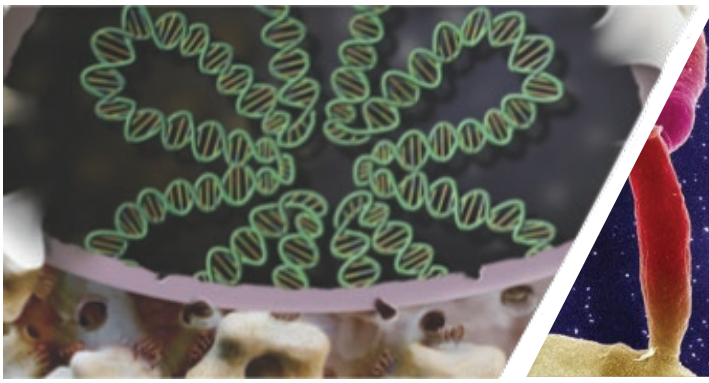

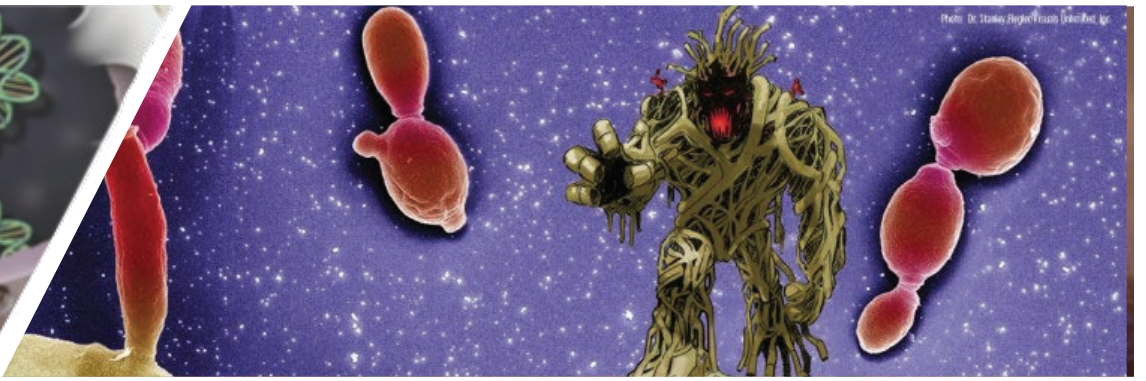

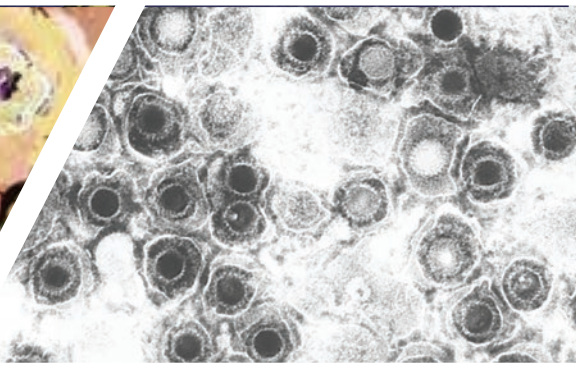

Biology of Human

Summative Evaluation Report

2012-2018

MERC

Methodology & Evaluation
Research Core Facility

BIOLOGY OF HUMAN SUMMATIVE EVALUATION REPORT

Summer 2018

If you have any questions or concerns regarding the information reported within, please contact us at:

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EXECUTIVE SUMMARY

The Biology of Human: Understanding Ourselves through the Lens of Current Biomedical Research ("BioHuman SEPA") project, funded by the National Institutes of Health (NIH) Science Education Partnership Award (SEPA) is a science education initiative based upon a collaboration between biomedical researchers, science educators, sociologists, artists, and journalists. The project, as initially envisioned, proposed to use a research-driven approach to broadly educate youth and adults about new biomedical research developments pertaining to human biology. This evaluation report reviews and summarizes the evaluation studies conducted for the BioHuman SEPA project since its inception in July 2012 and assesses the overall impacts and outcomes of the project as a whole. Integrating previously reported results with more recent findings, this report focuses on the four complementary, integrated components through which the BioHuman SEPA project developed and delivered resources to diverse audiences and researched how to increase broad audiences' interest in and knowledge of human biology and biomedical careers:

1. educator professional development,
2. creation and dissemination of biomedical learning materials,
3. public outreach, and
4. social science research.

Each component was evaluated through diverse methods. Data were collected via direct observation and through participant interviews, surveys and focus groups specifically designed to address evaluation questions. Formative feedback was used to iteratively improve and update ongoing programs and deliverables development; summative feedback was used to document and assess impacts of project efforts.

The evaluation found that **professional development activities** were delivered through a flexible approach that offered both in-depth and large-scale workshops, leveraging partnerships and resources at the local and state level. The unique inclusion of current social science research with Next Generation Science Standards framework and laboratory science experiences helped build teachers' capacity to encourage and maintain students interest in science, connected K-12 science educators with the museum and university, and positively impacted pedagogical practices of middle and high school level Nebraska science teachers. The array of **project deliverables** includes educational books and innovative comics geared to appeal across all age levels; interactive, multimedia apps; and the website. Focusing on biomedical topics, specifically microbes and infectious disease, they were developed through a comprehensive process utilizing extensive evaluation. Youth programming across all years of the project helped inform the development of the deliverables and was also integral to the successful collection of data for the Science Identity research study. Evaluation data indicate that tens of thousands of users accessed the website and bought the print materials, and feedback from educators about the appeal and utility of the materials was overwhelmingly positive. An in-depth study explored how classroom educators use science comics to address equity issues and to facilitate participation in STEM for diverse youth. Museum programs and other **informal outreach events** including exhibits, festivals, youth camps, university courses, and a promotional BigTenNetwork Video about the science comics reached nearly five million individuals. The **social science research** provided support for the evaluation of the effectiveness of the deliverables and contributed to the scientific literature on how science identities differ by gender and race and are influenced by friendships. The studies also captured insights into possible ways to ameliorate the gender gap in science participation through changes in afterschool programs, science materials, in-school and out-of-school science experiences, teacher preparation, access to resources and other personal influences. This research has resulted in three peer-reviewed articles published in the sociological literature to date, and dozens of local, regional and national conference presentations. Additional manuscripts are currently in progress.

The results from the numerous evaluation and research studies demonstrate that the project remained focused on its initial aims to stimulate interest in and understanding of biomedical research, establish partnerships to create dynamic educational resources, and increase youth's interest in biomedical science. The coordinated approach of the four components effectively addressed project goals, and resulted in the following important lessons learned:

- Building on prior SEPA work enabled greater distribution and impact of deliverables and activities, strengthened partnerships, and allowed fuller development of theory-based social science research.
- Collaborating with other researchers, educators, funded projects, and institutions extended the reach and visibility of the project, ensured relevancy, and leveraged resources effectively.

- Offering ongoing youth programming allowed trial testing of materials and built key relationships with students, teachers, and schools that facilitated trust and strong partnerships.
- Delivering a flexible, collaborative model of professional development that was adapted to the local context and varied over time was well-received, but precluded the development of a sustained, consistent program that could be iteratively improved and evaluated.
- Programming a diverse array of outreach activities and events to engage the public with BioHuman SEPA content reached a broad, diverse, and very large audience.
- Enlisting professional comic writers and artists, science writers, virologists, microbiologists, computer scientists, journalists and other experts in their fields enabled the creation of unique, engaging, and educational informal science learning materials, including comics, apps and books, that were appealing to youth and other target audiences.
- Distributing deliverables to classroom teachers provided an important and sizeable outlet to reach youth and to learn more about the strengths and limitations of the materials as educational tools.
- Disseminating project deliverables directly to interested users was effective and resulted in their use across a wide spectrum of settings and audiences. However, without continued contact and direct outreach to users about all the different deliverables, many prior users who would have been interested in learning more were unaware of subsequent deliverables produced by the project, indicating a lost opportunity.
- Publishing the print materials through professional publishing houses with national distribution outlets ensures that the deliverables will continue to be available after the project funding ends, and as long as there is demand.
- Integrating the social science research into project deliverable development helped clarify why deliverable design and program strategies were effective for different audiences and contributed to the content of the teacher professional development programs.
- Investing in social science research about adolescent science identity resulted in numerous publications and represents a unique contribution of scholarly research on increasing science participation of all youth, and particularly those from underrepresented populations.

The Biology of Human SEPA project employed effective strategies and created distinctive materials to reach a broad, diverse audience, increasing their awareness of, interest in, and understanding about microbes, current biomedical research, and human health. The project also made meaningful contributions to social science research in understanding and potentially removing barriers to participation in science by youth from underrepresented groups.

PROJECT SUMMARY

The Biology of Human: Understanding Ourselves through the Lens of Current Biomedical Research ("BioHuman SEPA") project, funded by the National Institutes of Health (NIH) Science Education Partnership Award (SEPA) is a science education initiative based upon a collaboration between biomedical researchers, science educators, sociologists, artists, and journalists. It is led by Principal Investigator/ Project Director Judy Diamond, Professor and Curator at the University of Nebraska State Museum, and Co-Investigators Julia McQuillan, Professor and Chair of the Department of Sociology at University of Nebraska-Lincoln (UNL), and Charles Wood, Lewis Lehr/3M Professor of the School of Biological Sciences, UNL, and Director of the Nebraska Center for Virology. As stated in the original proposal, the five-year program is focused on "helping youth and adult audiences understand themselves by exploring scientific principles that shape modern research in human biology." Using a systems approach to create and disseminate research-based science learning materials, the BioHuman SEPA project aims to both develop resources for diverse audiences and to research how to increase broad audiences' interest in and knowledge of human biology and biomedical careers. This project's funding period started in July 2012 and was scheduled to formally end in June 2017, but has been continued through a no-cost extension through June 2018.

The project comprised four complementary, integrated components of educator professional development, creation and dissemination of biomedical learning materials, public outreach, and a social science research plan. These four primary components are the focus of this final evaluation report.

PURPOSE OF EVALUATION

This evaluation is being completed by Amy N. Spiegel, Ph.D., from the Methodology and Evaluation Research Core Facility of the Social and Behavioral Sciences Research Consortium at UNL, and is overseen by external evaluation advisor Laura M. W. Martin, Ph.D., Consultant and Senior Director of Strategic Initiatives and Director of Science Interpretation at the Arizona Science Center. The primary task of the evaluation is to review and summarize the many evaluation studies, findings, and analyses of this complex and wide-ranging project into a comprehensive, cohesive and contextualized whole. This evaluation attempts to assess the overall impacts of this initiative and to reflect upon the different components and how effectively they fit together to meet the goals of the project.

METHODS

This report integrates the findings reported in the numerous evaluation reports that were issued during the life of the grant with more recent findings from the data collection and analyses conducted in the last year of the grant that are being reported here for the first time. All of the formal evaluation reports issued on the various activities and programs of the BioHuman SEPA project are publicly available in full on the website (biohuman.unl.edu).

Evaluation was woven throughout the project activities during the entire funding period. Data were collected to gather implementation information, document activities and track participation, assess short-term goals and objectives, and evaluate overall project impacts. The front-end and formative evaluation studies were designed to provide useful, timely feedback to the project team to make decisions about programming. The data collection for the evaluation and the social science research that was an integral part of the project was completed in a collaborative manner, enabling appropriate piloting of instruments, development of a strong working relationship with a local school, and reduction in redundancy and burden for youth participants in our program and research study.

Project and evaluation activities were documented through a series of formative reports. Participation of youth, families, educators and the general public in the SEPA BioHuman activities was tracked on an ongoing basis through direct and indirect means. To the extent possible, participation of target audience members was assessed through attendance tallies at project events (e.g., professional development workshops, informal education activities, conference presentations), while dissemination of deliverables was assessed through direct distribution numbers as well as printing totals, iTunes app downloads and web traffic data. One reason to track individuals receiving the BioHuman SEPA deliverables was to be able to follow-up with those users to see how they used our materials, and

to gather their feedback about the utility and impact of the different deliverables. These data are described in more detail in the section about outreach below.

Formative and summative data were gathered, analyzed and reported primarily by the internal evaluator. External oversight of the project was accomplished through two primary means: the use of an external advisor for the evaluation and the peer review process for publication and dissemination of project research. External evaluation advisor Dr. Laura Martin reviewed and critiqued the overall summative evaluation design, and periodically provided input through the review of internal evaluation reports. Dr. Martin's guidance contributed to a broader perspective, advice about appropriate instrumentation and methods, and thoughtful reflection on impacts. The social science research team worked closely with the evaluator on the data collection, analyses and writing for the research studies. These were developed into manuscripts and submitted to professional, peer-reviewed academic journals for publication. The independent scrutiny of the external reviewers ensures that the methods, hypotheses, data, and conclusions meet high standards of rigor and intellectual merit. Together, the evaluation studies and the social research investigations contribute to our understanding of the impacts of the project and to new knowledge in the informal science field.

The next sections of this report correspond to the four primary BioHuman SEPA project components:

I. Educator Professional Development
II. Project Deliverables: Development, Distribution, & Use
III. Museum Program and Informal Outreach
IV. Research on Science Identity

The goals and different activities of each component are described and the evaluation, data collection and results associated with the different project activities are reviewed, summarized and discussed. Finally, the last narrative section of the report addresses overall impact, opportunities and limitations of the BioHuman SEPA project.

I. EDUCATOR PROFESSIONAL DEVELOPMENT

One primary goal of the project is to increase the capacity of educators to engage youth in fundamental ideas that underlie human biology, and to generate greater interest in biomedical careers among youth. Toward this end, the Biology of Human project conducted and supported a variety of professional development activities for Nebraska educators to engage with current research in human biology, explore social science research on student science identity, become more familiar with Next Generation Science Standards (NGSS), and access resources for their classrooms. The following professional development offerings occurred in a variety of different formats and leveraged partnerships and resources to offer unique professional development opportunities to pre-service and in-service Nebraska teachers: 1) Teacher Professional Development Summer Workshops, intensive, weeklong workshops offered in the summer, 2) NGSS Professional Development for Nebraska Teachers, and 3) Mandatory professional development held by Lincoln Public Schools (LPS) every August in collaboration with the BioHuman SEPA project (see Table 1). LPS is an urban school district with over 40,000 students and 3,500 teachers. Nearly 7.5% of students are English Language Learner (ELL) immigrant and refugee students, and 46% qualify for free or reduced lunch. The BioHuman SEPA project collaborated extensively with this local school district for many of the professional development offerings. In the sections below, the overall professional development approach and impacts will be discussed first; then each of the types of professional development will be characterized in detail in the sections following.

