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Is Kinesiology a Bridge to STEM Engagement? Sport Science Labs in High School

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Is Kinesiology a Bridge to STEM Engagement? Sport Science Labs in High School

Abstract

Improving STEM education in schools is important to prepare students for the increasing number of STEM related jobs. As a STEM discipline, kinesiology, which includes the study of sport, exercise, movement and well-being, may be an effective link between science concepts and students' everyday lives and thus may stimulate science engagement. Our university's kinesiology programs developed a set of sport related kinesiology labs which were presented by faculty and students during one semester in local high school Freshmen and Senior science classes. Survey data included information about STEM engagement, scientific inquiry, and knowledge of kinesiology as a STEM field. Findings included improved understanding of kinesiology but no differences between treatment and control groups in science engagement or understanding. Implications and future directions for kinesiology and science engagement are discussed.

Keywords

STEM, kinesiology, science engagement, science literacy, STEM pathways, high school

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Improving STEM education in schools is important to prepare students for the increasing number of STEM related jobs. As a STEM discipline, kinesiology, which includes the study of sport, exercise, movement and well-being, may be an effective link between science concepts and students' everyday lives and thus may stimulate science engagement. Our university's kinesiology programs developed a set of sport related kinesiology labs which were presented by faculty and students during one semester in local high school freshmen and senior science classes. Survey data included information about STEM engagement, scientific inquiry, and knowledge of kinesiology as a STEM field. Findings included improved understanding of kinesiology but no differences between treatment and control groups in science engagement or understanding. Implications and future directions for kinesiology and science engagement are discussed.

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Introduction

Finding ways to integrate Science, Technology, Engineering, and Mathematics (STEM) into curricula is both a national (NGSS, 2013) and Washington State Office of the Superintendent of Public Instruction (OSPI) priority. Achieving STEM Literacy, defined as an awareness of STEM roles in society, basic familiarity of fundamental STEM foundations, and a basic level of application (NAE & NRC, 2014) can improve student preparation for STEM related jobs as well as greater participation in a democratic society. WashingtonSTEM (Twitchell, 2020) is actively prioritizing STEM-education projects which focus on problem-based learning, guidance in pursuit of post-secondary STEM education and career pathways, and efforts to recruit *all* students (including minorities, English language learners, girls, and students in poverty) into STEM pathways.

Despite the national and local emphasis on STEM literacy, problems still exist. In a recent systematic literature review, Margot & Kettler (2019) found that while many teachers value STEM integration, they also face barriers including a lack of preparation, training, and support. Others have called on teachers and educators to adopt student-centered approaches, emphasize teamwork, allow students to make mistakes (Moore et al., 2014) and integrate real-world applications to solve real-world problems (Chamberlin et al., 2017). It has been shown that student interest in STEM-related fields declines throughout primary and secondary school (e.g., Wigfield et al., 1997); although some progress is being made (Rosenzweig & Wigfield, 2016). This decline can lead to students avoiding STEM-related classes in college and failing to make the connection between their everyday activities and science content. Despite improved access to college, STEM disciplines often have higher dropout rates and lower percentages of both women and minority students (Twitchell, 2020).

One way to improve interest in STEM coursework and career paths is to build curricula that leverage student interest, engagement, and prior knowledge, and that approach science in an interdisciplinary way. Many students lack a deep understanding of how science is done, and more importantly, who is allowed to engage with science (Christidou, 2011). In order to bridge the divide between “science-in-school” and “science-in-society”, teachers need to contextualize science with problems that apply to everyday life, allow students opportunities for creative expression, and leverage topics that students are already interested in (Christidou, 2011; Cunningham et al., 2019). We suggest that kinesiology is a great way to overcome these problems. Besides being interesting, an additional advantage to using kinesiology content is that kinesiology programs often co-exist with teacher education programs in Colleges of Education.

