communal utility value intervention that highlighted how biomedical science helped others (e.g., individuals with impaired mobility) showed greater positivity toward biomedical research and a stronger motivation to pursue future careers in biomedicine compared to students who did not receive this information (Brown et al., 2015). Middle school girls (Weisgram & Bigler, 2006) and underrepresented minority college students (Thoman, Brown, Mason, Harsmen, & Smith, 2015) who believed more strongly in the altruistic value of science and biomedical research, respectively, became more interested and confident in science or more psychologically involved and expressed greater career interest in scientific research than students who did not believe that science afforded many altruistic benefits. As a result, though a significant volume of research on STEM value intervention has focused on personal utility value, emerging evidence suggests that communal utility value may be critical for students’ STEM motivations.

Previous intervention studies have also demonstrated that directly communicating utility value information can backfire for students who lack confidence, lowering their task interest (Durik, Shechter, Noh, Rozek, & Harackiewicz, 2015, Study 1). An alternative approach has been to encourage students to self-generate the usefulness or the relevance of STEM to their personal lives. Hulleman and colleagues (Hulleman et al., 2016; Hulleman & Harackiewicz, 2009) have found that students who wrote about the relevance of the course materials to their lives reported significantly higher interest and performance compared to those who wrote a summary of the course materials, especially when they held low expectations of success.

Gaspard, Dicke, Flunger, Brison et al. (2015), however, obtained slightly different results from their intervention study. Ninth-graders who evaluated the interview quotations of others on the utility value of mathematics significantly improved their perception of not only utility value but also the attainment and intrinsic value of mathematics, whereas those who generated their own arguments for the personal relevance of mathematics demonstrated enhanced utility value only. Still, this research once again demonstrated the efficacy of utility value intervention that includes elements of writing.

1.2. Our intervention program

Taken together, previous intervention studies provide an important insight into how STEM utility value can be instilled in students to enhance their STEM motivation. Nonetheless, several limitations are worth noting. First, a majority of the studies focus on high school and college students, whose attitudes towards STEM and career aspirations are expected to be fairly stable. Although some studies have shown that college students’ motivation fluctuates considerably over time and in different situations (e.g., Dietrich, Viljaranta, Moeller, & Kracke, 2017; Kosovich, Flake, & Hulleman, 2017), it is generally assumed that younger students’ STEM motivation is relatively more malleable than that of older students (Marcoulides, Gottfried, Gottfried, & Oliver, 2008). Second, although previous intervention studies have successfully established the link between STEM utility value and careers in both STEM and non-STEM fields (e.g., Gaspard, Dicke, Flunger, Brison et al., 2015; Harackiewicz et al., 2012), the specific career aspirations of the participating students were not taken into account in these studies.

Therefore, the approach taken might have worked mainly for students who were at least somewhat interested in pursuing the given careers but not for others. To improve the STEM motivation of all students, especially that of young learners, interventions should help the students see the value of STEM for their own future careers. Our intervention program was designed to do so with respect to science.

1.2.1. Utility value intervention connecting science to careers for elementary school students

It has been found that motivation in science starts to decline during the upper elementary school years (Eccles, Midgley, et al., 1993; Gottfried, Fleming, & Gottfried, 2001). However, motivation during the early school years predicts students’ choice behaviors related to science during high school (Simpkins, Davis-Kean, & Eccles, 2006). These findings suggest that any program that aims to improve student motivation in science may be most effective if it takes place prior to the transition to middle school.

Furthermore, students’ tentative plans for the future start to emerge during their elementary school years and these plans exert an enduring influence on their subsequent occupational choices. Hartung, Porfeli, and Vondracek (2005) have pointed out that most studies on vocational development have focused on adolescents and adults and only a few studies have examined vocational development during childhood. However, their review of the available evidence suggests that children as young as 3rd and 4th grade start exploring their career options. Children engage in active career exploration by the time they reach 10–12 years of age. It is argued, therefore, that vocational exploration starts much earlier than most researchers assume and that the knowledge, interests, and aspirations related to work and careers acquired during childhood influence the career choices made during adolescence and young adulthood. We thus recruited students in Grades 5 and 6, i.e., the final two years in elementary school within the Korean educational system, as our participants.

Young students’ perception of the value of STEM with respect to their career aspirations is particularly influential in their motivational development and outcomes in STEM (Rozek et al., 2015; Woolley, Rose, Ortner, Akos, & Jones-Sanpei, 2013). Nevertheless, these students often lack insight into how the material they learn at school relates to their future career (Johnson, 2000). When asked, an overwhelming majority of 11- and 12-year-olds answer that they often think about what they want to do in the future but have insufficient information about possible jobs (Ortner et al., 2010). To address this gap, early career education in schools has been called for (e.g., Woolley et al., 2013). Answering this call, we designed an intervention that emphasized the personal utility of science for a diverse range of careers, such as design, entertainment, cooking, and teaching. This intervention introduced how professionals in these occupations utilize scientific knowledge and skills to ensure successful job performance. We also provided students an opportunity to connect science with their own desired careers.

Our intervention approach of targeting young students’ career aspirations also aligns well with recent educational reform in Korea. The Korean Ministry of Education launched the “Test-Free Semester” policy nationwide in 2016, which aims at providing middle school freshmen with opportunities to explore their future career options without the pressure of examinations (Korean Ministry of Education, 2013). During the test-free semester, students take classes in the morning as they normally would but participate in a curriculum tailored by the school particularly for its students in the afternoon. This selective curriculum is designed to help students discover their career interests and talents by engaging them in various clubs, projects, arts, sports, experiments, and field studies both inside and outside of school. However, early reports on the effectiveness of the test-free semester have revealed that a lack of preparedness on the part of both students and teachers has prevented it from realizing its potential (e.g., Kim, Ra, Lee, Keum, & Park, 2016). By providing students with structured guidance in their
1.2.2. Emphasis on the communal utility of science in popular careers

Communal utility of science for various careers was another important focus of our intervention. According to the social developmental literature, students in upper elementary school start to move away from self-centeredness and exhibit a growing sensitivity towards social goals (Dawes, 2017). Many of the occupations desired by students at this age are people-oriented and heavily involve the communal component of helping others (Prediger, 1982). In fact, the belief that STEM careers offer few opportunities to fulfill communal goals is one of the major reasons why students tend not to value STEM subjects (for a review, see Boucher, Fuesting, Diekman, & Murphy, 2017). Our intervention encouraged students to consider how various professionals use scientific knowledge and skills to connect with and help others, thus demonstrating that science supports both intra- and inter-personal goals.