TABLE 1. BIOHUMAN SEPA PROJECT PROFESSIONAL DEVELOPMENT DELIVERED TO NEBRASKA SCIENCE TEACHERS

Type of Professional Development	Name of specific offering	Number of educators participating	Dates and contact time
Summer Workshops	Explore Students' Science Identity & Inquiry-based Investigations of Biology	16	Jun 2015 (5 days)
	Social Psychological Processes in the STEM Classroom: Activating STEM Identities	7	July 2017 (10 days)
NGSS-focused Workshops for Nebraska Teachers	The Nebraska Vision for Science Professional Development Conference	215	June 2016 (1 day)
	Ted Willard NGSS Science Institute	56	June 2017 (1 day)
LPS Mandatory District Science PD	LPS, Museum, SEPA & UNL Presentations 2014	150	Aug 2014 (4 hrs)
	LPS, Museum, SEPA & UNL Connectors Event 2015	150	Aug 2015 (4 hrs)
	LPS, Museum, SEPA & UNL Connectors Event 2016	155	Aug 2016 (4 hrs)
	LPS, Museum, SEPA & UNL Connectors Event 2017	160	Aug 2017 (4 hrs)

IA. DISCUSSION OF PROFESSIONAL DEVELOPMENT APPROACH AND OUTCOMES

Resources available to fund and support professional development by the BioHuman SEPA project were limited because it was just one element within the larger, more comprehensive project. Thus, the design and administration of the professional development needed to be strategically conducted to maximize the impacts. Rather than adopt a single model of professional development, the BioHuman SEPA project provided a combination of in-depth, intensive courses offered to a smaller number of regional teachers and larger scale workshops of shorter duration, offered to a large number of teachers from across the state. This flexible approach took advantage of local and state contexts, leveraging partnerships and opportunities as well as meeting needs identified by the local and state education leaders. This approach enhanced the use of BioHuman SEPA content and increased project visibility. These different activities also strengthened connections with UNL as a whole and individual UNL researchers to the local K-12 education community. There was a deliberate focus on establishing long-term relationships connecting K-12 science educators with UNSM and the university that could be sustained beyond the NIH SEPA funding period.

Research on effective teacher professional development has identified key features associated with positive change (Desimone, 2009). These features include *specific content focus, active learning, coherence, duration,* and *collective participation*. In identifying limitations of the BioHuman SEPA project approach to teacher professional development, a few observations can be made. First, providing such an array of diverse professional development

meant that continuous, iterative improvement of a single model was not possible. Second, although many of the LPS teachers were involved with the project over a long period of time, the amount of contact time and content did not constitute a sustained thematic program with delineated content goals and specific teaching outcomes (for example, enhancing teachers' capacity and skills in teaching about a particular content area with particular knowledge goals for students). Finally, more follow-up programming and/or support for the teachers who participated in the more intensive professional development offerings would have helped the teachers more fully implement and sustain changes in their classrooms. It should be noted that the goals for these workshops were intentionally limited in scope.

The teacher workshops were designed to provide exposure to BioHuman SEPA project content and resources, including social science research relevant to science teaching; to establish and support relationships to enhance the Nebraska and Lincoln science teaching network; and to help teachers learn about and apply the principles set forth in the Next Generation Science Standards. In assessing the strengths, the professional development activities were mostly successful in meeting these identified goals. As one part of a multi-faceted project, the approach to the professional development component within the BioHuman SEPA project capitalized on the ability to focus on local contexts and needs in a collaborative manner, thus providing more unified and cohesive programs offered to area science teachers. In addition, these programs were forward-looking toward the current national vision and support for NGSS. Particularly with professional development serving the Lincoln Public Schools, teachers were working with colleagues in their own district and often in their own schools, resulting in "collective participation," an important quality for effective teacher professional development (Garet, Porter, Desimone, Birman, & Yoon, 2001). In addition, the project team cultivated an enduring relationship with district science personnel and involved many of the same teachers over time.

The different types of professional development served different identified needs within the local, current context. The in-depth workshops provided unique content, linking laboratory science with social science research, and helping support teachers to encourage and maintain student interest in science. Teachers participated in current scientific research at UNL that they found exciting, interesting, and recognized as important. They felt a renewed enthusiasm for teaching science. These educators also learned about current investigations in student science identity that they could apply and reflect upon in their own teaching practice. Teachers indicated that much of the social science content was not something they had previously been exposed to, and that it provided them with unique and helpful tools for their science pedagogy. The collaborative NGSS workshops connected teachers with national pedagogical experts in a hands-on, active setting in which they worked with colleagues to begin to transform their teaching practices. Finally, the LPS-UNL Connector Events gave teachers direct access to local area scientists conducting active research and other available science resources, and many of these teachers followed up on these contacts to bring scientists, current research and/or career possibilities into their classrooms. Together, the professional development activities of the BioHuman SEPA program positively impacted pedagogical practices of middle and high school level Nebraska science teachers.

IB. Teacher Professional Development Summer Workshops

The most time-intensive and in-depth professional development activities were summer workshops that occurred in 2015 and 2017.

Explore Students' Science Identity & Inquiry-based Investigations of Biology was a weeklong workshop in June 2015 that engaged teachers in laboratory science investigations with viruses, bacteria, and parasites and also in current student science identity research (see Appendix A for the workshop agenda and goals). Through these activities, this workshop also sought to foster personal connections between the UNL researchers and local area teachers that would lead to continued contact during the academic year. This workshop provided participants with a unique combination of current social science investigations and laboratory science research experiences. The focus on student science identity arose from the social science research being conducted by the BioHuman SEPA project team, and was designed to highlight the sociological perspective of science teaching and learning, to share some initial BioHuman SEPA research findings with participating teachers, and to engage them in discussing the meaning, relevance and implications of these data. On the laboratory side, teachers participated in science investigations with several different UNL STEM collaborating scientists in their labs. These investigations included: comparing two

microbial profiles of different gut microbiota; studying life cycles of different parasites and identifying characteristics of a new parasite to place the species on a phylogenetic tree; and working in a HIV virology lab preparing PCR plates and learning about DNA analysis technology. Sixteen local area teachers participated.

The following conclusions were drawn from the executive summary from the report: Overall, the evaluation found the workshop to be successful in meeting its goals. The teachers liked the format of the workshop blending social and laboratory science components, agreed that the workshop created a safe, collegial community, and appreciated being able to work with their peers to process the content together. Teachers were overwhelmingly positive about the social science component that included information about student science identity, implicit bias and stereotype threat. They thought learning about the research findings and talking with their colleagues about the ideas presented were the most helpful and enjoyable aspects of the workshop. Most agreed that they gained conceptual tools to foster student science identity in their classrooms. However, many teachers wanted more guidance in translating the research findings into practice, and the majority felt they needed even more discussion to talk through these issues amongst themselves, and more time to develop strategies to implement in their classrooms. Nevertheless, as a result of the workshop, teachers indicated that they would incorporate more techniques to foster science identity in their students and to decrease bias. They planned to make their lessons more inquiry-based, through increasing the use of hands-on activities and/or greater emphasis on the process of science and relevance of content. Teachers felt that participation in the workshop helped renew their enthusiasm for teaching. With respect to participating in the research laboratory components, teachers voiced the dichotomy of seeing and doing "real" science as vital, exciting, and enriching; yet at the same time, these experiences were, for some teachers, too complex to be useful in their own classrooms. The opportunity to experience science in an authentic laboratory with "real" research scientists, who were engaging, personable and enthusiastic about their work, also helped the participants reflect upon themselves as teachers and as students. Overall, teachers agreed that the lab experiences helped them better understand the nature of authentic research and appreciate the research being conducted at UNL. Teachers talked about their appreciation for and recognition of the enormous amount of work and dedication it takes to be a scientist, and the importance of this work. Teachers felt these experiences would help them communicate more accurately to students about what research actually looks like and about future careers in science. Three-quarters of the teachers indicated that they planned to contact at least one of the scientists they worked with at this workshop to pursue additional collaboration.

Educational research has shown that high quality teacher professional development can foster teacher success. Within the limits of feasibility, the format of this workshop was designed to include several key core features that align with research on effective professional development, including content focus, active learning, coherence, duration, and collective participation (Desimone, 2009). Overall, the workshop was successful in meeting its goals of delivering professional development that incorporated these proven elements for effectiveness. With respect to limitations, allotting more time for the teachers to work together toward identifying ways to apply both the sociological research and the laboratory component to their own classrooms would have given this workshop more practical utility. Second, providing additional support for implementing and sustaining change in their classrooms during the coming school year was identified as a way to enhance the impacts of this professional development work.

Social Psychological Processes in the STEM Classroom: Activating STEM Identities (no separate report issued) was a 2017 two-weeklong summer course/workshop offered to in-service teachers (see Appendix B for course syllabus). The course, as described in the syllabus, presented a broad range of social psychological topics and processes to help participants better understand how social context impacts STEM learning and how using social psychological concepts can help teachers in their efforts to encourage and support youth interested in STEM. Goals for the course included helping teachers to recognize ways to use identity theory concepts and principles to enhance youth STEM identities and to create tools to integrate what teachers learned about STEM identity into their own pedagogical practices. The educators learned about social inequality in STEM fields, and how the individual, interactional and institutional barriers to developing a science identity for youth from a variety of social location (rural/urban, gender, race/ethnicity, socioeconomic status, English language learner). They also learned about implicit bias, stereotype threat, and identity theory, and how they impact formal and informal social interactions and learning in the STEM classroom. Seven local area teachers participated.

A feedback survey was administered to the participants at the conclusion of the course. Results from this feedback, which included both closed-ended and open-ended items, is summarized here. Overall, participants were overwhelmingly positive about their experiences, indicating they found the sociological concepts such as implicit bias, science identity and culture to be worthwhile, and the sociological perspective to be relevant to their teaching. They felt they had gained a better understanding of how science identity influences a student's engagement with science and the role of social inequality on a student's science identity. Perhaps most importantly, participants agreed that the workshop had provided them with conceptual tools to foster a student's science identity and specific ideas to implement in their classrooms. Teachers felt that their experiences in the workshop helped them to become more reflective of their own biases as well as understanding how to provide more encouragement and recognition of students as scientists. In their written comments, some teachers indicated that they had become more aware of the fluidity of identity, and the importance of supporting their students' science identities by, for example, making STEM topics more relevant and related to their interests. In response to a question designed to gauge overall satisfaction, all of the participating teachers indicated that they would recommend the workshop to colleagues.

Both these intensive summer workshops offered by the project were unique in their inclusion of social science research around adolescents' science identity development and the role of social context that impacts who pursues STEM careers. This content, in combination with laboratory science experiences, helped teachers also reflect on their own science identities. Feedback by teachers was very positive, and, in particular, indicated specific, concrete plans to implement changes in their science pedagogy.

IC. NGSS Professional Development for Nebraska Teachers

In April 2013, the Next Generation Science Standards (NGSS) were finalized by the National Research Council. Based on the AAAS Benchmarks for Science Literacy (1993), the National Science Education Standards (1996), and the Framework for K-12 Science Education (2012) the NGSS provides a new vision for science teaching and learning intended to guide K-12 science educators toward more meaningful and effective instruction. By 2015, several NGSS implementation guides had been published (Moulding, Bybee, & Paulson, 2015; Willard, 2015), and many states, particularly the "Lead State Partners" that had helped to develop them, were moving toward adoption. Although Nebraska has not yet officially adopted the NGSS, in practice, it has been moving toward this national vision of the research-based Framework for the last several years, and there is broad statewide support for the preparation of teachers to help them align their teaching with this new vision for how to engage students in science learning. In 2015, an Education Week article described how several states that had not yet and might not ever fully adopt the standards had districts implementing NGSS anyway. According to Heitin:

> *In Nebraska, one of the four states that never adopted the Common Core State Standards for reading and mathematics, and is therefore unlikely to adopt the science standards, one of the largest districts is already doing some NGSS work. James Blake, the K-12 science curriculum specialist for Lincoln Public Schools, which have 38,000 students, is piloting the standards at one middle school starting next year, in part because the teachers there were eager to teach the NGSS practices, or behaviors that scientists engage in (Heitin, 2015).*

Lincoln Public Schools has enjoyed an enduring and close relationship with the UNSM for over half a century. UNSM has supported science teachers at LPS through annual programs built into the curriculum as well as exhibits specially designed to meet LPS needs, among other activities. The BioHuman SEPA project built on this relationship to offer intensive support for the NGSS PD to teachers not only in Lincoln but throughout the state of Nebraska. During June of 2016, the BioHuman SEPA project team was lead organizer of a professional development workshop attended by 250 middle and high school science teachers from around the state. These teachers participated in an all-day workshop led by NGSS authors Brett Moulding and Rodger Bybee (see Appendix C for schedule). Of that group, 80 teachers then continued for two additional days to acquire skills from the workshop leaders that would allow them to mentor other Nebraska teachers on NGSS-aligned pedagogical approaches. In this effort, the BioHuman SEPA project team was joined by collaborators from LPS, the Nebraska Department of Education, and the Nebraska Mathematics and Sciences Partnership Program. This workshop activity was supported by Nebraska EPSCoR and multiple unites across UNL, including the: Department of Sociology, Nebraska Center for Virology, College of Agricultural Sciences and Natural Resources, College of Arts and Sciences, College of Education and Human Sciences,

College of Engineering, and Office of Research and Economic Development (ORED). Such unprecedented collaboration reflects the degree of cooperation and common goals evident within the state of Nebraska to advance science literacy in general and science instruction that is congruent with the principles and practices set forth within the NGSS.