Kinesiology is an interdisciplinary field of study that includes sport, exercise, movement, and well-being (Gill, 2007), and draws from physics, chemistry, biochemistry, statistics, advanced math, biology, anatomy and physiology, neuroscience, and the social sciences. For example, chemical reactions in the blood during exercise result in the production of lactate and lactic acid. Students can test blood lactate before and after exercise, derive the chemical reaction producing it, and learn about the behavioral and performance effects of lactate production during exercise in athletes. Other examples include exploration of Newton’s Laws in football, turbulence in the design and flight of golf balls and curve balls, and our ability to produce speech sounds. Fitts’ Law, connecting distance moved and target size to movement speed, is a concept often used in ergonomics and engineering. Once students have been exposed to the tools used in kinesiology, they can explore further, creating and testing their own hypotheses: Which golf ball will fly the farthest? What does this diver need to do in order to complete three rotations in the air before entering the water?

Sport-related instructional activities can provide salient links to individuals' personal identities, which is important for learning engagement (Cooper, 2014). We suggest that through hands-on participation in kinesiology laboratory sessions, students who traditionally may not see themselves as scientists may re-conceptualize their ideas of what science is and who can participate in conducting science. Furthermore, education in kinesiology can lead students into human performance related fields like strength training or coaching, but also into engineering and a variety of health-related fields, which comprise a number of unfilled STEM skill jobs in our state (Twitchell, 2020) and are among the fastest growing career paths in the United States today (United States Bureau of Labor Statistics, 2020). By increasing awareness of, and participation in STEM content through kinesiology, we hope to 'catch' student interest (Hidi & Renninger, 2006), which is a critical first step in long-term interest development.

Universities, communities, and school districts have previously collaborated in projects that contribute to both student engagement in traditional STEM activities (e.g., hands on engineering projects: Duran et al., 2014; Kukreti et al., 2003; Watters & Diezmann, 2013) and student physical activity and health (Castelli et al., 2012). However, kinesiology as a STEM field of study has not been a focus. Thus, the objective of our study was to bring inquiry-based activities from various kinesiology sub-disciplines into high school classes in a small school district to facilitate science engagement, understanding of scientific process, and awareness of kinesiology as a science. Clarkston School District (CSD) was specifically selected because it contains many students from populations underrepresented in STEM fields, aligning our study with the state's OSPI priorities.

The proposed Learning Outcomes for this project included:

1. Students will pose engaging, scientifically oriented questions and determine how to answer these questions, and pose hypotheses;
2. Students will gather and process valid and reliable data related to their questions;
3. Students will evaluate their hypotheses in the light of their data and consider possible alternative explanations;
4. Students will broaden their understanding of the scope and interrelationships of science and math;
5. Students and school district faculty will be exposed to various sub-disciplines of the kinesiology and start to associate it with other STEM disciplines.

We predicted that our kinesiology and sport-related presentations would improve student engagement in science inquiry and understanding of the scientific process, and students' awareness of kinesiology as a STEM discipline. To understand if our intervention was successful, we collected responses on STEM engagement

and scientific inquiry surveys, collected responses on a kinesiology as a science survey designed for this study and conducted a student focus group. We also report our lab activities to illustrate how we attempted to meet our learning objectives.

Methodology

Participants

Aggregate demographics for CSD were as follows: of the average 2600 K-12 students, 88% identified as White/Non-Hispanic, 2% American Indian, .9% Asian, 1.2% Black, 3.5% Hispanic, 3.9% Multiracial, and 13.84% Special Education, and 59% qualify for the National School Lunch Program. The high school enrolment in grades nine through twelve was approximately 700 students. Four classes with the same instructor participated: two senior AP biology classes, and two freshmen-level physical science classes. One of each class type was selected as the experimental group (receiving kinesiology-related STEM presentations) and the other served as the corresponding control class (no kinesiology-related STEM presentations). The determination of which of the two classes would be experimental and which control was made based on class times to make it convenient for faculty presenters commuting to the high school location.

Measures

The experimental materials and measures for this study included measures for science engagement, understanding of scientific process, and awareness of kinesiology as a science, multiple presentations and labs, and a focus-group interview.