Promoting the value of science in achieving long-term and communal goals was expected to be especially useful for the present sample of Korean students because prosocial, interdependent, and future-oriented values are a strong component of East Asian cultural heritage (Hofstede & Bond, 1988). Cross-cultural investigations have suggested that, compared to Westerners, East Asians tend to have more of an interdependent self-construal, in which the self is understood in its relationship to others (Markus & Kitayama, 1991). They also tend to think more holistically about events and contexts by connecting them to more distal outcomes (Lee & Bong, 2016; Maddux & Yuki, 2006). Supporting this view, East Asian students were found to be motivated by present tasks when they were important to their future goals, more so than their Western counterparts (Asakawa & Csikszentmihalyi, 2000; Shechter, Durik, Miyamoto, & Harackiewicz, 2011). Communal utility value information is also known to be particularly motivating for students with strong communal values (Diekman, Clark, Johnston, Brown, & Steinberg, 2011), a characteristic that often describes Asian culture.

1.2.3. Writing about utility of science

Gaspard, Dicke, Flunger, Brisson et al. (2015) had students either evaluate quotes from interviews with others regarding the utility of mathematics or generate arguments for the personal relevance of mathematics and subsequently write an essay on this topic. Both groups of students produced significantly higher ratings for the utility of mathematics compared to the control group. The use of quotes proved more effective than writing essays, increasing not only utility value but also attainment and intrinsic values. Based on this, we provided various statements on the personal and communal utility of science for different occupations and asked students to write about the topic, allowing them to copy the statements when necessary. This design took advantage of both other- and self-generated utility statements, while reducing the writing burden for students.

1.2.4. Effects of intervention on science motivation and achievement

Recent utility value interventions have been found to enhance young students’ math interest and achievement (Gaspard, Dicke, Flunger, Brisson et al., 2015; Woolley et al., 2013). We attempted to replicate this effect with elementary school science. Because choice behaviors and intentions are eventual motivational outcomes of increased task value (Bong, 2001; Rozek et al., 2015), we also assessed the degree to which students cognitively expanded their perception of science and connected science with their future careers both inside and outside the classroom, as well as their intention to choose science-related activities. Finally, their performance on a science test was used to assess achievement outcomes.

1.3. Hypotheses for the present study

We hypothesized that the fifth and sixth graders exposed to our intervention would express a stronger perception of the personal and communal utility value of science, interest in science, appreciation of the role of science in their future career, intention to choose science-related activities, and higher science achievement compared to the control group. We also predicted that enhanced utility value would mediate the effects of the intervention on other outcomes.

In the present study, students’ perceptions of the utility value of science in different careers was manipulated through a semester-long classroom intervention program. Based on this experimental design, we anticipated that gradual increases over time in the utility value of science held by students would precede changes in their motivation to learn science. Support for this hypothesis comes from previous value intervention studies, which have documented that strengthening personal and communal utility value via intervention brings about subsequent increases in the interest in, perceived importance of, positivity towards, and future career motivation in science (Hulleman et al., 2010). A recent review of the empirical literature on communal goals in STEM fields has likewise concluded that the perception of STEM as impeding the attainment of communal goals decreases student motivation in STEM fields (Boucher et al., 2017). Based on these findings and the ongoing nature of our utility value intervention, we hypothesized that the students’ perception of utility value would mediate the effects of the intervention on their motivation and achievement.

Bolstering both personal and communal utility value has been shown to be especially helpful for underrepresented groups such as girls and students with low competence (Diekman, Brown, Johnston, & Clark, 2010; Gaspard, Dicke, Flunger, Brisson et al., 2015; Hulleman & Harackiewicz, 2009), but evidence also exists that gender is not a moderator of utility intervention (Brown et al., 2015). Because our intervention involved a broad range of careers that elementary school girls and boys commonly aspire to, we expected our intervention to be equally effective for both genders. We also predicted our intervention to produce similar effects for students across different achievement levels because both the science motivation and achievement of the young students in our sample were presumed to be highly malleable (Marcoulides et al., 2008) and hence responsive to the experimental treatment.

We explored the distinct effects of personal and communal utility value on student outcomes. However, no specific hypothesis was generated for differences in their predictive pattern because there has not been enough previous research that directly compares the two types of utility value.

2. Method

2.1. Participants and procedure

A total of 416 students (219 boys and 197 girls) from 9 sixth grade (201 students) and 8 fifth grade classrooms (215 students) at a public elementary school in Seoul, Korea, participated in a program called “Boosting Motivation with Research-based Interventions–A Science Value Intervention” (BMRI-SVI). The program was introduced as a general career education program and the title was kept from the students to prevent any response bias if they guessed the purpose of the research. The proportion of students from low socioeconomic status (SES) families at this school (19.19%) was higher than the average for elementary schools in Seoul (4.94%; Seoul Metropolitan Office of Education, 2017). We used a cluster-randomized trial, randomly assigning classes within each grade-level to the experimental (utility intervention) and control conditions. All participants in the experimental and control conditions studied identical science content immediately before and after the intervention. The experimental treatment consisted of seven bi-weekly 40-min utility intervention sessions during regular
classroom hours, evenly distributed over three and a half months during the 2017 spring semester. The school had been selected as a model school for career education by the Korean Ministry of Education and our intervention was implemented as part of its regular career education curriculum. Parental consent for participation was obtained by the school at the beginning of the school year.

All sessions were taught by eight trained instructors who were preservice volunteer teachers (one male and seven female teachers). They were blind to the study hypotheses and were randomly assigned to either the experimental or the control group. All instructors participated in the respective training sessions, during which they rehearsed the intervention sessions and received feedback from researchers. The instructors were provided with fully scripted lesson plans developed by the research team that highlighted the essential components of each lesson, including the content and sequence of the teacher's instructions; these plans had to be adhered to in order to preserve intervention fidelity. The instructors' compliance with the lesson plan and the quality of their instructional delivery were closely monitored by researchers throughout the training sessions. To prevent potential instructor bias, the teachers were rotated within each treatment group so that all of the individual classes were exposed to all instructors within the same treatment group. Each instructor carried out 16 to 18 sessions.