The following is drawn from the executive summary of the evaluation report of this event:

The Nebraska Vision for Science Professional Development Conference on June 27, 2016 involved over 200 K-12 education professionals from around the state. Sponsored through a collaboration of multiple partners, this one-day, hands-on workshop focused on familiarizing teachers with the new vision for science education put forth by the National Academy of Sciences (2012) that centers around three essential dimensions of science: science and engineering practices, crosscutting concepts, and disciplinary core ideas (called "3-D"). The workshop was facilitated by Rodger Bybee, Brett Moulding and Nicole Paulsen, authors of *A Vision and Plan for Science Teaching and Learning: An Educator's Guide to A Framework for K-12 Science Education, Next Generation Science Standards, and State Science Standards (2105)*. The workshop evaluation assessed teachers' perceptions of the utility of the workshop in preparing them to use the 3-D model, provided insights into teachers' needs to successfully incorporate the three dimensions in their classrooms, and probed teachers' use of resources and inclusion of the topic of viruses and infectious disease.

Overall results comparing pre- to post-test responses about the 3-D instructional approach found that participation in the workshop significantly increased teachers' confidence in understanding the 3-D approach and their preparedness to apply it in their classrooms. Teachers were also significantly more confident in being able to design assessment aligned with the 3-D model and rated this way of teaching as significantly more useful than they did before the workshop.

Not surprisingly, responses also showed that to successfully implement the 3-D approach, the majority of teachers indicated they very much needed some additional supports and resources. These included additional example lesson plans, instructional materials better aligned with the 3-D model, more practice with the 3-D approach, and additional techniques for meeting needs of diverse learners. In addition, between 30% and 40% felt they very much needed clearer guidance on district requirement for content coverage, more support from both administrators and teachers, and individual mentoring/coaching with 3-D instructional practices. Nevertheless, teachers overwhelmingly reported that they anticipated that their students would respond positively to this approach, that it would result in increased engagement and excitement about science, and would lead to greater understanding and ownership of the content. Some teachers, however, noted the importance of appropriate implementation and recognized that it would take time for students to adjust.

When asked about what outside resources teachers use to enhance their teaching, teachers reported they use a wide variety, including internet and YouTube sites, print materials, as well as professional associations and governmental agencies, colleagues and locally available resources. When asked how they could integrate ideas about viruses and infectious diseases in their teaching, about two-thirds of the teachers indicated they could do this via a variety of content areas, methods or media approaches.

Overall, the NGSS PD workshop was very well received and succeeded in helping teachers become familiar with and begin to embrace the Nebraska vision of engaging students through three key dimensions of science: practice, crosscutting concepts and core ideas. While more work and support is obviously needed for full implementation, this workshop created a positive step forward in the collective vision for Nebraska K-12 Science education."

Ted Willard Science Institute (no separate report issued) conducted in June 2017 continued the strong collaboration with the Lincoln Public Schools and also focused on providing teachers with more support to understand and effectively implement the vision of the Next Generation Science Standards. This one-day LPS workshop, facilitated by Ted Willard, took place over two days, with middle level teachers participating together on the first day, and high school level teachers participating on the second. A short pre-workshop survey was administered online prior to the workshop, and a paper survey was administered at the end of each workshop day. Thirty-three (33) middle level teachers and twenty-three (23) high school teachers provided post-workshop feedback, and there was matched pre- and post-survey data for a total of 39 teachers. Findings from these data are presented below.

Participating teachers were asked, pre- and post-workshop, to rate their level of understanding of the integration of three dimensions (Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas), their preparedness to apply the 3-D instructional approach in their classrooms, their confidence in developing student assessments aligned with the 3-D approach, and how useful they perceived the 3-D approach is for their own science teaching. From pre- to post-workshop, teachers' responses showed significant changes. Teachers rated their understanding of 3-D as significantly higher, from an average of "some understanding" to an average rating closer to "good understanding" of 3-D approach ($t=5.28$, $df=38$, $p<.0001$). They also indicated they were better prepared to apply the 3-D approach in their classrooms, moving from ratings just over "a little bit prepared" to ratings just over "somewhat prepared" ($t=5.66$, $df=38$, $p<.0001$). Pre-workshop ratings of the usefulness of the 3-D approach were high, with an average rating near "mostly useful." Even with this high starting point, teachers rated the usefulness as significantly higher after their participation in the workshop ($t=2.83$, $df=36$, $p<.01$). However, there was no difference in how confident they felt in developing student assessments aligned with the 3-D approach. In addition to these pre-post items, teachers were asked, post-only, how confident they were in analyzing lessons for evidence of student opportunities to use all three dimensions, how confident they were in evaluating phenomena for their utility in driving student learning, and the extent to which they felt able to design coherent 3-D lessons. Teachers rated themselves as somewhat to mostly confident and able to apply and use these particular 3-D skills in their teaching.

Nevertheless, teachers felt that they still needed additional resources and supports to fully implement the 3-D approach in their own classrooms. When asked about specific needs, over 90% of responding teachers indicated that they needed additional lesson plans, and more that 75% indicated they needed more practice with the 3-D approach, clearer guidance on district requirements for content coverage, instructional materials better aligned to the 3-D approached and additional techniques for meeting the needs of diverse learners. More than 50% indicated they needed more support from teachers and administrators in their school. When asked about additional concerns in an open-ended question, by far the most frequently mentioned was "time." Comments included, "Amount of time it takes to revise content activities to 3D model," "Time to work with other subject/course teachers to prepare materials and develop lessons," and " "The time it will take to effectively plan and implement." Other concerns beyond the issue of time included the need for more practice and skill development, need for appropriate materials and more example activities and lessons, and concerns about helping students and parents understand and accept the changes. A few teachers also mentioned concern about alignment to state testing and other common assessments.

The vision presented in the Framework and the Next Generation Science Standards asks teachers to transform their teaching in fundamental ways, including redefining learning objectives, reorganizing curriculum, and restructuring lessons. This will be a long, incremental process. The BioHuman SEPA project partnered with LPS and the Nebraska Department of Education over a period of years to support movement toward alignment with the national science education agenda, enabling more teachers to have more and higher quality professional development than would have been able possible without this coordination. Although teachers will continue to need support and resources to move toward full implementation of the Framework and NGSS in their classrooms, the Nebraska Vision for Science professional development and the Ted Willard Science Institute provided crucial information, instruction, examples, and materials to begin these significant changes.

Prior to the TWSI professional development, teachers were asked to what extent they were already implementing the 3D approach in their classrooms. Seventy-five percent (75%) indicated "not at all" or "used in a few lessons," and 25% indicated "somewhat" or "mostly implemented." At the conclusion of the TWSI workshop, teachers were asked, "Imagine yourself five years from now. To what extent do you think you will have the 3D approach implemented in your classrooms?" Teachers were optimistic about their ability to modify their teaching to be aligned with the Framework, with 89% indicating they would be "mostly" or "fully implementing" the 3D approach by then.

ID. LPS SCIENCE PROFESSIONAL DEVELOPMENT

For the past 4 years, the BioHuman SEPA project has collaborated with the Lincoln Public Schools to host their annual 4-hour mandatory science professional development in August at the University of Nebraska State Museum. Nearly all of the approximately 150 middle and high school science teachers from the LPS district attend this event every

year. Jointly planned by the James Blake, LPS Science Curriculum Specialist, and Judy Diamond, the BioHuman SEPA Project PI, this morning of contact time with all of the science teachers in the district has served multiple purposes. It has connected LPS science teachers with university researchers in a one-on-one setting, helped familiarize teachers with the BioHuman SEPA project and content, provided teachers with resources and information including BioHuman SEPA deliverables, helped familiarize teachers with the university and museum in particular, and has enabled the creation of a strong partnership between the project, the district science leadership, and the teachers themselves.

Though the specific agenda and format for this professional development event varied from year to year, all (except the first one) included the following key components:

- a welcome by Judy Diamond, who provided information about the museum and the BioHuman SEPA project,
- a 90 minute "Science Connector Event" in which about 20 tables with UNL faculty representing a wide array of STEM disciplines were set up in a "meet and greet" open format on the third floor of the museum. Faculty shared their work in a variety of ways, including demonstrations, posters, printed materials, and simply talking about their interests and research. The goal was to provide an informal way for teachers to interact with the UNL scientists and learn about possible resources and collaboration opportunities.
- a presentation by Sara Cooper, Director of Science Education, Nebraska Department of Education (the particular content varied each year)
- presentation and wrap-up including district information updates and vision by James Blake.
- administration of brief, anonymous evaluation survey

The first collaborative meeting in 2014 focused more specifically on the BioHuman SEPA project and UNSM. This meeting included a formal presentation and discussion by Dr. Julia McQuillan, BioHuman SEPA co-PI, who shared initial social science research findings about student science identity, and a presentation by Kathy French, UNSM Education Coordinator, who provided information about the various UNSM resources available to teachers. Feedback provided verbally at the meeting and collected informally by James Blake afterward indicated generally positive comments as well as ideas for future meetings (no formal report was issued).

In 2015, the UNL Science Connector Event (described above) was introduced for the first time, and, in addition, the scheduled agenda included a welcome and introduction featuring the following individuals:

- Dr. Judy Diamond, Professor and Curator UNL State Museum and PI, BioHuman SEPA Project
- Nathan Meier, Director of Research Strategy, Office of Research and Economic Development, UNL
- Dr. Lawrence Scharmann, Chair of UNL Department of Teaching, Learning and Teacher Education
- James Blake, LPS K-12 Science Curriculum Specialist, LPS

This collaboration was designed to foster stronger connections between LPS science teachers, the BioHuman SEPA project, UNL researchers and educators, and the Nebraska Department of Education. Evaluation feedback from teachers about the perceived utility of the format and content of the event was overwhelmingly positive. Over 90% of teachers agreed that the Science Connector Event was a good use of the district contractual day, and 90% agreed that it was important for them to make connections with UNL scientists. Over three-quarters of teachers indicated they planned to follow-up with UNL faculty they had talked with at the event. Overall 90% agree that they had learned some things they would use in their classroom. Comments indicated that teachers really enjoyed talking with UNL researchers and learning about their work, and they also appreciated having time to spend with their colleagues. They liked the format of the event, appreciated getting resources, and liked learning more about the 5E Instructional Model, that both Sara Cooper and James Blake had discussed.

In 2016, the presentation by Sara Cooper, the Nebraska Department of Education Science Director, focused on the Nebraska Vision for Science that included information about the Next Generation Science Standards. Evaluation feedback indicated that overall, the continued collaborative effort between LPS and the BioHuman SEPA project was well received by the attending middle and high school teachers. Teachers gave high ratings on the utility of the professional development day, and overwhelmingly agreed that it provided them with resources and ideas that they will bring back to use in their classrooms. Half of the teachers had no recommendations for how the day could have been improved.

By far the most popular aspect of the day was NDE Science Director Sara Cooper's presentation on Nebraska Vision for Science that included information about the Next Generation Science Standards. They found the practice example reinforcing the importance of inquiry inspiring and useful, and liked learning more about the upcoming changes in the standards. Several teachers also mentioned the importance of hearing the LPS Science Curriculum Coordinator James Blake's presentation to learn more about district changes. Teachers indicated they wanted even more examples of activities relevant to their specific curricular areas, as well as more time spent on applying NGSS to their subject areas. Teachers also appreciated the opportunity to network with their colleagues. Several teachers indicated they wanted more time to work together around curricular goals and to share their ideas with one another.

The large majority of teachers thought the UNL Connector Session was worthwhile. One quarter of all teachers indicated that they had followed up during the school year with faculty they had met at the 2015 Connector Event. This is a substantial and impressive outcome to have one in four LPS science teachers connecting with university science faculty in the last year. High school teachers' ratings about this session were slightly lower than last year; as teachers become more connected to the faculty and resources at UNL, this type of session may become less useful. Nonetheless, the large majority of attending teachers liked meeting UNL faculty, and over half had plans to continue contact with those faculty. With the curriculum standards shifting, both at the state and district levels, science teachers appeared to be more focused on those aspects of this professional development day. The evaluation report noted that as teacher professional development needs and opportunities evolve, the collaboration between the BioHuman Project and LPS would need to continue to adjust to the changing landscape of science teaching.

In 2017, the format was revised to include three breakout sessions, each offered three times and attended by one-third of the participating teachers in each breakout. These sessions were 1) a "Campus Connector" with LPS, community partners and UNL faculty; 2) an LPS Science Update with James Blake about upcoming changes to the curriculum to align with the Nebraska Vision and NGSS; and 3) an Eclipse presentation at the Planetarium to help teachers prepare for a special science lesson on the total solar eclipse that would be occurring in Lincoln within a few weeks of the start of the school year. Feedback indicated again that the large majority of teachers were positive about the format and content of the event. Eighty percent (80%) of teachers believed that the Campus Connector session provided access to new resources they will use in their classrooms, and 90% thought the three breakout sessions were an effective format, with many teachers commenting positively about the eclipse session. Overall, 79% agreed the event was a good use of time, and 77% thought it provided useful information. Interestingly, the high school teachers were significantly less likely to agree with those statements than middle school teachers, although it was still a majority. As always, teachers liked being able to network with their peers, and 43% thought that more teacher-to-teacher planning and communication should have been included as part of the formal agenda.

Four years of hosting this annual event has built a strong relationship between the LPS science educators and not only the BioHuman SEPA project and staff, but also the larger UNSM community and UNL research scientist community. The different UNL colleges, departments, projects, faculty and community partners who participated in the "Campus Connector" events over the three years was diverse, and many participated multiple times. Below is a list detailing the science disciplines and organizations involved:

- BioHuman SEPA project
- University of Nebraska State Museum
- UNL School of Natural Resources
- UNL College of Engineering
- UNL School of Biological Sciences
- UNL School of Veterinary Medicine and Biomedical Sciences
- Nebraska Center for Virology
- Nebraska Center for Materials and Nanoscience
- UNL Center for Plant Science Innovation
- Institute of Agriculture and Natural Resources (Science Literacy)
- Department of Mechanical and Materials Engineering
- Department of Chemistry
- Department of Biochemistry
- Department of Earth and Atmospheric Sciences
- Department of Entomology
- Department of Sociology
- Department of Plant Pathology
- Robotics and Mechatronics Laboratory
- Bio/Flow Systems Research Laboratory
- Strategic Air Command and Aerospace Museum
- Nebraska Junior Academy of Sciences

- Nebraska Academy of Sciences
- Bureau of Sociological Research
- National Drought Mitigation Center
- Nebraska Soybean Board
- Computational Creativity, NSF project
- Nebraska EPSCOR (Established Program to Stimulate Competitive Research) -

The event evolved over time based on the formative feedback as well changing district needs and policy changes. By partnering with LPS, the district teachers were repeated exposed to BioHuman SEPA and other virology and microbiology content related to the project, given access to deliverables and other resources from the project, and introduced to diverse resources and personnel. As a result of this exposure, a significant percentage of teachers connected with university faculty to incorporate additional content in their classes and also used BioHuman SEPA deliverables with their students (see section below on Educator Use of Deliverables).