Science engagement. Science engagement was measured via a modification of the Youth Engagement in Science and Technology (YEST) survey (McCarty et al., 2010). This survey was designed based on three factors considered to be interrelated within the construct of engagement: action, interest, and identification. We included only questions that are science related (Appendix A), and our statistical analysis focused only on specific questions most related to our purposes. McCarty et al. reported a test-retest reliability of .85.

Science knowledge. We used the Science Knowledge Survey (SKS) from Evolution and the Nature of Science Institutes at Indiana University (Flammer et al., 1998). This open-access survey is widely used in high school science teaching as a way to evaluate and facilitate discussion on the nature of science (Clough, 2011). Unlike many online science knowledge surveys, which are about specific science content, the SKS assesses student knowledge of the scientific process. There are 25 questions, and total correct out of 25 was calculated for use in this study. The post-test revealed a Cronbach's alpha of 0.58, with an average score of

13.4 ($SD = 3.4$), indicating that students had significant difficulty with this measure.

Science discipline knowledge. We developed a Science Disciplines survey (SD, Appendix B) to determine whether students knew that kinesiology was the scientific study of human movement. Eleven possible fields of study were listed. Students were asked to mark ‘agree’, ‘disagree’, or ‘don’t know’ that a field is a science (worth 1 point), and then to identify the topic matter of the field (worth another point, for a total of 2 points). Traditional sciences like biology and chemistry along with foils like astrology were included. The post-test of this measure indicated a Cronbach’s alpha of 0.76, indicating that it performed reliably.

Focus group interview. At the end of the semester, students were given a chance to join an optional focus group to debrief the project. Questions discussed during this session were:

1. Which presentations did you like best and why?
2. How much did the application to sport questions motivate your interest in the presentation?
3. What did the presenters do that helped your engagement/understanding?
4. What could the presenters do better?
5. What other sport science questions came up for you this semester?

Laboratory Presentations

Over the course of the semester, each experimental group received five kinesiology-based laboratory presentations demonstrated by university faculty. Presentations included a short introductory lecture, an introduction of the lab questions and procedures, student hypothesis creation, student data collection, and discussion of findings. Since these lab activities were presented during a fall semester, we included questions related to fall sport activities (soccer, basketball, football). The discussion often included charting lab results either individually or as a group, and crafting concluding statements as well as follow up questions. On the lab days control groups had science-related movies or discussions not connected with kinesiology.

Exercise physiology. Students collected and analyzed blood lactate levels before and after strenuous exercise. Five simple finger prick samples were taken from each student volunteer before, during and after different types of physical activity: walking around a gym space for five minutes at a normal pace, performing intense exercises for five minutes and then walked again for 10 minutes at a normal pace. Using a portable Lactate Plus Measuring Meter and test strips, blood lactate results at each point in time were recorded. This equipment gives a blood lactate reading in 15 seconds, so students received immediate

feedback. Students who were not direct participants completed the physical activities without the blood testing.

Biomechanics and motor control. This activity involved using Backyard Brains Spiker boxes to record electromyography (EMG) as students performed various arm movements and arm wrestled each other. We equipped classroom iPads with software to view and compare the electrical signals recorded in the muscles. Students placed passive electrodes on the skin surface over the biceps brachii (front of upper arm) and triceps brachii (back of upper arm) in order to view the action of both muscles in voluntary muscle contraction. Students also measured EMG during maximum voluntary contractions and mimicking of basketball shots to several different distances.

Athletic Training and sport injury. Three volunteer athletic training students helped students explore the mechanism and effects of concussions in sport. Students participated in hands on activities simulating balance disruption (special goggles and platforms) and scored each other's balance ability in this situation using the Balance Error Scoring System developed for concussion evaluation. Concussion content was related to physics concepts (Newton's Laws of Motion) as well as common experiences in sport and daily life that may result in concussion.

Procedures

First, we pretested the classes on the YEST, SKS, and SD. Then, during the approximately nine weeks between administration of pre- and post-tests, experimental groups received kinesiology lab presentations as described, while students in the control groups had science-related movies or discussions not connected with kinesiology. At the end of the semester, each student again completed the three surveys. Fifteen students representing the experimental group classes also participated in an optional focus group discussion at the end of the semester.