During the intervention, two researchers accompanied each instructor to assist with classroom management. They independently completed a checklist that assessed intervention fidelity for all of the sessions taught by every instructor. The checklist was developed following the guidelines set forth by O'Donnell (2008). We first identified eight critical components of our intervention that needed to occur exactly as they had been designed to: the program introduction, topic introduction, bubble-sorting activity, activity worksheet, postcard writing, postcard replies, scientific skills, and wrap-up. Two to four questions were developed for each component to assess its fidelity and, depending on how many of the critical components were included in a particular session, 7 to 13 items were assessed using the fidelity checklist each session. With this checklist, the researchers monitored the instructor's adherence to the original lesson plan, the duration of the activities, and the differentiation between the two treatment groups.

Sample questions on the checklist included “Did the instructor fully describe the specific careers/science topics for today’s session?,” “Did the instructor follow all instructional details to explain the bubble-sorting activity?,” and “Did the instructor provide answer keys for the activity worksheet after all students had finished the activity?” Each item was rated on a 3-point scale ranging from 0 (no, not at all) to 2 (yes, completely). The fidelity ratings indicate that the instructors executed the intervention as intended ($M_{all} = 1.82$, $SD_{all} = 0.50$) for both the experimental ($M_{exp} = 1.86$, $SD_{exp} = .45$) and the control groups ($M_{con} = 1.78$, $SD_{con} = 0.54$). The mean fidelity score for each session ranged from 1.74 to 1.89 and none of the instructors were excluded for a low fidelity score. Rater agreement was 82.64% across the sessions, a figure comparable to that of a previous study (Hulleman et al., 2017). In addition to assessing intervention fidelity, the researchers ensured that all students complied with the instructions and engaged in the planned activities.

Students completed a self-report survey and a science test in their classroom twice, once approximately one week prior to the intervention (T1) and once one week after it (T2). Fig. 1 shows the overall schedule for the intervention program.

2.2. Intervention program

The experimental and control conditions included identical types and sequences of activities, which differed only in content. The details of each session are listed in Table 1.

2.2.1. Experimental condition

The intervention program was titled, ‘Finding Science in Jobs.’ Following an introductory session, three or four specific jobs within each of the four occupational categories (design, entertainment, cooking, and teaching) were introduced during the next four sessions, totalling 13 different jobs. These jobs were selected for their popularity among upper elementary school students in Korea (Korean Ministry of Education, 2016). The intervention activities emphasized the personal and communal utility value of science for these jobs.

The personal utility intervention focused on how professionals in each career utilize scientific knowledge to enhance their job performance (e.g., “Knowing how humidity and temperature affect food is useful for chefs because it helps them keep ingredients fresh. Placing food in warm and humid areas should be avoided as it allows harmful bacteria to multiply quickly.”). The communal utility intervention stressed that these professionals could also utilize scientific knowledge to help others (e.g., “Knowing the chemical composition of cosmetics and hair products can be useful for hair designers because it allows them to help their customers maintain healthier hair and skin.”). We generated five personal utility and two communal utility statements for each of the 13 specific jobs. The only exception was the teaching category, for which we provided five personal utility statements for teachers in general and three personal utility statements for teachers teaching specific subjects such as language, arts, and physical education. A total of 85 (59 personal and 26 communal) utility statements were printed on ‘bubbles’ (i.e., index-card-sized laminated pieces of paper with Velcro on the back to be used on a felt board) and formed the basis of activities such as bubble sorting and anagram making.

These statements had gone through numerous revisions before the intervention to ensure clarity and grade-level appropriateness. A team of nine educational psychology faculty and graduate student members first developed a set of approximately 20 statements per career (or science topic) to be used with the experimental (or the control) group. All scientific statements were drawn from elementary school science textbooks. Of these initial statements, the seven most compelling and informative were chosen via group discussion. These statements were revised to be of a length and difficulty appropriate for upper elementary school students, after which feedback from another six educational psychology experts was sought on the effectiveness of these statements. After another round of thorough revision, one sixth grader and two elementary school teachers (one with three and the other with over 30 years of teaching experience) went over the final statements to confirm their clarity and age-appropriateness. The development of these statements took over four months.

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During the sixth and seventh sessions, students were taught four general scientific skills (observation, measurement, reasoning and analysis, and communication) and learned how these skills can be used in four additional careers as well as their own desired future career. Students filled four bars representing each of the scientific skills with different colors to show the extent to which each skill is needed for each career. This activity communicated the idea that, in addition to scientific knowledge, scientific skills are also employed in most careers.

During the intervention program, students engaged in writing activities designed to facilitate the internalization of the utility value of science. They wrote letters to anonymous fourth graders, either individually (postcards; Sessions 2, 3, 5, and 7) or as a group (rolling paper; Session 4 only). They were asked to describe the jobs discussed during that session and how professionals in those careers use science, including at least two examples of personal utility and one example of communal utility. Students could copy the personal utility and communal utility statements that they were given, or they could create their own examples. Other than these guidelines, students were encouraged to write freely and decorate their postcards. Letters were collected at the end of each session. We provided students with bogus thank-you replies from fourth graders to keep them involved in the writing activity.

2.2.2. Control condition

For the control group, the program was titled, ‘Reviewing Science.’ Students in the control group completed the same activities as those in the experimental group, except that the content dealt with three or four specific science topics within four broad topic categories (plants, states of matter, light, and the solar system). For example, during Session 2 in the control condition, students matched 21 statements about plants with three specific science subtopics (i.e., structure & functions, growth, and habitats & shapes of plants). The statements described various characteristics of plants that had been introduced before (e.g., “Roots of a plant provide support for the plant and absorb water and nutrients,” “The age of a plant can be estimated by observing the size of its leaves and thickness of its stems,” “Cactuses can live in a dry desert where there is not enough water because they can store a great amount of water in their thick stems”).