II. PROJECT DELIVERABLES

An array of BioHuman SEPA project deliverables were created to span target audiences from elementary, middle and high school age youth, college students, families, and adults. These distinct print and online deliverables about biomedical topics, particularly focusing on microbes and infectious disease, were developed through a comprehensive process that included front-end and formative evaluation, youth feedback, expert (virologist) review, and trial testing. These development and evaluation activities were woven throughout the duration of the project timeline. After being finalized and professionally published, the BioHuman SEPA project deliverables were disseminated through a variety of means including web-based outreach, professional development workshops, youth programming, and large-scale science events and festivals. To the extent possible, dissemination activities were tracked to enumerate the distribution of the materials to different intended audiences. In the final year of the project, to gain a better understanding of how the materials were being used, we conducted two related studies designed to investigate how educators, including informal and formal educators, scientists, and librarians, had used the materials, and to look more closely at how classroom teachers incorporated the deliverables within their formal science instruction. Evaluation results indicate that tens of thousands of users accessed the website and bought the print materials, and that educators were overwhelmingly positive about the appeal and utility of the deliverables they had used. The in-depth research study explored how science comics can facilitate participation in STEM for diverse youth, and how educators use the comics to address equity issues in their classrooms.

The evaluation summary that follows includes three sections that describe in greater detail the different means used to assess the materials:

1) overall ***Deliverables Distribution*** to target audiences, which provides specific information about the types of deliverables and the overall estimated distribution
2) explanation of the iterative ***Deliverables development and Youth engagement*** that informed the process, with detailed contextual information about diverse BioHuman SEPA youth programming that was delivered throughout the funding period and dovetailed with the social science research agenda, and
3) ***Educator Use of Deliverables*** that includes two evaluation studies that examine, through qualitative and quantitative data gathering and analyses, how formal and informal educators incorporated the materials within their instruction and appraised their utility.

IIA. DELIVERABLES DISTRIBUTION

BioHuman SEPA project deliverables included an updated, redesigned website with access to biomedical education web-based resources and links to access all the project print materials, an array of educational books and innovative comics geared toward adults, adolescents and children focusing on biomedical topics, and interactive apps associated with the comic stories available through the iTunes app store (see below for additional details). Distribution and dissemination of deliverables were tracked in multiple ways. Traffic to the website was traced using the Google Analytics reporting over time, including number of sessions and users and devices used to access site. Print materials distributed by the project were tracked directly to create estimated numbers, and publications printed and distributed by professional publishing houses were reported through total copies sold. The use of the different iTunes apps was tallied using iTunes Connect program that counts the number of first time downloads of each individual app (App Units); app updates and redownloads are not counted.

TABLE 2. BIOHUMAN SEPA PROJECT DELIVERABLES: DESCRIPTIONS, TARGET AUDIENCES, AND DISTRIBUTION

Types of Deliverables	Description and target audience	Estimated distribution
BioHuman Website (biohuman.unl.edu)	Features access to the BioHuman SEPA comics, apps, and books, a bank of microbe images, middle and high school level science curricula with professional reviews, related audio stories and science media project, and information about project social science research and evaluation.	71,679 users since July 2012 (currently ~250/week)
Books and Comics (publication dates)		
Carnival of Contagion comic (Oct 2017)	This graphic novel for teens shows the adventures of a group of youth who learn about the dangers of measles when they are lured into a viral fantasy world by a mysterious and seductive carnival barker.	623 copies distributed to date
Watch Your Mouth! book (2016)	Full of activities for middle grade readers, this book provides an amusing look at the microbes inside your mouth while providing some serious science about human health.	1,201 copies distributed to date
Microbe Maniacs sticker books (2015)	Published in both English and Spanish, this booklet features SEM images and stickers of bacteria, viruses, fungi and archaea that live inside the human body, and also includes images of their comic personifications featured in the *Occupied by Microbes!* graphic story geared toward upper elementary and middle level students.	24,560 copies distributed
Planet of Viruses book (2015, 2nd ed; 2011, 1st ed)	An "eye-opening look at the hidden world of viruses...including stories of new outbreaks, such as Ebola, MERS, and chikungunya virus; new scientific discoveries; and new findings that show why climate change may lead to even deadlier outbreaks." Written by popular science writer Carl Zimmer for adults and the general public (2 editions in English; also published in several other languages: Turkish, Korean, Japanese, French, Russian, Chinese)	59,826 copies sold
World of Viruses comic (2012)	Collection of 5 graphic stories, each featuring a different virus, tell the "thrilling true stories of well-known threats like foot and mouth disease, HIV, the flu and HPV, as well as the lesser-known but helpful role that viruses play in saving global ecosystems from out-of-control blooms of algae" Written for adolescents (middle and high school level), by professional graphic story writers and illustrators with virologists.	4,925 copies sold
Interactive Apps (iOS based)	Available in the iTunes app store, these apps feature narrated graphic stories from the *World of Viruses* book with a variety of interactive, informational activities related to the virus, including impacts of the resulting disease, detailed drawings of the virus and interesting facts.	
World of Viruses apps (revised 2017)	Five individual apps, based on each of the different graphic stories from the World of Viruses comic book *(Phantom Planet, Never-ending Battle, Curse of the Tree-man*, *Confined!, Frozen Horror*), include professional narration and interactive activities (iOS based). The featured viruses include Emiliania huxleyi virus, flu, HPV, foot and mouth disease, and HIV.	30,343 app unit downloads (7/1/12 - 5/20/18)
Occupied by Microbes! (2016)	Two teens in science class enter the world of their microbial cousins and learn how "good" bacteria in the human gut team up against a local fungus to keep it from becoming dangerously out of control.	242 app unit downloads

The BioHuman SEPA website included some similar information and resources as the earlier, related World of Viruses SEPA project website, but was redesigned and additional components incorporated in the fall of 2014, through a collaboration with a professor in the UNL School of Art, Art History and Design. Professor Colleen Syron used the redesign of the Biology of Human website as a "real-world" project for her Interactive Design class, and developed the revamped website through a guided design process that included initial usability analyses, competition between several small-group draft blueprints, whole-class collaborative prototype testing and revision, and final website layout construction in consultation with the Biology of Human SEPA project staff. The content of the website continues to be updated with information about new deliverables and research publications as they become

available. See Table 3 for averages and totals of traffic to the website over the life of the project. Currently, about 1000 visitors use the website per month, visiting an average of 2.04 pages per session. Ninety percent of visitors are new to the website (10% returning users), and this has been consistent over time. Eighty percent of sessions were accessed using a desktop, 16% using a mobile phone, and 4% using a tablet.

TABLE 3. AVERAGES AND TOTALS FOR BIOLOGY OF HUMAN SEPA WEBSITE TRAFFIC

	Average/Year	Total
Sessions	14,138	84,830
Users	11,954	71,722
Pageviews	31,601	189,608
Pages/session	2.23	

While over 90% of web traffic to the site is directed there through a search engine such as Google or is undefined traffic, some visitors are referred to the site through other sites that link directly to the BioHuman SEPA website. Each of these referral sites represent less than 1% of traffic to the site, but together they add up to 1000's of visitors over the last 5 years. These linking websites include:

- scienceinschool.org
- museum.unl.edu
- nihsepa.org
- news.unl.edu
- techtalk.cteunt.org
- pformacion.educa.jcyl.es
- alexandra-goryashko.net
- thehealthmuseum.org
- soc.unl.edu
- facebook.com
- virology.wisc.edu
- news.sciencemag.org
- medicablogs.diariomedico.com

In addition, the Nebraska Department of Health and Human Services (NDHHS) recently requested to add a link to the Biology on Human SEPA webpage on their Immunization Program website, indicating they felt it was an important addition to the education of viruses and immunizations.

Some of the pages that link to the BioHuman SEPA website are clearly not United States sites, and this is similarly reflected in the location of audiences visiting the website. Over the life of project, approximately 69% of the web traffic is from the United States, with other English speaking countries making up the next 11% of visitors: Canada (4%), United Kingdom (3%), India (2%) and Australia (2%). Visitors from the Philippines and South Korea are the next most frequent users, with each country having over 1% of the total audience for the website. Other countries with more than .5% of total audience, from greater to fewer users, are Spain, Germany, Brazil, Italy, France, Pakistan, Russian, Mexico, and Indonesia. Altogether users from 198 different countries have accessed the BioHuman SEPA website.

IIB. Deliverable development and Youth engagement

Front-end and formative evaluation informed the development of all the BioHuman SEPA project deliverables. Pilot testing of early versions of print and interactive materials with target audiences was integrated with other activities to enable ongoing data-gathering. Throughout the five-year funding period, the BioHuman SEPA project collaborated with local schools and a Community Learning Center to offer youth science programming (see Table 4 below). This included a middle level summer science program, elementary level afterschool clubs, a series of semester-long middle-level afterschool science clubs, and pilot use of BioHuman SEPA print materials as part of the science curriculum for an alternative high school serving at-risk youth. These programs served not only to engage area youth with science activities and scientists, but also to provide the project with the opportunity to trial test many of the educational materials with members of the target audience as these deliverables, including comics (*Occupied by Microbes!*, *Carnival of Contagion)*, apps (*Occupied!*), and activities from the book (*Watch Your Mouth*), were being developed. We were also able to pilot evaluation and research instruments to assess their utility, understandability, reliability and validity. In addition, by forming a close, working relationship with one middle school, the BioHuman SEPA project was able to partner with the school to gather rich, longitudinal survey data from all of their students

about science attitudes, science identity, friendships, and other related constructs to conduct our social science research about adolescent science identity (see the section below on "Research on Science Identity").

TABLE 4. LIST OF YOUTH PROGRAMMING AND ATTENDANCE

Date	Name	Total unique participants	Average weekly attendance (estimated)	Brief description of example club activities (all of the clubs featured diverse, hands-on science activities related to biomedical topics)
Fall 2012	Genes & Germs	14 elementary youth	11	Activities included learning about and using science tools such as white lab coats, rubber gloves, agar to examine, and microscopes; growing bacteria; and draw-a-scientist and draw-a-biologist activities
Spring 2013	Germ Radio	5 elementary youth	4	Youth created their own audio stories to learn about the processes that affect human health by exploring topics related to disease, health, and the human body.
Spring 2013	Afterschool Science Club	12 middle level youth	10	Activities included growing out skin microbes, using a microscope, making your own snot, making model origami viruses, making parasite models, testing cleaning products on yeast and playing the immune system game
Summer 2013	Microbe Maniacs	121 middle level youth	100	Activities included microbe growing activity called "Growing Your Wildlife" led by microbiologist professor and later examining the growth using microscopes; comic drawing led by professional comic artist; "Stuff of Life" activity extracting DNA from cheek cells.
Spring 2014	CLC Microbe Maniacs Science	24 middle level youth	10	Activities included a Typhoid Mary presentation (a one-woman, original dramatization) and discussion, gnotobiotic mice (learning with a microbiologist about some of her research, including interacting with an isolator), cell reproduction mutation, transmission tracking activity looking at infection and vaccination; and tick disease and Otzi the Iceman.
Fall 2014	Microbe Maniacs Science Reporter	46 middle level youth	11	Club content used storytelling to stimulate students' critical thinking skills and interest, a research-based approach for experiencing science. Activities/topics included viewing NET documentary The Red Elephant (about children orphaned by AIDS in Zambia) and talking with NET producers, reading World of Viruses SEPA project comics, reviewing draft of BioHuman SEPA comic Occupied by Microbes! and trying out new technology including Occulus Rift, Google glasses and a 3D printer.
Spring 2015	3D Science	37 middle level youth	12	Activities included 3D face/head scans of the youth participants, 3D printing, interacting with 3D Drone Mapping of the Platte River Basin, remote sensing and imaging inside mummies, a UNSM Planetarium field trip, medical imaging with UNL health professionals, and veterinary imaging with a local DVM.
Spring 2016	Who Am I? Exploring Ourselves	28 middle level youth	10	This club provided students with multiple opportunities to consider the question about "Who am I?" in a variety of contexts. Activities included using phones to explore the human body, outer space and the entire world; a field trip to the UNL athletic training facility; American diversity discussion; selfie culture viewing ourselves through cameras: GoPros, Drones, VR, and Selfies with UNL journalism professor; investigating parasites with UNL parasitologist; and creating personal shrines.
Fall 2016	Health and Human Rights	60 middle level youth	11	This club's focus on both personal health and the inclusion of activities about health careers, public health, and social justice were purposeful decisions to make the club appealing to a

				broad demographic. A local registered nurse helped facilitate the club activities that included youth measuring their own blood pressure and pulse multiple times throughout the semester, discussions and activities around access to medical care, health disparities, water quality, water and viruses with a UNL virologist, and parasites and war with a UNL parasitologist.
Spring 2017	Being Human	48 middle level youth	12	UNL anthropology professor and a class of undergraduate biological anthropology students collaborated with the project to develop and lead some of the sessions. Activities included examining and comparing different primate skulls and discussing how and why the skulls, jaws and teeth differed; a field trip to the Galapagos and Evolution exhibits at UNSM; and a genealogy mapping activity that built on family origins.
Spring 2017	Omaha Street School science unit	8 high school level youth	5	The *World of Viruses* comics were used as a framing device for teaching a science unit on health and related biomedical topics at this faith-based alternative high school for at-risk youth.
July, Dec 2017	Game development at New York University	30 middle level youth	15	Building on the Biology of Human SEPA *Carnival of Contagion* comic about measles, youth design and develop games based on the comic, and researchers working with them study how games, narrative and visual media engage youth to learn about and identify with science.