Results

Design and Data Analysis

We used a mixed model with repeated measures comparisons and between subject factors of the two class types and experimental versus control groups. Students who were absent for either the pre-test or post-test were removed from the evaluation. If students were nonresponsive to a particular question, either pre-test or post-test, they were removed from analysis of that question.

Correlations

We found that whether or not students indicated that they saw themselves as scientists was more strongly related to interest in learning science *in* school rather than *outside* of school (although both relationships were significant, $r(59) = .51$ and $.38$, $p < .05$, respectively). Additionally, while seeing science as important was significantly correlated with nearly all measures, it was most strongly correlated with interest in learning about science *out* of school and less so with learning about science *in* school or with being a scientist in the future ($r(60) = .53$, $.48$, and $.28$, $p < .05$, respectively). Taken together, these results indicated that when students saw *themselves* as scientists, they were more interested in science *in school*, whereas when they saw science as *important*, they reported more interest in science *out of school*. While both interest in learning about science *in* and *out* of school were positively correlated with other measures of engagement, understanding, and discipline awareness, they did not correlate as strongly with one another as one may expect ($r(61) = .61$, $p < .05$). This finding indicates, to us, that students' interest in science may not be well developed, or we may need to include a more nuanced measure of interest and engagement. On the whole, we interpret these findings as indicating that interest in science both inside and outside a traditional classroom is important but may require different or overlapping approaches to foster.

Student Engagement

Table 1
Differences in Student Engagement

Importance of Science (All Classes)*		Interest in Science Out of School (Seniors)*		Interest in Science Out of School (Freshmen)*		Science Knowledge (Seniors)*		Science Knowledge (Freshmen)*	
Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
2.61	2.92	3.55	3.03	2.39	2.68	7.61	7.89	6.05	6.77
.91	.86	1.33	1.15	1.09	1.22	1.13	1.13	1.45	1.63

*Denotes significant differences pre to post

Table 1 illustrates differences in student engagement: when asked, 'How important is science to your everyday life?' we found a main effect for time, $F(1, 55) = 5.52$, $p = .023$, partial eta squared = $.091$, such that on average, students' perceptions of the importance of science in their lives increased from the beginning of the semester to the end of the semester regardless of experimental group. This finding is especially heartening when contrasted with previous

accounts of science interest declining during school years (Rosenfield & Wigfield, 2016; Wigfield, 1997).

Two questions evaluated science interest. No significant differences were revealed on interest in learning science in school. For interest in science learning outside of school, our analysis revealed a main effect for group, $F(1, 56) = 8.62$, $p = .005$, partial eta squared = .13), such that the seniors were generally more interested in science out of school regardless of time, as well as a time by group interaction $F(1, 56) = 4.87$, $p = .031$, partial eta squared = .08. The freshmen's interest increased slightly across the semester ($M = 2.39$, $SD = 1.09$, $M = 2.68$, $SD = 1.22$, respectively) while the seniors' interest decreased ($M = 3.55$, $SD = 1.33$, $M = 3.03$, $SD = 1.15$, respectively).

When students were asked to rate their science knowledge, there was a within-subjects main effect of time, $F(1, 55) = 6.32$, $p = .015$, partial eta squared = .103, and a between-subjects main effect of group, $F(1, 55) = 18.97$, $p < .001$, partial eta squared = .256. Specifically, all classes rated themselves as more knowledgeable at the end of the semester ($M = 7.79$, $SD = 1.52$) compared with the beginning ($M = 7.31$, $SD = 1.51$), and the seniors consistently rated themselves as more knowledgeable than the freshmen both pre ($M = 7.61$, $SD = 1.13$, $M = 6.05$, $SD = 1.45$, respectively) and post-test ($M = 7.89$, $SD = 1.13$, $M = 6.77$, $SD = 1.63$, respectively).