Statements used in the activities came from elementary school science textbooks and described science concepts and principles that students had already learned in their science classes. For the writing activity, students were told to explain to fourth graders the science concepts and principles covered during the session (e.g., “The angle at which the light bounces off depends on the surface of an object. On a smooth surface, the light would reflect at the same angle as it hits the object; on a rough surface, the reflected light rays would scatter at varying angles”), using at least three examples.

### 2.3. Measures

The appendix presents all of the items used in the self-report survey. Existing measures with proven reliability and validity were adapted for this research. Identical survey items were used before and after the intervention (T1 and T2, respectively). Items were translated into Korean and then back-translated into English by two bilingual researchers and three content experts compared the English-Korean item pairs for consistency in meaning. All items referred to science and students responded using a 5-point Likert scale ranging from 1 (not at all true) to 5 (very true). Table 2 presents the reliability information for the measures.

#### 2.3.1. Utility value

The personal utility value of science was measured using seven items, three of which came from the scale for proximal personal utility value used by Hullman and Harackiewicz (2009) and four from the scale for distal personal utility value used by Conley (2012). The communal utility value of science was assessed with an adapted version of the five-item scale used by Brown et al. (2015). Confirmatory factor analysis with two latent variables, personal utility value and communal utility value, fit the data to a satisfactory degree, $\chi^2(53,$
Table 2
Descriptive statistics for major variables.

<table>
<thead>
<tr>
<th>Variable</th>
<th>T1</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n  M   SD  α</td>
<td>n  M   SD  α</td>
</tr>
<tr>
<td>Personal utility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental condition</td>
<td>216  3.65 0.88 .91</td>
<td>215  3.83 0.93 .93</td>
</tr>
<tr>
<td>Control condition</td>
<td>191  3.84 0.81</td>
<td>190  3.60 0.90</td>
</tr>
<tr>
<td>Communal utility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental condition</td>
<td>216  3.31 0.87 .89</td>
<td>215  3.60 0.96 .92</td>
</tr>
<tr>
<td>Control condition</td>
<td>191  3.51 0.84</td>
<td>190  3.35 0.95</td>
</tr>
<tr>
<td>Interest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental condition</td>
<td>216  3.39 0.99 .88</td>
<td>215  3.43 1.00 .87</td>
</tr>
<tr>
<td>Control condition</td>
<td>191  3.60 0.96</td>
<td>190  3.39 .93</td>
</tr>
<tr>
<td>ARSC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental condition</td>
<td>216  3.12 1.05 .89</td>
<td>211  3.39 1.05 .91</td>
</tr>
<tr>
<td>Control condition</td>
<td>191  3.33 1.01</td>
<td>187  3.28 0.97</td>
</tr>
<tr>
<td>IESA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental condition</td>
<td>216  2.98 1.02 .91</td>
<td>215  3.24 1.07 .92</td>
</tr>
<tr>
<td>Control condition</td>
<td>191  3.21 1.06</td>
<td>190  3.04 1.06</td>
</tr>
<tr>
<td>Achievement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experimental condition</td>
<td>216  0.01 0.99 .77</td>
<td>217  0.00 1.03 .77</td>
</tr>
<tr>
<td>Control condition</td>
<td>192  −0.01 1.01</td>
<td>192  −0.01 0.96</td>
</tr>
</tbody>
</table>

Note. Achievement scores are standardized as Z scores. ARSC = appreciation of the role of science in future careers; IESA = intention to engage in science-related activities.

N = 416 = 222.64, p < .001 (CFI = 0.95, TLI = 0.92, RMSEA = 0.09), with all items demonstrating substantial loadings on their respective factors (all p’s < .05).

2.3.2. Interest

We assessed students’ interest in science with a four-item measure adapted from the one used by Durik et al. (2015).

2.3.3. Motivational outcomes

The appreciation of the role of science in future careers was measured using four items from the expansion of perception subscale from the transformative experience scale by Pugh, Linnenbrink-Garcia, Koskey, Stewart, and Manzey (2010). We also assessed students’ intention to engage in science-related activities using four items modified from the future course enrollment intention scale used by Bong (2001) as an index of their choice behaviors.

2.3.4. Achievement

Students’ science achievement prior to the intervention (i.e., T1 achievement) was measured using 25 multiple-choice questions that covered the content taught previously. Students’ T2 achievement was tested with 22 multiple-choice and 3 short-answer questions for the fifth graders and 20 multiple-choice and 5 short-answer questions for the sixth graders. The exams were developed and administered by school teachers. Scores were converted as Z scores for analysis.

3. Results

3.1. Descriptive statistics and randomization check

Tables 2 and 3 present the descriptive statistics and zero-order correlations, respectively, for all variables at measurement points T1 and T2. All variables were significantly and positively correlated. The correlation between personal and communal utility value was quite high at both T1 (r = 0.83) and T2 (r = 0.89, both p < .001), hinting at potential multicollinearity. However, when we tested a single-factor CFA model without distinguishing between personal and communal utility value, χ²(54, N = 416) = 276.48, p < .001 (CFI = 0.93, TLI = 0.90, RMSEA = 0.10), the model fit was significantly lower than for the two-factor model, Δχ²(1, N = 416) = 53.84, p < .001. Therefore, we treated personal and communal utility value as separate factors in the analysis.

As a test of randomization, independent-samples t-tests were used to compare the T1 scores for the experimental and control groups. Despite the random assignment of classes to the two conditions, for all variables except for achievement score, the control group had significantly higher scores before the intervention than did the experimental group, including personal utility value, t(405) = 2.26, p = .02 (d = 0.23), communal utility value, t(405) = 2.40, p = .02 (d = 0.24), science interest, t(405) = 2.20, p = .03 (d = 0.22), and in- tention to engage in science-related activities, t(405) = 2.16, p = .03 (d = 0.21).

3.2. Effects of the intervention on outcomes

We conducted two types of analyses, each trying to answer three slightly different questions: (a) repeated measures multivariate analysis of variance (MANOVA), followed by univariate analyses of variance (ANOVA) when the overall effect was significant, to detect differences in the change in student outcomes from T1 to T2 between the experimental and control groups; and (b) regression analyses with clustered robust standard errors (CR-SEs; McNeish, Stapleton, & Silverman, 2017) to examine the direct effects of the intervention on the outcomes and test the hypothesized mediation by personal and communal utility value, while accounting for the nesting of students within classes.