Findings and results from the evaluation studies conducted for materials development and on youth programming are highlighted below.

Biology of Human Front-End Evaluation: Youth Focus Groups on Perceptions of Microbes (2013). This front-end evaluation provided us with important information about youth's understanding, knowledge and attitudes about microbes, science and scientists to inform material development. Results indicated participating students displayed a limited but relatively functional knowledge of microbes, that they indicated they had learned both in and out of school. They were interested in learning more about microbes. Their perception of a "science kind of person" was somewhat stereotypical and appeared to be drawn from their school experiences with science teachers. The focus group provided a guide for the researchers to better understand the current level of knowledge and usage of scientific terminology by the youths in the target age group.

Biology of Human Formative Evaluation: Youth Feedback on Occupied! Comic (2014). This formative evaluation study conducted on a draft, print version of the comic indicated that youth enjoyed the characters and story, and liked learning about germs in a comic format. All students in the group were engaged with the comic and were able to describe the general message of the storyline, but some found elements of the story confusing. When probed, students indicated they wanted more information about the microbes, such as where they live in the body, what they actually do, and what they look like. Consequently, to provide interested readers with more information about the microbes and other topics in the comic, an iPad-based app was developed around the comic.

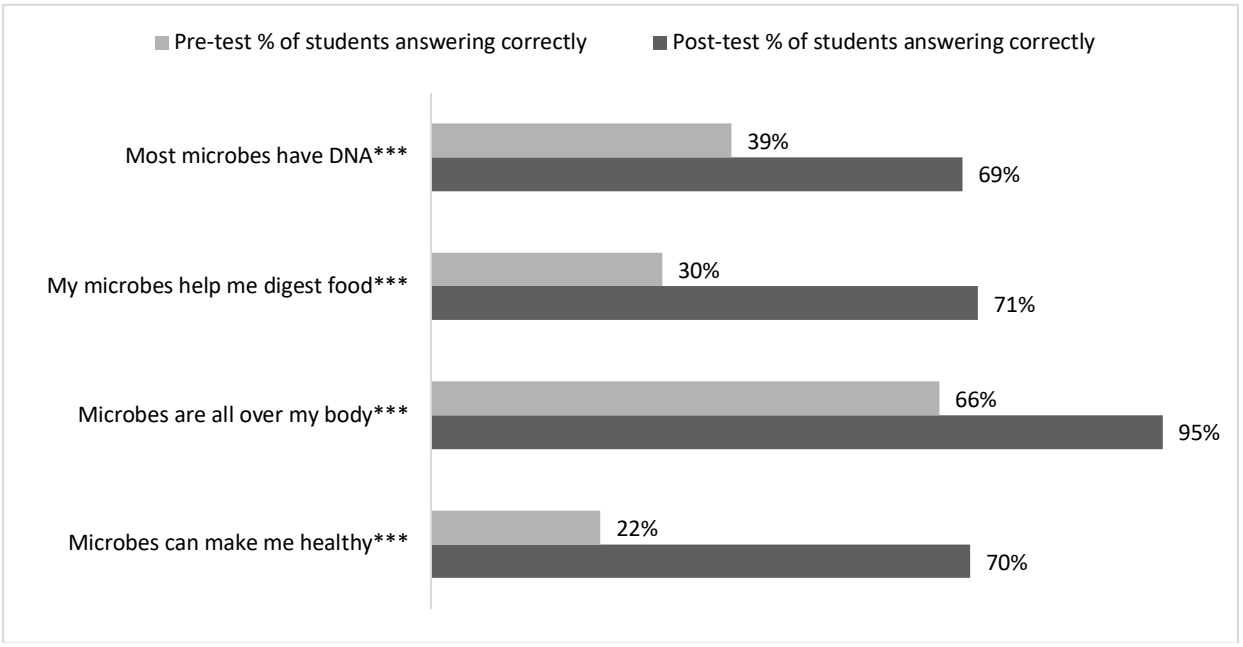
Occupied! App: Pilot Testing UNL iLab App Development Formative Evaluation (2015). The purpose of this evaluation was to trial test the app using a target age group audience to assess usability and understandability in order to make recommendations to the development team about how to improve the user interface. This was conducted in two phases. First, with a version of the app that was about 90% complete, and second, after modifications were made and all app features were functional, to finalize the design. Feedback provided designers with specific, detailed information to make the app more user friendly. Results of the trial testing suggested that without the changes identified through this evaluation process, many users of the app would not have accessed the interactive features available in the app. These recommendations, which were also presented and discussed in face-to-face meeting with the developers, improved usability by making the app features more intuitive, easier to access, and less frustrating to use for members of the target audience.

Microbe Maniacs Summer Science was a BioHuman SEPA youth program integrated with other offerings of a local Community Learning Center as part of a four-week day-camp in June 2013. One afternoon per week, about 120 middle level students engaged in different science activities led by BioHuman SEPA staff. Each weekly session, except

the final day, was organized around two activities: conducting a microbe experiment and drawing a comic. Each student was provided with their own drawing materials, a paperback copy of the World of Viruses graphic stories, and materials specific to the planned microbe activity each week. Activities included a presentation by UNL microbiologist Andy Benson, a drawing demonstration and interaction with comic artist Tom Floyd, a microbe growing activity and extraction of DNA from their own cheek cells.

The Microbe Maniacs program focused primarily on providing the students with a fun, engaging science experience. While the activities included science content about microbes, the primary goal was to show science in an interesting way to encourage the youth to engage with science through fun, ungraded activities that were relevant to their own lives. Pre and post-program data were collected from students on both their knowledge of microbes and their attitudes and perceptions about microbes and science. While changes in knowledge about microbes was not necessarily anticipated in this short program, we gathered these data to have a greater understanding of what students this age understand about microbes and took advantage of the opportunity to see if there were any changes in students' understanding. Results from the assessment indicated that a substantial proportion of students learned some of the big ideas presented through the activities, with greater numbers of students correctly answering items after the program that they incorrectly answered prior to the program (see Figure 1).

FIGURE 1. SIGNIFICANTLY MORE MIDDLE SCHOOL STUDENTS CORRECTLY ANSWERED QUESTIONS ABOUT MICROBES AFTER PARTICIPATION IN SUMMER PROGRAM (N=77)



***p < .001

Students were also asked some attitudinal questions about microbes and science in general and the extent to which they agreed or disagreed with them on a 5-point Likert scale from strongly disagree to strongly agree. Significant positive change was found on two items from the pre- to the post-survey: " People in my life think of me as a science person" and " I know a lot about microbes." No significant changes were found on any other items, pre- to post-survey. This suggests that while in most areas students did not change their opinions about microbes or attitudes about science, students thought that they had learned a lot about microbes, which was corroborated by the results on the content portion of the survey, and that they felt people viewed them more as a “science person” after their Microbe Maniacs experience. Both of these are positive changes and suggest the overall impact of the program was beneficial for the students. Microbe Maniacs increased students’ knowledge of microbes and appeared to move them a little more toward identifying themselves as “science kind of people.”

This evaluation was part of a larger data collection effort designed to serve not only program evaluation goals, but also to provide important data as a pilot for the learning research goals. Overall, the Microbe Maniacs summer program provided engaging science content for middle level students. The questions, comments and reactions from

students indicated many were interested and curious about the activities and about microbes, and the finished comics that the students created also reflected this. These results, including the pre-post survey findings, indicate that the Microbe Maniacs summer program was beneficial to students and had a measurable impact on them, and also provided important data about the measures used to assess those changes.

CLC Afterschool Science Clubs were a series of a semester-long science-themed afterschool clubs designed, facilitated and staffed by the BioHuman SEPA project and offered through the local Community Learning Center at a local public middle school. This collaborative outreach effort served multiple purposes, not only providing rich, hands-on science experiences for participating youth that afforded them direct contact with local area scientists, but also providing the BioHuman SEPA staff with an age appropriate target audience to trial test project deliverables and get relevant timely feedback to make modifications. The primary organizer and facilitator for these clubs was Sara LeRoy-Toren, a retired high school science teacher and former Science Department Chair at the LPS high school Science Focus Program. Formative data in the form of facilitator feedback on youth comments and questions, strengths of the session format and program, and suggestions for change were collected at every afterschool club meeting session to provide ongoing, timely feedback and to provide a record of the activities, youth reactions, and recommendations for change. More formal feedback from the youth through surveys, interviews and focus groups were gathered periodically. Except for the first club offering which was more general in content, each of the clubs focused on a particular theme related to the BioHuman SEPA project content, and brief evaluation reports documenting participation, planned activities, weekly reflections by the lead educator, weekly facilitator feedback, and youth feedback when available were issued at the end of each semester. Table 4 provides short descriptions of each of the informal science club, including the summer club, offerings with examples of some of the specific activities that the youth engaged with.

Across all the afterschool programming for which gender and racial/ethnic data were available, 51% of all participants were male; 49% female; 49% European American, 23% African American, 11% Middle Eastern, 12% Hispanic, 4% multi/bi-racial, less than 1% Asian/Pacific Islander, less than 1% Native American. In the first two offerings of the afterschool program, more boys than girls were participating, so an effort was made to make the topics, format, and experience of the afterschool club more welcoming to girls. Research shows specific strategies can be used to make science and engineering activities more attractive to girls, including making the content more personally relevant (Ilumoka, 2012; Liben & Coyle, 2014; National Academy of Engineering, 2008; Thompson, 2014). Thus the club's topics from Spring 2016 forward, which included exploration of the self, health and human rights and the study of humans, were made with the intent to make the club appealing to a broad demographic. In addition, the promotional information was designed to also be more broadly appealing. These efforts were successful in attracting more girls -- a greater proportion of girls than boys participated in all of the last three afterschool club groups.

For the clubs in which detailed evaluation data were gathered, youth comments about their experiences indicated that while the youth responded to the clubs in individual ways, overall feedback was positive. For example, when asked individually in interviews, nearly every youth respondent in the ***Microbe Maniacs Science Reporter*** club said it had changed their ideas about science, and one student also thought that the club had changed his/her ideas about technology. Responses included the following comments:

> *I didn't think [scientists] could use so much technology, like going to find a fossil, like putting it in Oculus Rift and watching what you did.*
>
> *[It changed my ideas about] how a scientist might do his work – not just go do an experiment, but might need to do research, look for other sources and use other scientists. So scientists look at other things to come to a legitimate reason.*

When asked, "how is this club different from science class?" students had a variety of responses, indicating that both the content and the format differed from their typical experiences in school science. And, it was as much about what was included, as what was not included.

> *We got to use more technology than just a computer.*
>
> *We got do art, make comics. And we like comics.*

No homework.

No tests.

We got to play games.

We got to actually tell stories.

We were asked our opinion.

It's more fun.

No lecturing – don't have to sit there while the teacher goes on and on.

Their comments provided evidence that the club broadened students' views and helped enrich their conceptions of what science and also what scientists actually do. In providing feedback about the Being Human club, students described many of the aspects that were goals of the club, including creating a sense of belonging for all students, discussing topics and having activities of particular interest to the students, and enabling direct interaction with scientists and other science experts. Comments included:

We get to paint and we don't have to read from a textbook.

During science, we're forced to sit in one place with people you don't like-- it affects your learning. Here you're with people who understand what you're doing and want to be here and are thinking about the same things.

In class, we learn about all kinds of things - electricity, geology, but here we learn about biology, anthropology and animals.

My science teacher is rude to us; here, people are nice.

For me, in the club setting, you have experts in the field who come here. In school, there are teachers who have training but it's in science teaching. Here [in the afterschool club], the people specialize in something. They are experts at it.

Student responses to other feedback questions indicated they were enthusiastic about science, think they are good at it and may have a future in it, find it enjoyable and think it is relevant. They found the club topics interesting and felt a sense of belonging in the club.

Omaha Street School, a faith-based alternative high school serving at-risk, inner city youth was the site of a small pilot study using the *World of Viruses* comics. The BioHuman SEPA project collaborated with an educator/ researcher at the school, who chose to use the comics as a framing device for teaching one of her science units. We took advantage of this opportunity to gather some qualitative evaluation data about how an innovative teacher with wide latitude to create science lessons plans would make use of the comic. This setting was challenging because many students at the school contend with a variety of difficult circumstances in their home lives and had not succeeded in a traditional school setting. However, these are students who fall within our target demographic: youth from disadvantaged backgrounds who don't see themselves as science kinds of people. In addition, the observations and insights resulting from this pilot can help us better understand the particular benefits, opportunities, challenges, and limitations of using our materials in such a setting, because of the unique science unit design and the different resources this teacher chose to use with the comics. A variety of data were gathered for this pilot by the teacher/researcher (field notes and reflections, youth surveys and assessments) and also by the evaluator (classroom observations, interviews with the teacher/researcher about her experiences). Findings from this small case study are summarized here (no separate report was issued).

As the collaborating teacher/researcher explained, she chose to use the comics for an array of reasons, but first and foremost because, "I believe very much in using student interest as the center of classroom life, and the comics offered me a way to help kids connect to multiple kinds of their life experiences." Echoing findings from the comic study described later in this report (Comic Use Study), she felt the comics provided an innovative "hook" for her students whom, she noted, had not been served well by typical science curriculum. In particular, she noted how the stories embraced diversity, "[The comics] used women as protagonists; they used people of color as not always the

bad guy," which she felt provided an important connection to her students. In addition, she felt the comics helped students to see science as "socially important" and as more than just a textbook topic with formulas and figures.

She saw the comics as an accessible way to approach the science content and to connect related, relevant topics in a coherent way. She explained,

> *I used the comic to help introduce content in a way that was successful, right? And then turned toward world impact, local impact and some facts about HIV and how it works, how HIV looks, how it works and how viruses work. Then I brought in someone who does health education in the community...I had [the students] do a mini research project on a pathogen of their choice and then we did a health messaging campaign where we made health materials to distribute...The comics features especially support the content related to viruses and start to help us draw the connections between viruses and people in real lives.*

She explained how the comics made science relevant and comprehensible to her students. "Real life hooks are really important so I think that was part of why HPV was really successful is that it had a real-life picture of a real-life person, and we show the tree man on the screen and talk about what's going on...They got to see, they really thought about life through the lens of the man who was suffering with the disease." She also appreciated that the technical information was understandable to a broad audience, saying, "you can't just google T-cells...you're going to get six paragraphs of jargon, so [the comics] were a nice and accessible way for people to learn about health topics or virus topics, [or] science topics without having an advanced degree." However, she also saw some limitations in some of the comics topics that were less relevant to her students, such as foot and mouth disease, saying, "they don't really care that the UK lost 7 million cattle."