For the impact of science on students' lives, the results revealed that the experimental groups saw science as more important in their professions both before and after the treatment compared to the control group. $F(1, 57) = 12.27$, $p = .011$. Similarly, experimental groups saw science as more important in their personal lives both pre- and post-test. $F(1, 57) = 6.43$, $p = .014$.

Overall, it appears that students saw science as important for both their personal lives as well as their future careers. And while Seniors' interest declined, their knowledge still improved. This could be an artifact of seniors deciding their future course of study at university, although this is speculative.

Scientific Understanding

Our analysis of the SKS revealed a main effect for time, $F(1, 51) = 11.44$, $p = .001$, partial eta squared = .183, and a main effect for group, $F(1, 51) = 17.10$, partial eta squared = .251. On average, knowledge scores decreased from pre ($M = 14.96$, $SD = 2.37$) to post ($M = 13.75$, $SD = 2.79$) and were lower for freshmen ($M = 13.27$, $SD = 2.57$) than for seniors ($M = 15.48$, $SD = 2.07$). However, we found a significant interaction between grade and condition, $F(1, 51) = 6.87$, $p = .012$, partial eta squared = .119. See Figure 1.

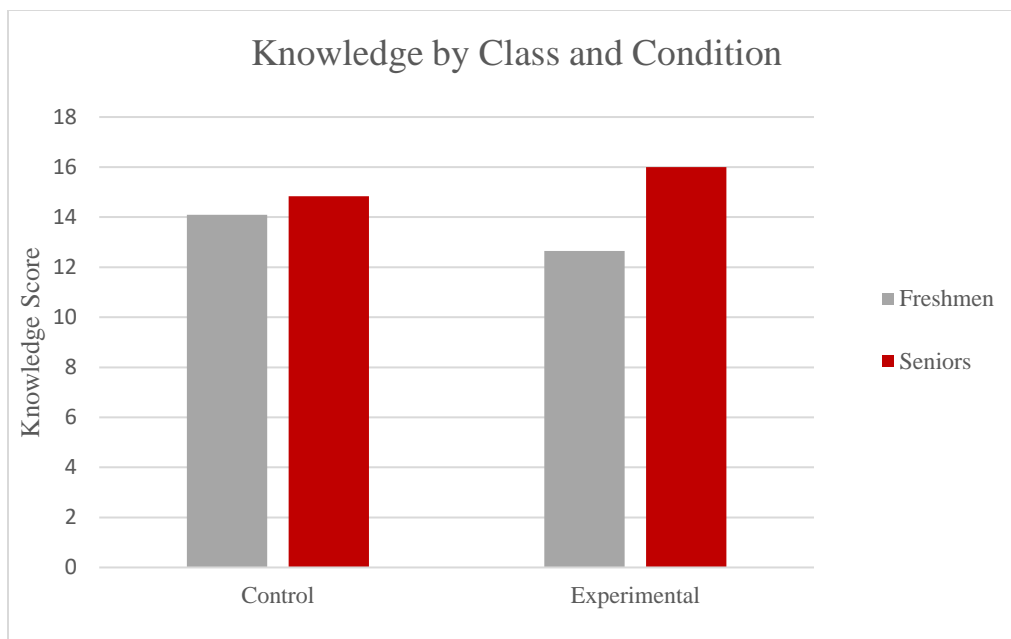


Figure 1. Knowledge by Class and Condition

This interaction illustrated in Figure 1 suggested that while freshmen and seniors in the control group saw no differences between their scores ($M = 14.1$ and $M = 14.83$, respectively), freshmen in the experimental group performed worse ($M = 12.65$) than seniors ($M = 16$). Given these results, we suspect that the intervention was not as successful for freshmen when compared with seniors. As a group, the seniors' scores were significantly above their freshmen counterparts and were resistant to declining over the course of the semester. There could be multiple reasons for this occurrence. First, having a better grasp of biology and other sciences (due to their advanced studies), seniors were more able to apply their previous knowledge to our intervention, making it relatively more successful. By contrast, freshmen may have found the standard curriculum well-suited to their levels of knowledge but were overwhelmed by the interventions. Another possibility is that seniors are more receptive to this intervention due to their proximity to college and thus are more likely to make connections with their future studies and goals. While these stipulations provide avenues for future research, in the present investigation, our treatment did not result in the predicted improvement in scientific process knowledge over the semester, as measured by the SKS.