3.2.1. Changes from T1 to T2

To identify possible differences in the change in science motivation and achievement over time between the two groups, we conducted a repeated measures MANOVA, with treatment (experimental = 1, control = 0) as a between-subjects factor and time (T1 vs. T2) as a within-subjects factor. Both time, F(6, 375) = 4.84, p < .001 (partial η² = 0.07), and the time × treatment interaction, F(6, 375) = 4.92, p < .001 (partial η² = 0.07), had a significant multivariate effect, indicating that the overall difference between the T1 and T2 scores was significant but the magnitude of this difference between the two groups. Repeated measures ANOVAs showed that the time × condition interaction was significant for personal utility value, F(1, 380) = 20.45, p < .001 (partial η² = 0.05), communal utility value, F(1, 380) = 19.00, p < .001 (partial η² = 0.05), interest, F(1, 380) = 5.42,
p = .02 (partial $\eta^2 = 0.01$), appreciation of the role of science in future careers, $F(1, 380) = 8.06, p = .005$ (partial $\eta^2 = 0.02$), and intention to engage in science-related activities, $F(1, 380) = 17.61, p < .001$ (partial $\eta^2 = 0.04$). As seen in Fig. 2 and Table 2, all of the scores improved within the experimental group but declined in the control group from T1 to T2. The time × condition interaction was not significant for science achievement.

All possible two-way and three-way interactions between treatment, gender, and T1 science achievement were tested by computing the CRSEs for the regression estimates. By doing so, we investigated the possibility that the intervention was more effective for a certain group of students, such as girls or low achievers in science, while correcting for the nested structure of the data. As expected, neither gender nor T1 science achievement alone, nor any of the interactions, were significant for any of the outcomes. Therefore, these two variables were no longer considered in subsequent analyses.

3.2.2. Direct effects of the intervention

Students in the present study were nested within 17 classes and the intervention was implemented at the classroom level. A widely used method to account for a nested data structure is multilevel modeling. However, two factors prevented us from taking advantage of this method. First, none of the intraclass correlation coefficients (ICCs) for the dependent variables at either time point exceeded .1, indicating that

![Fig. 2. Mean changes of motivational and behavioral outcomes based on MANOVA results. Achievement scores are standardized as Z scores.](image-url)
class membership did not account for a meaningful portion of the variance in student outcomes. Second, our sample size for Level 2 was very small at only 17 classes. Several researchers have warned against using multilevel modeling with such a small number of clusters (Maas & Hox, 2005; see McNeish & Stapleton, 2016, for a review). This is because sample sizes smaller than 50 (or 30 at a minimum) at Level 2 result in downward-biased estimates of the 2nd level standard errors, leading to serious inflation in Type-I error rates.

Alternatively, we made use of cluster-robust standard errors (CR-SEs; McNeish et al., 2017), which are estimated by statistically adjusting for the nested data structure by correcting for the non-independence of the data with a relatively small number of clusters, as in the present study. All analyses were carried out with Mplus 7.4 (Muthén & Muthén, 1998–2015), with a robust maximum likelihood estimator (MLR) and the design-based correction of standard errors (i.e., type = complex). We first analyzed models for each of the six motivation and achievement variables (i.e., personal utility value, communal utility value, interest, appreciation of the role of science in future careers, β = 0.22, p < .003, and intention to engage in science-related activities, β = 0.07, p = .07, appreciation of the role of science in future careers, β = 0.17, p = .003, and interest, β = 0.17, p = .08, communal utility value, β = 0.15, p = .09, and intention to engage in science-related activities, β = 0.15, p = .11, but not interest, β = 0.07, p = .07, appreciation of the role of science in future careers, β = 0.09, p = .20, or achievement, β = −0.01, p = .78.

3.2.3. Indirect effects of the intervention via personal and communal utility value

We then examined whether the two forms of utility value mediated the intervention effects using the CR-SEs. Personal utility value positively related to interest, β = 0.46, p < .001, appreciation of the role of science in future careers, β = 0.48, p < .001, intention to engage in science-related activities, β = 0.18, p = .04, and science achievement β = 0.22, p = .004. Communal utility value also related positively to appreciation of the role of science in future careers, β = 0.25, p = .02 and intention to engage in science-related activities, β = 0.08, p < .001, while, unexpectedly, relating negatively to science achievement, β = −0.16, p = .004. The zero-order correlation between communal utility value and science achievement was positive (r = 0.11, p < .05; see Table 3), indicating that this negative path is a result of a suppression effect owing to the high correlation between the personal and communal utility values.

The indirect effect of the intervention on the outcomes via personal utility value was significant for interest, β = 0.08, p = .02, appreciation of the role of science in future careers, β = 0.08, p = .01, and intention to engage in science-related activities, β = 0.03, p = .01. Our intervention thus enhanced science interest and appreciation of the role of science in future careers only indirectly by increasing the personal utility value of science, indicating “indirect-only mediation” (i.e., significant indirect paths with no direct path; Zhao, Lynch, & Chen, 2010). The indirect effect of the intervention through communal utility value was significant only for intention to engage in science-related activities, β = 0.09, p = .007. The intervention had no effect on science achievement either directly or indirectly via utility value.

4. Discussion

An increasing body of research has successfully brought the EVT into the classroom, emphasizing the importance of utility value in enhancing students’ STEM motivation (e.g., Gaspard, Dicke, Flunger, Brisson et al., 2015; Hulleman et al., 2010, 2017). Taking this further, the current study reports on the efficacy of a theory-based science utility value intervention for upper elementary school students, who are on the verge of transitioning to middle school, a move which is associated with a decrease in STEM motivation (Jacobs et al., 2003).

This research extends previous value intervention research in several important respects. As far as we are aware, this is one of the rare intervention studies (along with the one by Woolley et al., 2013) that has demonstrated that learners as young as the fifth and sixth grade at elementary school can benefit from a utility value intervention when it is introduced with developmentally meaningful material. Although our

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### Table 4

Results from mediation analyses.