The teacher envisioned using the comics as a framework to support multidisciplinary instructional goals, including exploring story-telling, literature, perspective-taking and metaphor, as well as exploring what is science. To that end, she integrated diverse resources to scaffold and enrich her students' experiences, including web-based resources, paper models of viruses that students put together, guest speakers, and a field trip. She assigned presentations to her students, and had them complete online quizzes and design a game for their peers. She had also intended for students to do more with the comic text itself and to delve into "seeing words and making sense of words" in a more extensive way, but found that most students' low reading ability was a barrier to their comprehension and learning from the comics. She explained, "[I realized that] it's not because the comics weren't working with [the students], it's just reading, sitting and reading, was a really challenging thing [for my students] to do." In addition, there were other issues that interfered with her making as much progress in the science unit as she had hoped. These issues included dropping student attendance rates, noncompliance in the classroom, competing school and class requirements, the need for differentiated and individualized instruction, and technological and internet access difficulties.

As a case study, this teacher's and her students' experiences highlight the potential for using the *World of Viruses* comics with a group of students in the target population group. The comics can provide a good jumping off point for a wide array of related content, can be readily integrated with other health and virus resources, and can help meet important pedagogical goals. Challenges to using the comics with these kinds of students were also revealed. Although rich with imagery, the comics still require reading skills to fully understand the content. And, some of the topics may not resonate with students in this demographic. This teacher felt she had learned a lot about both her students and using the comics to teach science, and indicated she would definitely use them again, but would attempt to provide more scaffolding and support to encourage reluctant readers.

Game Development was an experimental youth program developed by a BioHuman SEPA project collaborator, Dr. Camillia Matuk, at New York University who works in the Media and Game Network Department as an Assistant Professor of Learning Sciences and Technology. She is also Director of the RIDDLE (Research in Design for Discovery within Learning Environments) Lab, based in NYU's Educational Communication and Technology program and part of CREATE: the Consortium for Research and Evaluation of Advanced Technologies in Education. Dr. Matuk had been involved with the BioHuman SEPA project since the beginning, having designed an interactive game included as part of one of the World of Viruses comic apps and providing critical feedback on some of the student deliverables.

Working with about 15 middle school youth and their teacher, Dr. Matuk and about 8 NYU graduate student facilitators run a weeklong program on game design. In the 2017 summer session, the youth created an educational game based on BioHuman SEPA graphic story *Carnival of Contagion*. The professor explained that she hoped to "engage the kids in different scientific practices (systems thinking, experimentation, explanation, argumentation, etc.) through world-building, design and play." She and her colleagues conduct research on game-based learning, and the roles of narrative and visual media in learning about and identifying with science. This innovative extension of the comics illustrates another creative use for the BioHuman SEPA deliverables to engage youth with science, and resulted in two upcoming poster presentations:

Hovey, C., Matuk, C. & Hurwich, T. (2018). "If you add too much science it gets boring." Exploring students' conceptual change through their game design iterations. In Proceedings of the 13th International Conference for the Learning Sciences (Vol. X, pp. xxxx-xxxx). London: International Society for the Learning Sciences.

Matuk, C., Hovey, C., Hurwich, T., Sarmiento, J. P. (2018). Cognitive processes and collaborative supports for knowledge integration among youth designing games for science learning. In Linn, M. C. & Eylon, B.-S. (chairs), Osborne, J. & Laurillard, D (discussants), Kidron, A. (organizer), Knowledge Integration in the Digital Age: Trajectories, Opportunities and Future Directions. In Proceedings of the 13th International Conference for the Learning Sciences (Vol. X, pp. xxxx-xxxx). London: International Society for the Learning Sciences.

IIC. EDUCATOR USE OF DELIVERABLES

Two broader evaluation studies were conducted to assess the use and utility of the Biology of Human SEPA deliverables. Survey feedback from educators on the different print and multimedia deliverables indicated that the materials have strong, broad appeal, are effective in a wide array of settings and with ages ranging from preschool to adult, and have been used for many distinct purposes. Educators overwhelmingly agreed that the materials were effective in helping users better understand and engage with science, and become motivated to learn more about the topics. However, the feedback from educators also highlighted the challenges of distributing these materials. Interviews with classroom educators explored in detail how and why teachers choose to use comics in their classrooms and the potential advantages and challenges of integrating these non-traditional instructional materials in science teaching. Table 5 below details the data gathered for each of these studies, and findings from the studies are highlighted below.

TABLE 5. EVALUATION STUDIES ON DELIVERABLES USE: GOALS AND DATA SOURCES

Deliverable Use Studies	Evaluation goals	Data sources
Educator Web Survey	Investigates how diverse audiences, including informal educators, scientists and others, used the different materials and their feedback about its utility	Web-based (Qualtrics) survey (n=52)
Educator Interview Study	Examines why teachers decide to use comics in their teaching, and how comics may support science instruction, literacy and equity in unique ways.	Focal interviews & brief surveys with middle and high school science teachers (n=18), classroom observations (n=8), and student surveys (n=177)

The ***Educator Web Survey*** captured data through an online survey of all the educators, including classroom teachers, informal educators, faculty and others, who had requested our print materials and for whom we had email contact information. This included a total of 116 individuals. Of this group, 52 provided responses (45% response rate) to the Qualtrics survey about their use of the following project deliverables: *World of Viruses* Comics, *Microbe Maniacs Sticker Book*, Comic Apps, *Planet of Viruses* book and the BioHuman website. Because the deliverables were disseminated through diverse means, only some of which were traceable directly to the individual users, the pool of potential respondents has an overrepresentation of users who were more closely associated with the project. Much of the distribution of project materials is to users who are unidentifiable: many books were sold directly through

Amazon or other secondary markets, the website is available to anyone with internet access, and the apps are similarly freely distributed and accessible through the iTunes store. Thus, the feedback provided from this survey must be viewed as descriptive data rather than as a quantitative measure of the type and number of users. These data serve to illuminate the array of settings and uses through which the materials have been employed. The feedback from the respondents is summarized below (no separate report was issued).

Educators were asked which of deliverables they had used, and for each type they had used, how they had used them (formal/classroom, informal/afterschool, personal use, and/or other) and the age level with whom they had worked (elementary, middle level, high school and/or adult). Then, respondents were asked to indicate the extent to which they felt the materials had been effective in helping users to understand science topics, to visualize science, to engage with science, to become motivated to learn more about science, and to identify with scientists. These were specific goals around which the materials were designed.

Among the respondents, the most commonly used deliverable was the *World of Virus* comic (69%), followed by the *Microbe Maniacs Sticker Book* (37%), *Planet of Viruses* book (29%), apps (21%) and the website (15%). Just over one third indicated using only one of the deliverables, while 54% indicated using two or more. Altogether, these 52 individuals estimated that they had directly shared these BioHuman SEPA materials with over 2085 youth and adults.

For respondents who used the *World of Viruses* comic book(n=36), they most often used it in informal settings, and indicated they used it across all levels from pre-K to adult. These included uses in afterschool programs and clubs at middle and elementary school levels and for summer programming, at a daycare center, and as an extra classroom resource. The next most frequently cited use was personal and "other" use, and respondents indicated they shared the comic with teachers, with children in their lives, and to disseminate at a local health clinic. Again, because some of the respondents were associated with the project at some time, they had access to quantities of materials if requested. Interestingly, one individual indicated s/he shared the materials with relatives, including his/her spouse to "explain some aspects of what I do for a living." In formal school classrooms, the comics were used again from elementary level to adults, and were even included as part of college level biology course. These responses indicate an incredibly wide range of uses across all age levels from a daycare center to a college course about viruses, and from personal reading to a resource for a health clinic and afterschool programs (see Table 6 for a list of settings and uses of the comic).

TABLE 6. SETTINGS AND EXAMPLE USES OF *WORLD OF VIRUSES* COMIC

Setting	Example descriptions of use
Informal (all age groups)	**Elementary:** "Daycare center" [parent] "afterschool club" [informal educator] **Middle**: "Science club", "placed out so that students that had extra time in class could look at them" "Science Olympiad" [all middle level science teachers]
Formal (all age groups)	**Middle:** "General Biology: viruses" "Personal reading - 7th grade science microorganisms" "Human body lessons" [all middle level science teachers] **High:** "General biology: viruses" "Introductory reading assignment" "Viruses and bacteria" [all high school science teachers] **Adult:** "Literacy and science learning" [Professor of Teaching, Learning, and Teacher Education], "Biology 326 [college course] Biology of Viruses" [Professor of Biological Sciences], "Flu, HIV, HPV for Virology course" [Professor of Biological Sciences]
Personal/ Other	"Give away items at the local health clinic" [Healthcare worker] "Son and daughter read the comics" [Professor of Biological Sciences] "Given to teachers in teacher workshops" [Public school curriculum specialist] "Example of an exemplary educational comic book" [Professor of English] "With [spouse], and niece and nephew to gain their impressions and to explain some aspects of what I do for a living" [Professor of Biological Sciences]

When asked for any additional comments specific to the *World of Viruses* comics, respondents had many remarks. One respondent had anticipated that the comic would be useful with his/her high school students, but found them more appropriate for younger students, saying,

> *I originally obtained these for high school use but the "hook" that these provide is more for middle school aged students and perhaps students with an interest in reading graphic novel. [High school science teacher]*

Several focused on the overall high quality, appeal, and/or accuracy of the comics, while others spoke more specifically to the particular appeal or use they observed. Comments included,

> *Several occasions I have found the comics to be excellent for promoting UNL and also the Virology Center. For example, I participated in the High School Science Fair Outreach that occurred on UNL campus in 2015. I displayed World of Viruses materials and answered questions about viruses. There were several High School teachers and students who were fascinated by the WOV comics, so much so, that all were given away. Also, when we have undergraduate visitors to the Virology Center, I give them a WOV comic or a postcard. [Professor of Biological Sciences]*
>
> *the pictures draw the kids in and they 'have to' ask questions.... then it is on, as they have began [sic] the conversation... [Middle level teacher, alternative program]*
>
> *As a teacher educator I appreciate being able to show this type of resource to science teachers and help them make as many connections as possible among literacy and science, engagement using pop culture, NOS [Nature of Science], and learning theory. [Professor of Teaching, Learning and Teacher Education]*
>
> *Because I am not using these with students, I cannot comment directly. I know of their use in my district and have appreciated how widespread they are and teachers finding they reach different audiences effectively. [Public school administrator]*
>
> *The use of comics to elucidate various topics appears to be a trend in society. These particular comics have been very carefully constructed to be scientifically accurate and very attractive to middle and high school students. They (anecdotally) seem to attract both students interested in science and students to do not express an overwhelming interest in science. [Informal educator]*
>
> *My students love these graphic novels. The ideas are so current. [Middle level science teacher]*

Overall, the comments were very positive and spoke to the comics' broad appeal and utility.

Respondents who indicated they used the *Microbe Maniacs Sticker Book* (n=19), used it across all categories of settings and across all age groups (see Table 7). Again, the materials were employed in a variety of settings, from classroom lessons focused on transmission of infectious disease to immunology and workshops for STEM-inclined youth to pre-service teacher education to use as handouts at museums and medical centers.

TABLE 7. SETTINGS AND EXAMPLE USES OF *MICROBE MANIACS STICKER* BOOKLET

Setting	Example descriptions of use
Informal (all age groups)	**Elem:** "Afterschool programs" [informal educator] **Middle:** "These have been used as 'add ons' for use of the comics" "Afterschool programs" [both informal educators] **High:** "Extra credit for students" [high school science teacher]
Formal (all age groups)	**Elem: "**Transmission of infectious disease" [Professor of Civil and Environmental Engineering] **Middle:** "7th grade immunology" [secondary science teacher] "Pictures of microbes" [middle level teacher, alternative program] **High:** "Parasite workshop at Young Nebraska Scientists" [Graduate student, Biological Sciences] "Bacteria" [high school science teacher] **Adult:** "Science methods class" [Senior Lecturer, Teacher Education]
Personal/ Other	"Alongside our exhibit - Zoo In You - at museum venues" [Museum staff member] "The sticker book was handed out to middle school children who were in the Emergency Dept." [Health care worker]

Comments about using the sticker books indicated their appeal across diverse audiences.