Kinesiology Awareness

Analysis of the SD revealed a main effect for time, group, condition, and a (nearly significant) interaction between time and condition and group and

condition. Specifically, students indicated greater understanding of the discipline of kinesiology at the end of the semester than at the beginning, $F(1, 49) = 8.38, p < .05$, partial eta squared = 1.46, seniors indicated greater understanding than freshmen, $F(1, 49) = 21.76, p < .05$, partial eta squared = .61, and students in the experimental condition indicated greater understanding than in the control condition, $F(1, 49) = 4.04, p = .05$, partial eta squared = .076. And although it is approaching significance, seniors in the experimental group indicated the greatest understanding, and learners in the experimental group showed the largest gains over time ($p = .087$), and those in the experimental group showed the largest gains from pre to post ($p = .083$). See Table 2.

Table 2
Differences in Kinesiology Knowledge

	Knowledge of Kinesiology (All Classes)		Knowledge of Kinesiology		Knowledge of Kinesiology	
	Pre	Post	Seniors	Freshmen	Exp.	Control
<i>Mean</i>	1.02	1.64	1.26	.45	.99	.65
<i>SD</i>	.95	.81	.83	.74	.84	.89

These results are promising as they indicate to us that the intervention was successful in teaching not only science content but also how this content is applied in the discipline of kinesiology. Additionally, it appears that seniors benefitted the most from this direct application. We suspect the connection of science content to their daily lives coupled with their approaching graduation allowed seniors in the experimental condition to see kinesiology in a new light.

Focus group results

Finally, 15 students participated in a post-project focus group to discuss their impressions and suggestions. Their favorite laboratory session was the blood lactate session because of their access to and interest in the actual equipment used in exercise physiology labs, and the engagement in movement outside of the classroom. Sample quotes include:

“It was a good way to get students involved if they’re really not interested in science.”

“We liked the labs best when the teachers were more enthusiastic.”

“It was fun to have the students from the university presenting.”

“I would have liked to have labs more connected with our class material.”

Suggestions included having two days for the projects, since students and presenters felt rushed, and that fewer labs in more depth would have been more useful to them overall.

Discussion

This investigation sought to stimulate interest in STEM fields and careers in high school students. To achieve this goal, we engaged students in two high school classrooms in hands on science labs related to kinesiology and sport. Our results were mixed. Our quantitative measures indicated that most of the engagement differences were found in the main effects of experimental versus control group. This suggests that there were initial differences between experimental and control groups such that both experimental groups, regardless of class type and level, felt better about themselves as science students and better about science than both control classes. In addition to the tendency for the experimental groups to be generally more engaged in school and science in general, we noted that all classes increased their rating of science's importance to their lives across the semester, which is a tribute to the science teacher and science program at this high school.

However, recognition of kinesiology as a STEM discipline did improve in the experimental group, especially in the senior level class. Thus, our results suggest that while our kinesiology STEM labs resulted in facilitating understanding of kinesiology as a science, we were not able to detect improvements in engagement or scientific process understanding using our measures. This finding is similar to the findings of Lachapelle et al., (2012), who found that engineering activities brought into the public schools had no impact on general interest in science but interest and knowledge specific to engineering increased. It is possible that integration of kinesiology and sport application into science methods courses for pre-service teachers would improve the development and delivery of this type of curriculum.

Although science engagement and science inquiry results were not as expected in our survey measures for this project, we clearly made an impact on the senior students' understanding of our kinesiology discipline. The student focus group felt especially that they could connect with the topics because of the sport focus. Further, the student focus group clearly remembered our lab presentations, and talked about them to students in the control classes, who were disappointed that they were not allowed to receive the kinesiology labs. Thus, we conclude that the project is worth continuing, with some adaptations, as discussed below.