<table>
<thead>
<tr>
<th>Tested effect</th>
<th>Interest</th>
<th>ARSC</th>
<th>IESA</th>
<th>Achievement</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 score</td>
<td>β</td>
<td>SE</td>
<td>β</td>
<td>SE</td>
</tr>
<tr>
<td>Condition</td>
<td>.66***</td>
<td>.03</td>
<td>.59***</td>
<td>.04</td>
</tr>
<tr>
<td>Condition</td>
<td>.07</td>
<td>.07</td>
<td>.09</td>
<td>.07</td>
</tr>
<tr>
<td>T1 score</td>
<td>.40***</td>
<td>.04</td>
<td>.26***</td>
<td>.05</td>
</tr>
<tr>
<td>Condition</td>
<td>.02</td>
<td>.04</td>
<td>.01</td>
<td>.04</td>
</tr>
<tr>
<td>Indirect effect</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Condition → PUV → outcome</td>
<td>.08*</td>
<td>.04</td>
<td>.08*</td>
<td>.04</td>
</tr>
<tr>
<td>Condition → CUV → outcome</td>
<td>.03</td>
<td>.02</td>
<td>.04</td>
<td>.03</td>
</tr>
<tr>
<td>Total R²</td>
<td>.64***</td>
<td>.59***</td>
<td>.63***</td>
<td>.40***</td>
</tr>
<tr>
<td>n</td>
<td>397</td>
<td>390</td>
<td>397</td>
<td>394</td>
</tr>
</tbody>
</table>

Note. Values are standardized regression coefficients. All variables are from T2, except for the T1 score. Achievement scores are standardized as Z scores. PUV = personal utility value; CUV = communal utility value; ARSC = appreciation of the role of science in future careers; IESA = intention to engage in science-related activities. Condition = 0 (control) and 1 (experimental).

*p < .05. **p < .01. ***p < .001.
intervention was relatively long—seven bi-weekly 40-min sessions over 14 weeks—this design feature encouraged the participating students to view the intervention as part of the regular curriculum rather than a discrete component detached from what they usually do at school on a daily basis. We believe the time and effort invested in implementing the intervention were justified by the students' gains in science motivation.

It is also noteworthy that the volunteer instructors, who were college students with limited prior teaching experience, were able to execute the intervention program successfully. They also rotated classrooms during the intervention, so all students were exposed to all instructors within each condition. The experimental treatment consequently had an effect on all student outcomes except for achievement. This research thus illustrates that a carefully designed intervention program can achieve its intended purposes as long as it is implemented with fidelity, even when delivered by non-experts.

The effect of utility value interventions, previously observed in high school (Gaspard, Dicke, Flunger, Brisson et al., 2015; Hulleman & Harackiewicz, 2009) and college students (Hulleman et al., 2010) in Western cultures, was replicated in this study with much younger students in a cultural setting that is known to promote different goals and values (Hofstede & Bond, 1988; Markus & Kitayama, 1991). The inevitable culture-specific components of the experimental material notwithstanding, the results as a whole speak to the cross-cultural applicability of utility value interventions in enhancing student motivation in STEM areas.

4.1. Changes in young students’ science motivation

Students who were introduced to the potential links between science and personal and communal utility inherent in a diverse range of non-STEM careers perceived high utility value in science compared to students who were not exposed to these connections. Students in the intervention program also displayed a stronger intention to engage in science-related extracurricular activities. In contrast, control group students exhibited a decrease in most of the measured forms of science motivation from the beginning to the end of the semester, supporting previous research that reported that students' STEM motivation began to decline rapidly in upper elementary school (Jacobs et al., 2002).

A large number of previous efforts have been successful in reversing the decline in STEM motivation after students advance to high school (e.g., Gaspard, Dicke, Flunger, Brisson et al., 2015; Hulleman & Harackiewicz, 2009). While these achievements are encouraging, we decided in the present research to intervene in science motivation before the decline took hold. Because the motivation of young students is predictive of their later motivational development (Gottfried et al., 2001), it is crucial not only to prevent this decrease in motivation but to also attempt to increase motivation during their early educational years. The success of our intervention program in boosting students' science motivation provides powerful evidence that the motivation of young children is malleable and that it is possible to improve it substantially by bolstering their perception of utility value, both on a personal and communal level. We believe these findings are an important addition to the current literature on utility value interventions.

4.2. Science utility value interventions that work for all students

We designed and tested a science utility value intervention aimed at enhancing the science motivation of all students. The results revealed that our intervention was effective for both girls and boys and both high and low achievers in science. Utility value interventions have sometimes been likened to a double-edged sword because, while communicating the value of STEM serves to motivate certain groups of learners, such as girls and minority students (Gaspard, Dicke, Flunger, Brisson et al., 2015; Harackiewicz, Canning, Tibbetts, Priniski, & Hyde, 2016), it can pose a threat to other groups of learners, such as those who doubt their ability to succeed in STEM (Canning & Harackiewicz, 2015, Study 1; Durik et al., 2015, Study 1). Being aware of this, we were careful to avoid or neutralize information that could provoke gender-specific or competence-relevant representations in an attempt to devise an intervention that could boost the science motivation of all students.

We believe several elements in our intervention were particularly helpful in achieving this goal. One of these was the focus on a diverse range of careers that are popular among Korean elementary school students. A total of 18 occupations were discussed in relation to science.
during the intervention, including the 13 most popular jobs among elementary school students (Korean Ministry of Education, 2016) categorized into four occupational categories (design, entertainment, cooking, and teaching), four additional careers introduced during the session on scientific skills in jobs (TV reporters, criminal psychologists, writers, and athletes), and the students’ own desired future career. This diversity ensured that the students considered traditionally male- and female-typed occupations in relation to science, which would have contributed to erasing potential gender differences in the effectiveness of the intervention.

There is evidence that gender stereotypes in science have weakened considerably among children in recent years, and this might have helped the program in this study to affect both genders similarly. In one past study (Chambers, 1983), only 28 girls out of 4807 U.S. and Canadian children (49% of whom were girls) in kindergarten to Grade 5 drew a female scientist when given the Draw-a-Scientist Test, representing only .6% of the entire sample and 1.2% of the girls in the study. However, this increased substantially in a more recent investigation (Farland-Smith, 2009). When 225 fourth and fifth graders in the U.S. and 225 fourth and fifth graders in China completed the same task, 56% of the drawings produced by American girls and 38% by Chinese girls were women; 14% of the drawings by American boys and 6% by Chinese boys were also of female scientists. Presumably, gender stereotypes surrounding science become stronger as students grow older, causing the effect of interventions to differ between the genders in older students.