> *Stickers are awesome, kids grab them and create pictures and paste the stickers where appropriate. [middle level teacher, alternative program]*

The kids had fun putting stickers on each other to make people "sick." [Professor of Civil and Environmental Engineering]

It was a fun visual way to discuss bacteria. I had the students take out the stickers and apply them to their notes as we discussed bacteria. [high school science teacher]

Little kids love these. The Spanish/English version is particularly useful. Parents also find these delightful. [Professor of Sociology]

The students loved the stickers, even though they are High School Students. [high school career and technical education health science teacher]

Respondents who had used *The Planet of Viruses* book (n=15) similarly indicated a range of uses, from middle school age through adult, and across all types of settings. Not as many descriptions were offered about how they used the book, but most described uses with middle level students including "afterschool STEM program," "science club," "Science Olympiad" and teaching about viral infectious disease. One respondent, a teacher educator, indicated s/he had given the book to teachers in a workshop, and elaborated with this comment, "Teachers were very excited about the resource and reported that they used the book successfully in the classroom." In addition, one respondent indicated an in-depth use of the book in a college course s/he was teaching. As this person explained, "The book was used as an introduction to the semester long student projects [assigned in Biology 326, Biology of Viruses]. [Students] were asked to pick a topic from the book that became the basis of their group project." Other comments about using the book included,

Great resource for read a loud and engaging students, creating conversations and applying to real world. [middle level teacher]

I loved this book. I learned a great deal and highly recommend it. [Professor of Sociology]

Respondents who had used the interactive apps that correspond to the WoV graphic stories (n=11) also indicated using them with all age groups and across all settings. Similar to the print materials, the apps were used in afterschool science programming at the elementary and middle school levels. At the middle school level, one respondent who is an informal educator wrote, "In particular, we have used the influenza and HPV comics to introduce and analyze the impacts of these 2 disease agents on human health." At the high school level, teachers used them to discuss viruses vs. bacteria. The apps were also used in pre-service and in-service teacher professional development, and one respondent focused on their use for "literacy and science." Comments included,

I used these with my students who were UNL preservice science teachers. The biology teachers were most interested in the comic books and app as a resource since the content was most relevant to the courses they were learning to teach. While the physics and chemistry teachers thought it was a nice resource with high quality materials, they didn't see being able to use it themselves. The use of educational technology is very effective and well-done as these materials are quite interactive in app form. [Professor of Teaching, Learning and Teacher Education]

The apps make science very relatable for the groups of students who have not expressed a big affinity for science, as well as the students who are interested. Being able to see a visual expression of the data involved in the stories (example: the incidence, mortality and location of influenza outbreaks) appears to provide meaningful connections for the students participating. [Informal educator]

I think the kids were more engaged with the app than the print version of the comic. [Informal educator]

Respondents who used the website (N=8) indicated they used it across all settings, but identified only middle level youth and adults as target audiences. Given the small number of respondents in this group, it is not possible to generalize to the broader group of users who access the website. However, the comments indicate some of the ways the website is used and perceived. Uses include, "resources for myself," "science methods class," "as part of [afterschool programming]," "for students to explore," "as a resources in the [college] course syllabus," and

"connecting other researchers to the overall [BioHuman SEPA] project and to the findings regarding the research." Comments about the website included the following:

> *The website makes it very easy to find information. It is also visually appealing and easy to navigate. [Professor of Sociology]*
>
> *I used this website just for browsing purposes for myself. Great design. [Secondary level science teacher]*

Respondents also rated the deliverables with respect to their effectiveness in five different dimensions that were identified as important goals by the project team. Respondents overwhelmingly rated the materials as effective in all areas, with some variation based on type of material. Over 90% of all respondents rated the World of Virus comic, the Planet of Viruses book and WoV apps as "somewhat" or "very" effective with respect to helping users "understand science topics," "visualize science," "engage with science," and "become motivated to learn more," and 80% or more also felt that those materials were similarly effective in helping users "identify with scientists." The Microbe Maniacs Sticker Book and the BioHuman website were also rated highly along these dimensions, but, not surprisingly, slightly lower in their effectiveness in helping users identify with scientists.

Of the five different resources (WoV comic, Planet of Viruses book, WoV Apps, Microbe Maniac sticker book, and BioHuman Website) we asked about in the survey, many respondents indicated that they only used one or two. When asked why they had not used the others, by far the most frequent response was that they were unaware of the other resources available. The next most frequent reason was limited access, generally because their educational setting lacked internet access or lacked an iOS device to access the apps. Lastly, some indicated that the materials were not a good fit, either because of the reading level for the students they were working with, or because of parameters within the curriculum.

When asked for any final comments about the project materials, comments were overwhelmingly positive. They focused on the broad appeal and scientific accuracy of the materials, and also how well-received they were by people they had used them with. Comments included,

> *I appreciate your efforts to engage students of all ages in the wonderful and interesting world or viruses; I wish more people had a better understanding of why one should not take antibiotics for a viral infection! [Senior lecturer, Teacher Education]*
>
> *I recall that about 2 years ago, I had a group of extension visitors to campus, who wanted to know more about virology, I shared the WOV comics with them and they were fascinated. [Professor of Biological Sciences]*
>
> *I love giving them to people and referring people to them. I love that the apps are free, the science is accurate and interesting, and the art and stories are interesting. [Professor of Sociology]*
>
> *These comics have provided a great way for students to engage with the material I teach. While not all students connect in the same fashion to viruses, I feel that there has been some level of benefit using these for all of my students. [high school science teacher]*
>
> *Now that NGSS standards will be a focus in Nebraska, the "story line" component of the books and other resources appear to be a good fit, thus allowing for more use over multiple classrooms. However I feel the virus books are more 7-8 grade level. [high school science teacher]*
>
> *Great resource that enhanced my curriculum. My students enjoyed the sticker books--and if students are enjoying themselves they tend to remember more. [middle level teacher]*
>
> *I see these materials as significant tools in both formal and informal science education grades 7-12. [former high school teacher and current informal educator]*

Feedback given by the different users indicate that the BioHuman SEPA materials have broad appeal, extensive utility across different settings and age levels, and have been used for a variety of purposes. Educators overwhelmingly rated all the materials they used as effective in helping users better understand and visualize science concepts, to

engage with science and become motivated to learn more, and to identify with scientists. However, even among educators familiar with the project, many users who accessed one BioHuman SEPA resources were not aware of the other kinds of materials and resources available from the project. In a crowded landscape of educational materials, it is a challenge to gain visibility and encourage use of print and online resources, particularly if they are not part of larger curriculum or ongoing series. While the BioHuman SEPA project used many diverse means for distribution, even more widespread "marketing" of the different deliverables as they became available might have been beneficial to increase awareness of them.

This ***Educator Interview Study*** was an in-depth exploration into science teachers' decisions about using comics in their instruction (Matuk, Hurwich, Spiegel, & Diamond, 2018) conducted by the evaluator and researchers collaborating with the BioHuman SEPA project. Using qualitative analyses to examine why and how teachers used comics in their classrooms and the potential they perceived in comics, we explored the use of comics as teaching tools to support science learning and literacy and to address issues of equity. Specifically, we asked:

1. What potential do teachers see in comics for promoting equitable science learning? That is, what features of comics do teachers recognize as being useful for supporting their efforts to create equitable science learning opportunities for their students?
2. How do comic books support teachers' equitable approaches to science teaching? In other words, how do teachers build upon the features of comic books, and enact their potential through the activities they conduct in their classrooms?
3. What challenges do teachers encounter in using comic books in their teaching? Understanding the benefits of comics in relation to the potential difficulties is important for informing other teachers' decisions about using comics in their own teaching.

Through surveys and interviews with 18 teachers, classroom observations, teaching artifacts and students' survey responses, we describe teachers' motivations, strategies, and approaches in using the *World of Viruses* comic book in their classrooms. The study addresses both the potential of comics in science education, and the continued challenges that teachers face when using novel, nontraditional materials to create equitable learning opportunities for students. We found that the comics helped facilitate teachers' use of multiple literacies for interdisciplinary teaching and for engaging underrepresented students in science. By unpacking the characteristics of science comics and by exploring what teachers are likely to identify as relevant, and the ways they are likely to leverage features of comic books for their instructional goals, this study contributes to our understanding of how innovative curriculum materials are identified, adopted, integrated, and enacted. Implications for the role of comics in supporting equitable science teaching and learning through their adaptation and integration into science curricula are discussed.

III. MUSEUM PROGRAMS AND INFORMAL OUTREACH

The project sponsored a variety of informal outreach events, through museum programming, exhibits, and special events (see Table 8 for a listing with brief descriptions). Some specifically targeted youth, and others were designed to appeal broadly to the general public. Several were collaborative in nature, taking advantage of ongoing educational series at the museum or partnering with other funded projects to enhance the distribution of the BioHuman SEPA resources. Altogether these events, along with other direct distribution of resources and other means of outreach, reached an estimated 4,632,868 individuals who received, interacted with and/or viewed BioHuman SEPA project educational materials about current biomedical topics. Some more specific details and examples of the various different outreach channels are described below.

TABLE 8. LIST AND DESCRIPTION OF OUTREACH PROGRAMS AND EVENTS

Informal Outreach:	Dates	Participants	Brief description
Exhibits			
Contagion Exhibit at UNMC Library	Jan - Apr 2018	48 youth and adults (event) 3,000 total audience for exhibit	Exhibit featuring enlarged poster prints of each page of the *Carnival of Contagion* comic and displays with materials illustrating how the book was created. An official reception and book signing event was hosted by the University of Nebraska Medical Center.
Contagion Exhibit at UNL Love Library	Aug 2017 - Jan 2018	97 youth and adults (event) 75,000 total audience for exhibit	Same exhibit (described above) displayed at additional venue. A public book signing and reception event was hosted by the UNL Office of Research and Economic Development as part of the annual Research Fair.
Galapagos Evolution Exhibit	Mar - Aug, 2017	59,000 youth and adults (estimated)	An interactive, traveling exhibition highlighting Darwin's journey to the Galapagos Islands, the unique and diverse animal species he encountered there, and his conclusions about evolution of species.
OMSI Human Microbiome exhibit	Jun 2014 - Dec 2016	10,000 youth and adults	BioHuman SEPA provided 10,000 Microbe Maniacs Sticker Books to be distributed with this traveling exhibit called *Zoo in You: The Human Microbiome*, funded by NIH SEPA and produced by Oregon Museum of Science and Industry. The closely related content about microbes living in and on humans led to this collaboration between SEPA projects.
Programs, Camps, & Festivals			
Sunday with a Scientist: Regenerative Medicine	Jul 2017	60 youth	BioHuman SEPA project provided materials to support participants in the Sovereign Native Youth STEM Academy attending the Sunday with a Scientist event.
Investigate: Second Saturday Science Lab	May 2017 Jun 2017	63 adults 53 youth (total for both programs)	Monthly "science labs" that feature a variety of science and natural history topics through hands-on activities, exploration, and interaction with local scientists. BioHuman SEPA sponsored two events, "Evolution" and "Viruses."
UNSM Science Cafe	Mar 2017	54 adults	"casual, educational, and entertaining monthly series for adults (21+) exploring a variety of science and natural history topics" BioHuman SEPA sponsored "Nebraska to the Galapagos" event
Discovery Days at AT&T Park	Nov 2016	1946 (est) youth and adults	BioHuman SEPA distributed materials and provided hands-on science activities to teach about microbes at the annual Bay Area Science Festival hosted by UCSF Science and Health Education Partnership.
AAUW Ultimate STEM day	Jun 2016	100 youth	BioHuman SEPA provided print materials that were distributed to participants in this one-day STEM camp for middle level girls hosted by American Association of University Women.
Young Nebraska Scientists (YNS) Summer Camp	Jun 2015	50 youth and adults	BioHuman SEPA provided print materials that were distributed to participants and family members in a summer Nanoscience summer camp sponsored by YNS, an NSF EPSCoR program.

"Science of Chemistry" at UNL for Native youth	Jun 2015	60 Native youth	BioHuman SEPA provided a variety of materials distributed to participants in NIH funded "Building Bridges: Health Science Education in Native American Communities," led by Maurice Godfrey.
Science Olympiad National Tournament	May 2015	150 high school youth	BioHuman SEPA provided a variety of print materials that were distributed to participants in the Science Olympiad National Tournament.
UCSF SEP Project	Oct 2014	1640 elementary level youth	BioHuman SEPA provided 1640 Microbe Maniacs Sticker Books to be distributed to San Francisco and San Mateo public school children in collaboration with the University of California San Francisco's Science and Health Education Partnership programs.
Yuckology Science Camp	Jul 2014	25 youth (ages 6-10 yrs old)	Weeklong summer day-camp held at Lincoln Children's Museum, featuring BioHuman activities for elementary level youth
USA Science and Engineering Festival	Apr 2014	4200 youth and adults (estimated)	Festival held in Washington, DC to "reinvigorate the interest of our nation's youth in science, technology, engineering and math by producing and presenting the most compelling, exciting, educational and entertaining science festival in the US." BioHuman staff and collaborators hosted an informational booth, presented hands-on activities, experiments, and interactive apps, and distributed Microbe Maniacs Sticker Books and World of Virus comic books.
Planetarium and UNL Campus Visit	Nov 2013	180 8th grade youth	The entire 8th grade class from a local middle school were hosted at the UNL campus for a day-long field trip that included a planetarium show, tour of the campus and lunch at a dining hall. BioHuman SEPA provided partial funding for the students.
Sunday with a Scientist with Dr. Eileen Hebets	Feb 2013	847 youth and adults	One of a series of monthly UNSM events highlighting the work of different scientists to educate youth and families in a fun, informal way through demonstrations, activities or conducting science on site at the museum. This one focused on spiders and sponsored by BioHuman SEPA.
Fright Night at UNSM	Oct 2013	1318 youth and adults	Three-night event in late October featuring activities throughout the museum designed to be spooky, educational and fun. BioHuman SEPA tables included live spiders, interactive activities, and distribution of materials.
Native Youth Leadership Camps	Sep 2012; Nov 2013; Jul 2015	128 Native youth	BioHuman SEPA provided a variety of materials each year to support this Sovereign Native Youth Leadership Camp, sponsored by the Nebraska Commission on Indian Affairs, to provide Native students with leadership skills to positively impact their tribal communities and their own futures.
UNL Courses, Public Relations & Training			
Exhibits: Design, Development & Assessment	Spring 2018	17 advanced undergraduate and graduate students	Journalism and Mass Communication course cross-listed in Art-Graphic Design and Illustration and in Anthropology, co-taught by Diamond and professors and instructors from participating departments in collaboration with Innovation Studio (Maker Space) creating permanent exhibit for UNL Center for Virology
BigTenNetwork Video	Oct 2015 - Dec 2016	4,474,806 general public	In Fall 2015 and 2016, this one-minute promotional video entitled, "Huskers, heroes, villains and viruses," was shown to BTN In-game, live and on-demand audiences, and online through their YouTube channel and promotion on social media. It described the development and use of the World of Viruses comic, and its goal of making learning science fun.
Women in STEM Learning Community	Fall 2013	13 undergraduate students	Sociology course taught by Julia McQuillan, BioHuman SEPA Co-PI
Science Communication through Outreach	Spring 2013	13 advanced undergraduate and graduate students	Joint NSF and NIH sponsored School of Biological Sciences course taught by Diamond and Prof Eileen Hebets

Documentation of participation was gathered for all of these events, with more formal evaluation conducted for just one type of museum outreach activity: *Investigate: Second Saturday Science Lab*, a hands-on activity-based program offered monthly by the UNSM. Visitors were observed as they interacted with staff and participated in the activities at the different stations, and visitors were also briefly interviewed as they exited the event location. Data gathered indicated positive reactions to the programs by attending youth and adults. They were engaged with and enjoyed the specific activities that included comparing skull specimens, folding paper models, and interacting directly with scientists, and were able to identify particular concepts that they had learned about. Overall, results indicated that the events were well-planned and effective in reaching the target audiences.

