Engagement in Science and Engineering through Animal-Based Curricula

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Abstract

One of the persistent challenges in science, technology, engineering, and math (STEM) education is increasing interest, learning, and retention, particularly with regard to girls and students in underserved areas. Educational curricula that promote process and content knowledge development as well as interest and engagement in STEM are critical in supporting student success and pathways to careers in STEM-related fields. One new and innovative method for promoting STEM learning is animal-based curricula, which can provide the opportunity to introduce students to science and engineering principles in an active, engaging way that promotes an optimal learning environment. The goal of this study was to pilot test the effectiveness of animal-based curricula in motivating middle-school students' interest in science and engineering, as a gateway to them learning more broadly about science and engineering careers. The present study used data from two veterinary medicine-based out-of-school time STEM programs for middle school students. Students in both programs reported a significant increase in scores on interest in engineering after completing the program, but no significant difference in science interest scores. The findings from these pilot data provide exploratory information about the potential effectiveness of animal-based STEM education as a strategy for increasing interest in STEM careers for middle school students.

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Educational curricula that promote interest and engagement in science, technology, engineering, and math (STEM), as well as process and content knowledge development, are critical in supporting both student success and pathways to careers in STEM-related fields (National Academy of Engineering, 2012). Currently, girls report significantly lower levels of interest in STEM careers by the end of high school (39.7% of males compared to 12.7% of females; Sadler et al., 2012). There is evidence that girls form attitudes toward STEM (particularly science) as young as elementary school (Kotte, 1992; Sullins et al., 1995). In post-secondary education, women are less likely than their male counterparts to enroll in a STEM major (13% of women compared to 34% of men; Griffith, 2010). Similarly, only 36% of minority students who originally planned on majoring in a STEM field persisted in that major by senior year (compared to 46% of non-minority students; Griffith, 2010). These data indicate that increasing interest, learning, and engagement in STEM for diverse students is a continuing challenge in preK-12 STEM education.

As concern over the diversity of STEM field continues, there is mounting evidence that the personal interest of individual students is strongly related to their educational choices and career outcomes (e.g., Gushue, 2006; Scheuermann et al., 2014; Waller, 2006). While many STEM disciplines struggle to attract and retain female students, veterinary medicine is an increasingly female-dominated profession, with women constituting 78% of veterinary school graduates (American Veterinary Medical Association [AVMA], 2013). This is not unexpected given that research has reported female interests around science include animals (e.g. Jones, Howe, & Rua, 2000). Furthermore, national pet ownership statistics suggest the importance of animals in the lives of diverse youth, with 68% of all families in the United States having at least one pet (American Pet Products Association [APPA], 2017). Therefore, animal-based curricula may provide a highly motivating context for authentic science and engineering problems that are engaging and intrinsically motivating for students, as it connects with personal interests. Furthermore, animal-based curricula provide a natural overlap between science and engineering principles, and therefore is an ideal context for integrating these two STEM fields.

Educational curricula that utilize animal-based content can provide a unique opportunity to introduce students to science and engineering principles in an active, accessible way. Prior work has suggested that children respond with interest to live animals (Jalongo et al., 2004; LoBue et al., 2013), and that animal-based content can increase student motivation for learning by providing an intrinsically interesting and emotionally relevant topic of learning (Edenburg & Van Lith, 2011).

In fact, empirical evidence is mounting for the effectiveness of animal-based pedagogy in many different topic areas. Incorporating animals into curricular efforts has been associated with creating a learning environment that promotes increased motivation (see Gee et al., 2015 for review of research on animal-assisted education). A significant portion of the existing research on animal-assisted education has focused on the presence of live animals in the classroom as facilitators, suggesting that the animal can mediate students' stress responses (e.g., Friedmann et al., 1983; 1993) and increase their executive functioning and/or performance. For example, there is increasing evidence suggesting that interacting with animals can improve reading performance in elementary school age children (Hall et al., 2016; Jalongo, 2005; Linder et al., 2017). However, there has also been research indicating that live animals may cause over-arousal or distraction for students (Popp et al., 2016; Somervill et al., 2009). Combined with the practical challenges of scaling up live animal programs, and potential safety and allergy concerns, animal-based approaches that do not rely on live animals are another promising strategy for utilizing the educational benefits of animals in a practical way.

Animal-based pedagogy that instead uses animals as content (compared to live animals as facilitators) can leverage the intrinsically appealing nature of animals and focus directly on science and engineering concepts, drawing a direct parallel between animals and the educational content. In fact, past work with animal-based education without the presence of live animals has shown to be effective in changing children's attitudes about animals and knowledge about different species (Mariti et al., 2011). Preliminary evidence in computer science projects suggest that animal related content enhances engagement and learning (Liao et al., 2011; Weigend, 2014). Therefore, the approach of animals as content may be both more appropriate than animals as facilitators for the context of science and engineering education, as well as more practical for scaling up to a broader audience.