Selecting non-STEM careers for our intervention also had the inadvertent consequence of introducing many careers familiar to children in which success does not depend greatly on academic abilities or credentials (e.g., hair and makeup designers, actors, bakers, and athletes). Even if students lacked confidence in science, talking about these careers would not have posed a serious threat to them. We think this might be why students at different achievement levels responded equally positively to our intervention.

4.3. Effects of personal and communal utility value on science motivation and achievement

We addressed two distinct types of utility value in our science intervention program: personal and communal. Several researchers have proposed “self-focused agentic value” and “other-focused communal value” as two superordinate categories of utility value (Brown et al., 2015; Vansteenkiste et al., 2004) and have conceptualized personal and communal utility value as being orthogonal to each other (Brown et al., 2015). Whereas the structure of the utility value construct appears similar across genders, mean levels of specific utility value facets (e.g., utility of math for jobs, general utility of math for future life) differ between the genders (Gaspard, Dicke, Flunger, Schreier et al., 2015). These findings illustrated to us the need to address multiple aspects of utility value. Most importantly, recent studies have demonstrated that emphasizing the communal utility value of STEM could appeal to a wider range of college students, including traditionally under-represented groups in STEM fields (Boucher et al., 2017; Brown et al., 2015).

Previous studies have compared the effect of communal utility value alone with that of both personal and communal utility value together have found that providing additional utility value information did not result in greater motivational benefits for students over and above that of communal utility value alone (Brown et al., 2015; Vansteenkiste et al., 2004). These studies, however, dealt with either STEM careers (e.g., biomedical science) or a personally dispassionate task (e.g., recycling), for which the two types of utility value might not have been easily instilled in the students. To overcome this problem, our intervention stressed the personal utility value of science in various careers that are commonly aspired to by upper elementary school students. Further, these careers typically involved working with and helping others. Cultural sway aside, early adolescents, like the current sample of students, are known to be particularly susceptible to communal information (Dawes, 2017). Presenting instrumentality information that highlighted the personal and communal utility of science in future careers appeared to have appealed to our students and helped them appreciate the two discrete forms of utility value in meaningful ways.

Our intervention directly enhanced not only the students’ intention to engage in science-related activities but also indirectly improved their science interest and appreciation of the role of science in future careers via personal utility value. This indirect-only mediation may be attributable to several factors (Rucker, Preacher, Tormala, & Petty, 2011), including the difficulty in detecting intervention effects on longer-term outcomes such as interest and connecting science to students’ own future goals, for which improvement is assumed to be progressive. It is also possible that factors in our intervention other than utility value had an unintended influence on the students’ interest in and appreciation of science. Still, our results make theoretical sense based on the model of interest development (Hidi & Renninger, 2006). The model posits that perceiving and internalizing the value of a task or a domain is one of the most critical prerequisites for the development of consistent individual interest. While our finding supports the results of a previous study (Hulleman et al., 2010), it also illustrates that increasing not only personal utility value but also communal utility value can promote student interest in science.

Our findings suggest the possibility that the function of the two types of utility value may be both distinct and complementary. The indirect effect of the intervention on the cognitive engagement variables such as science interest and the appreciation of the role of science in future careers was significant only via personal utility value. In comparison, the intervention significantly increased the students’ intention to engage in science-related activities via both types of utility value, with communal utility value being a stronger mediator. These results are supported by previous studies that have found that individuals who perceive stronger communal utility value in a particular domain express stronger intentions to engage (Watt & Richardson, 2007) and willingness to choose a career (Brown et al., 2015) in that domain. Nonetheless, a firm conclusion regarding the differences in their roles requires further evidence because the two types of utility value correlated strongly with each other in this study.

4.4. Practical implications for STEM intervention

The present study offers several practical implications for designing STEM motivation interventions. First, our intervention was aimed at elementary school students in general rather than students with specific characteristics. Our program encouraged students to think about possible connections between science and various popular occupations, thereby attempting to enhance the STEM motivation of all students, including those who do not aspire to STEM careers. STEM literacy has become a basic competency in the fourth industrial revolution era (OECD, 2016; U.S. Department of Education, Office of Innovation and Improvement, 2016) and intervention programs should be responsive to this educational need.

Second, although our program was designed for students in general, the participating school had an above-average percentage of students from low-income families. Considerable evidence suggests that students of low SES are more likely to struggle in STEM courses and subsequently suffer from low STEM motivation (Harackiewicz et al., 2014; Wang & Degol, 2013). These students may lack the parental support and educational opportunities necessary to develop the early skills required for STEM subjects, which further weakens their STEM motivation (Simpkins et al., 2006). The strong promotion of utility value in the present study produced many significant effects among the participating students and we encourage greater intervention efforts geared towards disadvantaged young learners.
Third, our findings indicate that upper elementary school is indeed a critical period for students’ STEM motivation. The science motivation of the fifth and sixth graders in our study decreased over a single semester in the absence of an intervention. Early exposure to a STEM intervention is called for because it can halt or even reverse this unfortunate motivational trend, as demonstrated in this research.

Finally, we believe our program has strong potential for large-scale implementation. Positive changes in many student outcomes were observed with minimal involvement by the researchers in delivering the intervention. The set of fidelity criteria developed in the study can easily guide interested teachers through the lessons by pointing out the essential components that need to be adhered to in order to obtain similar intervention effects (O’Donnell, 2008). Yeager and Walton (2011) claimed that scaling intervention requires the materials to be meaningful for a diverse range of students at different school sites. The careers we incorporated into this intervention were popular among upper elementary school students in Korea and thus attractive to students with varying interests and aspirations.

Although our intervention required a higher number of sessions than other brief interventions validated for large-scale implementation (e.g., online mindset interventions; Paunesku et al., 2015), its close integration with the subject of science is, in our view, a clear strength. Embedding the intervention in the school science curriculum and supplying teachers with ready-to-go instructional materials (e.g., uploading lesson materials online; Woolley et al., 2013) are practical options to consider when looking to introduce our intervention to more students.