Limitations and Future Directions

One limitation of this study is that as university faculty, we may not have achieved a uniformity of lively teaching, academic rigor, and connective instruction required for good high school science engagement (Cooper, 2014). While all the authors are teachers, we recognize that some student-engagement

strategies that work in our (college) classrooms may not translate to the high-school level. While some labs may have been more engaging, others may not have this effect. The results of the student focus group lend credit to this supposition. Additionally, building rapport with students can take time. It is possible that our approach (having multiple instructors on different topics) engaged some students while provoking disengagement in others.

Future Directions

To overcome this limitation, we suggest that researchers be cognizant that establishing rapport with students requires a significant amount of time and energy from high-school teachers. Encouraging college students (rather than professors) to lead these labs and presentations may help establish this rapport by illustrating more relatable pathways into the field and major (Finkel, 2017). This may also allow high school students to see themselves as college students, as graduate students are much closer in age and experience with high school students. They may share similar backgrounds and could be from similar areas, and may have even attended local high schools. Stories about a graduate student's journey from high school senior to college graduate – a difference of about five years, may be more relatable than similar stories from high school teachers or college professors. Finally, incorporating multiple measures of learning and engagement may shed light on how these students engaged with the materials. Incorporating STEM curiosity, more nuanced observational measures of interest and emotions around science, and more hands-on assessments may help triangulate how students experience science in general and kinesiology more specifically.

References

- Castelli, W.J., Antero, E., Boehrnsen, H., Barclay, D., & Bundy, C. (2012). School-university partnership: The wizard, the warrior, and the wagoner. *Journal of Physical Education, Recreation and Dance*, 83(9), 15-35. <https://doi.org/10.1080/07303084.2012.10598841>
- Chamberlin, S.A., Pereira, N., Dailey, D., & Cotabish, A. (2017). Differentiating engineering activities for use in a mathematics setting. *Engineering Instruction for High-Ability Learners in K-8 Classrooms*, 45-55.
- Christidou, V. (2011). Interest, attitudes and images related to science: Combining students' voices with the voices of school science, teachers, and popular science. *International Journal of Environmental and Science Education*, 6(2), 141-159. <https://doi.org/11615/26665>
- Clough, M. (2011). Teaching and assessing the nature of science. *The Science Teachers*, 78, 56-60. <https://doi.org/10.1007/s11191-007-9083-9>

- Cooper, K.S. (2014). Eliciting engagement in the high school classroom: A mixed methods examination of teaching practices. *American Educational Research Journal*, 51, 363-402. <https://doi.org/10.3102/0002831213507973>
- Cunningham, C. M., Lachapelle, C.P., Brennan, R.T., Kelly, G.J., Tunis, C.S.A., & Gentry, C.A. (2019). The impact of engineering curriculum design principles on elementary students' engineering and science learning. *Journal of Research in Science Teaching*, 57(3), 423-453. <https://doi.org/10.1002/tea.21601>
- Duran, M., Hoeft, M., Lawson, D. B., Medjahed, B., & Orady, E.A. (2014). Urban high school students' IT/STEM learning: Findings from a collaborative inquiry- and design-based afterschool program. *Journal of Science Education Technology*, 23, 116-137. <https://doi.org/10.1007/s10956-013-9457-5>
- Fillipi, A. & Agarwal, D. (2017). Teachers from instructors to designers of inquiry-based science, technology, engineering, and mathematics education: How effective inquiry-based science education implementation can result in innovative teachers and students. *Science Education International*, 28(4), 258-270.
- Finkel, L. (2017). Walking the path together from high school to STEM majors and careers: Utilizing community engagement and a focus on teaching to increase opportunities for URM students. *Journal of Science Education and Technology*, 26(1), 116-126. <https://doi.org/10.1007/s10956-016-9656-y>
- Flammer, L., J. Beard, C.E. Nelson, & M. Nickels (1998). Science Knowledge Survey. *ENSIWEB*. Evolution/Nature of Science Institutes. Retrieved June 2013 from <https://web.archive.org/web/20180220170105/http://www.indiana.edu:80/~ensiweb/home.html>
- Gill, D. L. (2007). Integration: The key to sustaining kinesiology in higher education. *Quest*, 59, 270-286. <https://doi.org/10.1007/s10956-013-9457-5>
- Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist*, 41(2), 111-127. https://doi.org/10.1207/s15326985ep4102_4
- Kukreti, A.R. Islam, S., Miller, R.A., Davis, K., Prather, E.N., Fowler, T.W., & Soled, S.W. (2003). Bridges with engineering to teach authentic inquiry-based mathematics and science courses to middle and high school students. *33rd Annual Frontiers in Education*, 2, F1A-14. <https://doi.org/10.1186/s40594-018-0151-2>
- Lachapelle, C.P., Phadnis, P.S., Jocz, J., & Cunningham, C.M. (2012). The impact of engineering curriculum units on students' interest in engineering and science. In *NARST annual international conference, Indianapolis, IN*.