Furthermore, animal-based content provides an excellent context for integrating science and engineering principles, thereby allowing students to learn key tenets from both fields simultaneously. Integration of STEM curricula has generally been associated with improved student learning outcomes (Becker & Park, 2011) and there is evidence that it is achievable, particularly the integration of science and engineering, for teachers with proper support (Roehrig et al., 2012). For example, Wendell and Rogers (2013) found that students showed greater content knowledge gains when exposed to engineering-based science units versus traditional science units. However, more research is needed on the processes by which interest develops in an integrated STEM curriculum (Honey et al., 2014). Animal-based content provides an ideal context for integrating science and engineering principles that allows students to engage in learning principles from both fields simultaneously. For example, an activity that involves designing and building a splint for a dog with a broken bone requires an understanding of animal physiology (science), as well as of the design principles necessary to build an effective device (engineering).

Given the direct link between animals and many topics relevant to science and engineering, animal-based curricula provide the opportunity to introduce students to STEM principles in an engaging way that promotes an optimal learning environment. However, despite this clear theoretical link, there is little existing research documenting proof-of-concept for animal-based education within the context of science and engineering. Therefore, the goal of this study was to pilot test the effectiveness of animal-based curricula in motivating students' interest in science and engineering within a short-term, out-of-school time setting. We hypothesized that students would report significantly higher interest in science and engineering after completing an animal-based out-of-school time program, as compared to their pre-program scores.

Method

Participants & Procedure

Data were collected from two animal-based out-of-school programs for middle-school students. One program met weekly for four weeks ($N = 43$), and the second program ran daily for one week ($N = 34$). Both programs included curricula on careers in science, and an animal-based engineering activity with integrated science principles. These activities included animal-focused problems such as designing a mobility assistance device for a disabled dog and building a splint for a broken bone.

After parental consent and youth assent, participants were asked to complete a pre- and post-program survey to assess science and engineering interest. All data collection procedures were approved by the Tufts University Institutional Review Board

Design Challenge

Students were presented with a design challenge problem based on an actual case previously seen at a veterinary hospital, and then worked with a team to develop a solution to the problem. For example, the broken bone activity involved presenting a case scenario where a dog breaks a leg in a car accident. Using a leg model and x-rays, students were led in an active, hands-on discussion of the musculoskeletal structure of the leg and the function and purpose of each part (e.g., bones, muscles, tendons, ligaments). Students were then given the task of designing a splint for the broken leg bone.

Students grouped into pairs, and were given a design sheet to outline their plan for the splint, and a selection of materials (a small makerspace) from which they were able to "purchase" supplies for their design within a set budgetary constraint (to foster critical thinking and planning). After designing and building the splint, each group conducted both a static and dynamic weight test using hanging weights to assess the strength of their design.

After each group had tested their splint, they were led in a discussion of their solution with the following prompts:

- What worked well with your design? Are there any ideas that others have that you didn't have?
- What did not work with your design? Have other groups come up with a solution that you haven't thought of?

Finally, the students were given time to modify their designs, rebuild, and re-test the design. The activity duration was approximately 2.5 contact hours. This duration was chosen as a feasible time frame to integrate into an existing out-of-school time program.

Traditional "cookbook science" where every student runs the same experiment from a pre-determined recipe with pre-determined outcomes has not proven to be an optimal strategy for promoting learning (Berger, 2003). Structuring these design challenges as open-ended problems required the students to scope the problems and gather information to understand the problem (Watkins et al., 2014). This information included that which was pertinent to the specific animal as well as learning about the science behind the problem. Further, students were called on to justify their design decisions based on information gathered during problem scoping and from the science and engineering principles that supported their designs.

Measures

Demographic information was collected for the participants, including age, grade, gender, race/ethnicity, and information about pets that participants may have in their homes. To measure student interest in science and engineering, we used the engineering and science subscales (11 items each) of the STEM Career Interest Survey (STEM-CIS; Kier, Blanchard, Osborne, & Albert, 2013). These subscales assess student self-efficacy, personal goals, outcome expectations, and engagement with the topic, and are validated for use in adolescence. Both subscales demonstrated adequate reliability across the groups and time points; science subscale Cronbach's $\alpha = 0.68$ to 0.77, engineering subscale Cronbach's $\alpha = 0.88$ to 0.89.