4.5. Limitations and future directions

We acknowledge that the generalizability of our findings may be limited because only students attending a single school in Korea participated in this research. The intervention program should be implemented in multiple schools in multiple regions before its effectiveness for the general population of elementary school students can be confirmed. Obviously, if an intervention is to be implemented in different cultural and educational settings, customization of the intervention materials to suit the specific setting is required (Harackiewicz & Priniski, 2018). Nevertheless, we are cautiously optimistic that the effects of our intervention will hold across schools if the essential features of the program—emphasizing the usefulness of science for attaining the personal and communal goals inherent to various STEM and non-STEM careers—is maintained. Future research should test the generalizability of our findings with diverse samples in diverse contexts, preferably across different cultural and educational settings.

As is typically the case in survey research with elementary school students (e.g., Bong, 2009), the correlations among self-reported motivational variables were quite strong. While this phenomenon owes, in large part, to the lack of differentiation in the belief system of young students, the strong correlation between personal utility value and communal utility value deserves attention. Although personal and communal utility value are theoretically and empirically distinct (Brown et al., 2015; Gaspard, Dicke, Flunger, Schreier et al., 2015), the high correlation between the two utility value constructs in the present study does not allow their unique effects on student motivation and achievement outcomes to be fully explicated. We have suggested the possibility that the two utility value constructs play a distinct role in student motivation and achievement. Future research can test the validity of our claim using a more diverse set of outcomes.

Motivation in science improved significantly for students who experienced the intervention, both compared to those students who did not and in relation to their motivation before the intervention. Nonetheless, the effect sizes of our intervention associated with student outcomes were generally smaller than those reported in previous value intervention studies (average $d = 0.39$; Lazowski & Hulleman, 2016). While the results are still encouraging given that our sample consisted of young students on the verge of experiencing a decline in STEM motivation, it is necessary to follow up on these students to see whether the intervention effects are observable after a certain period of time.

Canning et al. (2017) argued that determining the optimal dosage of a utility value intervention is important from a practical standpoint. Previous utility value interventions with college students have produced significant positive effects on student interest and performance with a smaller dosage (e.g., a single writing session; Hulleman et al., 2010, Study 2) than that employed by the current intervention. Our intervention successfully enhanced the students’ value perceptions but did not directly predict students’ science achievement, which may suggest that the intervention program used in this study was not long enough to enhance achievement. It is possible that younger students require a higher intervention dosage to demonstrate tangible improvements such as greater academic performance. We believe that increasing science motivation in students will eventually benefit their science achievement. Without long-term assessment or a longitudinal investigation, however, our assumption remains another hypothesis that needs to be tested.

5. Conclusions

As the world has become more complex and students are increasingly expected to be knowledgeable in STEM, theory-driven interventions to boost young students’ STEM motivation have been called for. We have responded to this call by designing an ecologically valid science intervention program for elementary school children during regular class hours and demonstrating its positive impact on various facets of science motivation. Our findings illustrate the clear benefit of emphasizing the usefulness of science in achieving students’ personal and communal goals. These two types of utility value functioned both together and independently to enhance students’ interest, engagement intention, career considerations, and achievement in science. The success of our intervention program, designed and implemented for upper elementary school students, is particularly meaningful because it sheds light on how to resolve the challenges we face in facilitating students’ STEM competence and enhancing the abilities of the STEM workforce.

Acknowledgments

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Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.learninstruc.2018.12.003.
Appendix A. Self-report survey items

<table>
<thead>
<tr>
<th>Variable</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal utility value of science</td>
<td>1. Science is useful for my daily life.</td>
</tr>
<tr>
<td></td>
<td>2. What I am studying in science is useful for me now.</td>
</tr>
<tr>
<td></td>
<td>3. What I learn from science can be applied to life.</td>
</tr>
<tr>
<td></td>
<td>4. Learning science is useful for what I want to do after I graduate and go to work.</td>
</tr>
<tr>
<td></td>
<td>5. Science will be useful for me later in life.</td>
</tr>
<tr>
<td></td>
<td>6. Knowing science is valuable because it will help me in the future.</td>
</tr>
<tr>
<td></td>
<td>7. Being good at science will be important when I get a job or go to college.</td>
</tr>
<tr>
<td>Communal utility value of science</td>
<td>1. Science will be useful for me when helping others.</td>
</tr>
<tr>
<td></td>
<td>2. Science is valuable because it will help me to serve my community.</td>
</tr>
<tr>
<td></td>
<td>3. Science will help me connect with others.</td>
</tr>
<tr>
<td></td>
<td>4. Science will be useful for me when I attend to others' needs.</td>
</tr>
<tr>
<td></td>
<td>5. Science will be useful when I care for others.</td>
</tr>
<tr>
<td>Interest in science</td>
<td>1. I find science enjoyable.</td>
</tr>
<tr>
<td></td>
<td>2. Science just doesn't appeal to me. (reverse scoring)</td>
</tr>
<tr>
<td></td>
<td>3. I enjoy working on science problems.</td>
</tr>
<tr>
<td></td>
<td>4. I like learning new science concepts.</td>
</tr>
<tr>
<td>Appreciation of the role of science in future careers</td>
<td>1. During science class, I try to connect things with my future career.</td>
</tr>
<tr>
<td></td>
<td>2. I pay special attention to things related to my future career during science class.</td>
</tr>
<tr>
<td></td>
<td>3. When I see really interesting scientific knowledge either in real life or on TV, I try to associate it with my future career.</td>
</tr>
<tr>
<td></td>
<td>4. I think about how science can be used in my future career outside of class.</td>
</tr>
<tr>
<td>Intention to engage in science-related activities</td>
<td>1. If I were to choose a club, I'd like to join one that's science-related.</td>
</tr>
<tr>
<td></td>
<td>2. I'd like to participate in after-school science activities if I were given a choice.</td>
</tr>
<tr>
<td></td>
<td>3. When I get a chance, I'd like to take part in science-related activities.</td>
</tr>
<tr>
<td></td>
<td>4. I want to participate in science-related extracurricular activities or programs in the future.</td>
</tr>
</tbody>
</table>

References