- Margot, K.C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education*, 6(1), 2. <https://doi.org/10.1186/s40594-018-0151-2>
- McCarty, G., Hope, J., & Polman, J.L. (2010, March 21-24). *The Youth Engagement with Science and Technology Survey: Informing practice and measuring outcomes* [Conference presentation]. NARST 2010 Conference, Philadelphia, PA, United States. <https://silo.tips/download/running-head-engagement-survey-1>
- National Academy of Engineering (NAE) and National Research Council (NRC). (2014). STEM integration in K-12 education: status, prospects, and an agenda for research. In M. Honey, G. Pearson, & H. Schweingruber (Eds.), *Committee on K-12 engineering education*. Washington, DC: National Academies Press.
- NGSS Lead States (2013). Next Generation Science Standards: For states, by states. Retrieved December 8, 2020). <https://www.nextgenscience.org/>
- Rosenzweig, E.Q., & Wigfield, A. (2016). STEM motivation interventions for adolescents: A promising start, but further to go. *Educational Psychologist*, 51(2), 146-163. <https://doi.org/10.1080/00461520.2016.1154792>
- Twitchell, J. (2020, November 24). STEM by the Numbers. Retrieved December 08, 2020, from https://washingtonstem.org/focus_area/stembythenumbers/
- United States Bureau of Labor Statistics (2020, September 1). *Employment in STEM occupations*. <https://www.bls.gov/emp/tables/stem-employment.htm>
- Watters, J.J., & Diezmann, C. M. (2013). Community partnerships for fostering student interest and engagement in STEM. *Journal of STEM Education*, 14, 47-55. <https://doi.org/10.1080/01900690601117812>
- Wigfield, A., Eccles, J.S., Yoon, K.S., Harold, R.D., Arbreton, A.J., Freedman-Doan, C., & Blumenfeld, P.C., (1997). Change in children's competence beliefs and subjective task values across the elementary school years: A 3-year study. *Journal of Educational Psychology*, 89, 451-469. <https://doi.org/10.1037/0022-0663.89.3.451>

Appendix A: Shortened Version of YEST

Specifically, these questions are (numbers are from the actual YEST (McCarty et al., 2010):

10. How important is science to your everyday life? (5 point Likert response)
22. How interested are you in school? (5 point Likert response)
23. How do you rate yourself as a student, in terms of grades? (5 point Likert response)
24. How do you rate yourself as a student, in terms of learning? (5 point Likert response)
26. How interested are you in learning science in school? (5 point Likert response)
27. How interested are you in learning science outside of school? (5 point Likert response)
32. On a scale of 1 to 10, rate your knowledge of science compared with the 'average high school student' (10 point Likert response)
33. Do you ever see yourself as a scientist? (Y/N)
35. How important will science be in your future education and profession? (4 point Likert response)
36. How important will science be in your future personal life? (4 point Likert response)

Appendix B Science Field Knowledge

The following fields of study are Scientific:	Agree	Disagree	Don't know	If science, Study of What?
Anthropology				
Biology				
Chemistry				
Economics				
Kinesiology				
Physics				
Psychology				
Cosmetology				
Scientology				
Astrology				
Astronomy				