Data Analysis

Descriptive statistics were used to report on participant demographic characteristics. Data for the science and engineering subscales were normally distributed, therefore paired samples t-tests were then used to test change in science and engineering interest from pre-program to post-program. Taking a conservative approach, differences were tested separately for each type of program (weekly and daily). Independent samples *t*-tests were used to assess if pet ownership predicted change in science and engineering interest for each group.

Results

The participants were 83% female, and identified as 67.5% Caucasian/White, 18.1% Asian, 5.2% Hispanic or Latino, 2.6% Black or African American, 1.3% American Indian or Alaska Native, and 5.2% Other. Overall, 79% of the participants had at least one pet at home, which is higher than the national average (65%; American Pet Products Association, 2016).

Results of paired sample *t*-tests indicated that students in both programs reported a significant increase in scores on the engineering interest subscale after completing the program (Weekly Program: $t = -2.72$, $p = .01$; Daily Program: $t = -2.39$, $p = .02$), but no significant differences in the science interest subscale (Weekly

	Weekly Program (N = 43)		Daily Program (N = 34)	
	Pre-Program *M (SD)*	Post-Program *M (SD)*	Pre-Program *M (SD)*	Post-Program *M(SD)*
Engineering Interest	3.83 (.58)	3.97 (.59)**	3.73 (.62)	3.88 (.63)*
Science Interest	4.22 (.45)	4.25 (.40)	4.35 (.40)	4.40 (.41)

*$p<.05$, **$p<.01$

Table 1. Means and standard deviations for engineering and science interest subscales and pre-program and post-program (range 1 to 5).

Program: $t = -0.35$, $p = .73$; Daily Program: $t = -1.43$, $p = .16$). See Table 1 for means and standard deviations for each subscale by group and time point.

Despite the high number of pet owners within this sample, independent samples t-tests indicated that there were no differences between pet owners and non-pet owners on change in science interest (Weekly Program: $t = -0.54$, $p = .59$; Daily Program: $t = 1.48$, $p = .15$), or engineering interest (Weekly Program: $t = -0.07$, $p = .95$; Daily Program: $t = 0.10$, $p = .32$).

Discussion

The purpose of this pilot study was to assess the potential for animal-based curricula to be used as a context for promoting interest and engagement in science and engineering. The results from this study suggest that relatively short exposure to animal-based curricula was associated with an increase in interest in engineering. Lack of significant findings with regard to the science subscale may be due to a ceiling effect; the majority of participants reported a relatively high interest in science upon entering the program. Alternatively, it may be that students receive exposure to science careers in their schools, but relatively less prior exposure to engineering, providing an opportunity for impact.

The curricula tested in this study directly links knowledge of science (e.g., musculoskeletal system) to engineering principles (e.g., kinesthetics). For this particular population of youth who demonstrated high pre-program levels of science interest, this integrated approach may have allowed them to connect their existing interests in science to engineering and provide an accessible entry point to engineering as a field. Future research on animal-based STEM pedagogy should further explore the utility of integrating science and engineering concepts within animal-focused problems to provide an engaging context for learning core principles.

The primary limitation of this study was the selective sample. The participants in this study voluntarily participated in a veterinary-medicine-based out-of-school time program, and therefore were more likely to be predisposed to have an interest in STEM topics. As previously noted, the self-selecting nature of the sample likely contributed to a ceiling effect for interest in science, with most of the students being highly interested in science careers upon starting the program. The sample did achieve diversity with regard to gender (demonstrating the potential appeal for animals among female students), but future work should include more diverse populations with respect to race/ethnicity. In addition, this study was limited by the lack of a control group, and therefore the findings are based on within-subjects pre/post change. Furthermore, although the findings were similar between the two types of programs, further exploration of duration and intensity of programming is necessary. This pilot study included a relatively short duration in terms of contact hours, to test an approach that would be feasible to work into existing out-of-school time program settings. However, it may be that additional contact hours would produce more significant and durable results with regard to sustained interest in STEM, highlighting the importance of future research assessing optimal duration. Similarly, future work should include follow-up to assess if changes in perceptions were durable over time.

Despite these limitations, there is potential for future work in this area. The findings from this study provide initial proof-of-concept that animal-based educational approaches can be useful in engaging youth in engineering. Future work with more diverse, representative samples without prior selection for science interest is important to determine if similar results are found with regard to science interest. In addition, future research employing the use of control groups will be necessary for comparing animal-based approaches to more traditional science and engineering curricula, and to assess the unique contributions of an animal-based approach compared to other non-animal focused problem-based models. Finally, expanding outcomes beyond interest to learning, engagement, and career aspirations will be useful in assessing the impact of animal-based curricular approaches.

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