In addition to public outreach events described above, the BioHuman SEPA project used several other avenues of outreach to the general public and to specific audiences. The *World of Viruses* comic was featured in a Big 10 Network promotional video as part of a series of one-minute vignettes designed to highlight university research, innovation, and community service. The "BTN LiveBig: Huskers, heroes, villains, and viruses" aired nationally on the Big Ten Network during Nebraska football, men's basketball, women's volleyball, and other Nebraska sports broadcasts to an estimated 4,000,000 viewers. An article about the *World of Viruses* comic appeared in the member magazine of the American Society of Biology and Molecular Biology entitled, "Real Science Gets Inked" (Sirajuddin, 2015), reaching an estimated 60,000 members. With multiple full color images of the comics and a description of the process of weaving art and science together, this online and print article included links to the project website and related research articles.

The project also directly supported ten individual undergraduate and graduate students in a variety of ways. These students were trained and educated while working with the project in various capacities alongside BioHuman SEPA collaborators that included virologists, microbiologists, parasitologists, educators, journalists, and social scientists. Some students worked a semester or more with the afterschool clubs, helping deliver content and working directly with middle level students. Others conducted research under the direction of BioHuman SEPA project staff, contributing to the project goals and to the literature on youth science identity. All of these university students were involved in a substantive way, and more than half came from underprivileged backgrounds themselves. Although no formal evaluation of this involvement was conducted, the opportunities afforded these students provided unique experiences to learn more about human biology and to work with scientists and researchers in related fields.

Through these diverse means of outreach, the BioHuman SEPA project was able to reach a wide audience, sharing science content with the public, engaging with youth around science ideas, disseminating the innovative resources and materials developed by the project, and presenting the social science research investigating essential questions about how to enhance youth interest and participation in science.

IV. RESEARCH ON SCIENCE IDENTITY

The final component of the BioHuman SEPA project is social science research designed to contribute to our understanding of, and to the research literature about, youth and their engagement with science. The BioHuman research studies informed the project's strategies for building public understanding of and correcting misconceptions about the biology of viruses and vaccination, and they aided in the creation of the different deliverables designed to explain the scientific concepts that underlie infectious disease. Presented at conferences and published in peer-reviewed journals, the studies also provide support for the effectiveness of our deliverables and contribute to the broader understanding of youth science interest and inequalities in youth science engagement.

Two research studies conducted during the prior World of Viruses SEPA project and published during the BioHuman SEPA funding period directly shaped the social science research agenda for this project. First, in a randomized comparison study, we compared comics and essays with similar factual information but with different narrative and graphical techniques. A total of 873 students in high school biology classes were randomly assigned to read either a comic or a text-based essay with the same virus information and then to complete a short survey. The results demonstrated no differences between the two formats in knowledge about viruses, suggesting that comics can be as effective as essays in teaching youth about science principles and ideas. However, we found significant differences in degrees of engagement: youth across all levels of science identity were more engaged by the comics than the essays, and, importantly, youth with the lowest science identities were more likely to be motivated by the comics to read more. These findings demonstrated the power of comics to reach teenagers who might otherwise have little interest in science (Spiegel, McQuillan, Halpin, Matuk, & Diamond, 2013). These studies indicate the potential for creative, fun, and entertaining material to connect youth with science—even those with low science identities.

Second, in a related study, we conducted semi-structured interviews of virologists, teachers, and students. These clinical interviews allowed a comparison of expert, teacher, and student mental models of infectious disease. We found distinctive mental models of infection, vaccination, and immune response in the three groups (Jee, Uttal, Spiegel, & Diamond, 2013). As expected, the teachers and students lacked the detailed, precise knowledge about viral infection that was evident among the virologists. The study, however, provided striking perspectives on students' misconceptions about vaccination. For example, almost half of the students believed incorrectly that vaccination worked by directly attacking viruses in the body in much the same way that chemotherapy kills cancer cells. These findings helped the BioHuman SEPA project team to target specific misconceptions in the development of the educational outreach materials. These initial studies led to questions about the role of science identity to better understand what factors influence youth's engagement with science.

Thus, these two studies informed the Biology of Human social science research agenda, which was originally designed to help understand how "to increase broad audiences' interest in and knowledge of human biology and biomedical careers – with particular emphasis on diverse groups that are non-dominant in biomedical research careers" (language from the proposal). A decline in youth interest in science and science-related careers has been an area of intense concern for many years, and the gender, race/ethnicity, and social class disparity in science interest and engagement remains a key issue (Archer, Dawson, DeWitt, Seakins, & Wong, 2015). Many social scientists focus on reducing barriers and increasing inclusion of groups historically marginalized from endeavors perceived as "prestigious" or "exclusive" such as biomedical research and science (Charles & Bradley, 2009; Committee on Maximizing the Potential of Women in Academic Science and Engineering (U.S.) & Committee on Science, Engineering, and Public Policy (U.S.), 2007). The National Research Council (2009) summarized research showing that non-dominant and marginalized social groups are more likely to conceive of the science of human biology as not relevant to their lives. A key strand in the report focused on the need to help "...people develop identities as science learners, and, in some cases, as scientists - by helping them identify and solidify their interests, commitments and social networks, thereby providing access to scientific communities and careers.... it is an important goal that all members of society identify themselves as being comfortable with, knowledgeable about, or interested in sciences" (p. 46, National Research Council, 2009). Broadening participation in science at all levels is important to both increase innovation and reduce social inequality (Beede et al., 2011; Holdren, 2011; Page, 2008). Thus, the BioHuman SEPA social science research plan built on sociological research designs and statistical methods assessing effects of interventions on medical practices for low-income ethnic minority groups (Fifield et al., 2010)

and studies of adolescent identity, behavior, and psychosocial trajectories (Crosnoe & Johnson, 2011) to learn more about the race/ethnic and gender gaps in science persistence (Shadish, Cook, & Campbell, 2001).

The broader context of social inequalities in science identities, educational persistence and careers therefore informed our research agenda for discerning the best ways to reach marginalized groups with SEPA materials and activities. Small children are almost universally interested in the natural world and how it works, which is the foundation of the natural sciences. But this interest begins to wane during the middle school years, a developmental time when race/ethnicity and gender gaps in interest also emerge (Barmby, Kind, & Jones, 2008; Blue & Gann, 2008). Youth attitudes toward science develop within a broader social context stratified by social class, race/ethnicity, and gender. Aware of their status characteristics, youth may perceive certain careers as more or less suitable for themselves and choose activities and classes consistent with those perceptions (Correll, 2004; Riegle-Crumb, Farkas, & Muller, 2006). Implicit biases of teachers, parents, and peers also influence youth's interaction with science (Banchefsky, Westfall, Park, & Judd, 2016; Grunspan et al., 2016; Walton & Spencer, 2009). Eventually, choices based on assumptions about what is appropriate for them, that may not even be conscious, can lead girls and youth of color away from science pursuits, even those youth with high science interest and achievement (DeWitt, Archer, & Osborne, 2014a) (DeWitt, Archer, & Osborne, 2014b). Science identity, or having others think of one or thinking of oneself as a "science kind of person," is shaped by many social and developmental processes including science interest and enjoyment, perceived science ability, recognition for science achievements, and encouragement to do science (Blanchard Kyte & Riegle-Crumb, 2017; Carlone & Johnson, 2007; Hazari, Sadler, & Sonnert, 2013). Combining insights from prior empirical research on youth science identity, interest and achievement with a social-cognitive theoretical framework, the BioHuman SEPA social science research team developed a longitudinal, quantitative data collection plan to study youth science identity stability and change over time.

The Biohuman research focused on middle school age youth for a variety of reasons. In the prior SEPA (World of Viruses) we focused on high school audiences and through that research discovered that we likely needed to shift to middle school audiences to develop higher science identities, accurate science knowledge of human biology, and interest in biomedical careers. Early adolescence is a time of significant physical, emotional, and social growth. This is a time when youth are trying on identities, and negotiating their place in a world, both where they hope to fit in, and where they hope to stand out (Eccles, Lord, Roeser, Barber, & Jozefowicz, Debbie, 1997). Rapid developmental and cognitive growth lead to more sophisticated negotiations and tensions between how they see themselves and how they perceive others see them. Depending on the social and cultural context, youth become more aware of the social hierarchy and social identities during this developmental period that can encourage more or less engagement with science.

In the United States, the middle school context and organization is itself very different than primary schools. For youth in suburban and urban areas, the transition from primary to secondary school marks an achievement and reorganization of the structure and social environment of learning. For example, elementary schools usually consist of neighbors in close proximity who have similar socioeconomic and racial/ethnic statuses, whereas middle schools tend to be larger, to pull from larger geographical areas, and are consequently more racially, ethnically, and economically diverse (Mickelson, 2015). Elementary schools usually focus more on reading, writing, and math than science, and elementary students usually have only one to two teachers in a year and a core group of classmates in most of their classes. Middle school instruction tends to be more subject based, and science in particular is typically a clearly defined area of study with designated subject teachers and classrooms.

Whether it is due to the more complex social structure of middle schools, or due to psychosocial development, this age is also a time of transition when parents become less influential and friends become more important for social support, well-being, belonging, and self-esteem (Barber, Eccles, & Stone, 2001; Kinney, 1993). Peers help shape adolescents' beliefs and norms around acceptable behaviors, and hold sway over one another's opinions and decisions about music, fashion, sports, out-of-school activities, and academic achievement (Barber, Stone, Hunt, & Eccles, 2005; Bishop et al., 2003). Therefore, understanding how youth perceive peers, teachers, parents, and adults see them is likely to be important for understanding science identity development.

Finally, early adolescence is when career aspirations, which are closely tied to identity, begin to develop and have an influence on later academic choices and attainment (Tai, Liu, Maltese, & Fan, 2006). This is a crucial developmental time to understand more about how youth may become interested in, stay interested in, or lose interest in pursuing science (DeWitt et al., 2013; Tai et al., 2006).

We surveyed 792 students from diverse backgrounds in grades six to eight during four waves of data collection in 2013 to 2015 at a Title I middle school. On computers students answered survey questions about explicit perceptions of science (e.g., science enjoyment, salience, and competence), science identity (if they are a science kind of person), perceived science support (teacher and parent support, perceptions of others seeing them as a science kind of person), friendship networks, and a measure that the team created—discovery orientation (e.g., curiosity about the world, learning about new discoveries, etc.). These survey items built upon the research team's prior survey measures of science attitudes, interests and behaviors that came from a variety of sources and added questions to measure discovery orientation, to differentiate self and other science identities and to measure reflected appraisals and perceptions of ability. Leveraging these data, we have published three articles in peer-reviewed journals.

The first, “Discovery orientation, cognitive schemas, and disparities in science identity in early adolescence,” appeared in *Sociological Perspectives*. In addition to contributing new knowledge about factors associated with lower or higher science identities in adolescents and persistence in science, we created a new theoretical construct, "discovery orientation," to separate science propensity from implicit biases. "Science" culturally infers "white" and "male" in U.S. society. Our goal was to assess science interest and prediliction without triggering implicit associations of science with gender and race/ethnicity categories (Cai, Luo, Shi, Liu, & Yang, 2016; Nosek et al., 2009). The items on our discovery orientation survey ask about personal interests and activities that capture science propensity but do not use the word “science.” For example, we ask youth about their curiosity about the world and how much they like exploring nature. By separating discovery orientation from science identity we were able to assess whether differences in science identities reflect actual differences in science propensity (discovery orientation) or differences in the implicit associations of science with gender and race/ethnicity (Bigler & Wright, 2014; Cohen, Garcia, Apfel, & Master, 2006; Master, Cheryan, & Meltzoff, 2016). This study showed that discovery orientation does not vary by gender and race/ethnicity, but science identity does. In other words, we found that boys who are white have the strongest direct association with science identity, but for youth in marginalized social statuses (minority boys, minority girls and girls who are white), the association of discovery orientation with science identity is mediated and youth in the marginalized groups have lower science identities even though they do not have lower discovery orientations. Why is this finding important? Because it supports the argument that youth from all social groups have the propensity to have high science identities and to engage in science careers, but that gender and race/ethnicity biases shape which youth are more or less likely to have science identities. The article on discovery orientation and science identities advances understanding of how science attitudes and recognition may contribute to the underrepresentation of girls and/or minorities in science. Therefore the BioHuman SEPA efforts to include characters in comic books and leaders in activities who bring positive images of women and/or minorities in science has the potential to disrupt barriers to inclusion.

The second paper, “The potential scientist’s dilemma: How the masculine framing of science shapes friendships and science job aspirations”(Gauthier, Hill, McQuillan, Spiegel, & Diamond, 2017), was published in *Social Sciences*. This article uses social network analysis to explore how friendship patterns may influence girls’ aspirations for science careers. We found that many middle school youth have gendered norms about which of their friends can be scientists. Indeed, both boys and girls were more likely to say that their female friends are "***not*** science kinds of people,” even though there were no differences in how boys and girls viewed their own science capabilities. This finding provides evidence for implicit gender science norms among middle school age youth. The observed patterns of youths' perceptions about their friends reveals a middle school norm of science as a masculine activity. Thus, girls who have high science career aspirations are counter-normative, as are boys with low science career aspirations. Our analyses found that youth with gender-inconsistent science aspirations (high for girls and low for boys) were more likely to be friends with one another than with youth who had gender normative science career aspirations. These findings suggest friendships and social interactions in middle school matter with respect to understanding gendered patterns of science career aspirations. This work contributes to our knowledge of youth perceptions, gender, social dynamics and science aspirations, and suggests possible avenues in efforts to support more girls

staying in science. These findings also supported the BioHuman SEPA efforts to create communities of science learners who could see each other as science kinds of people through afterschool science clubs.

The third paper, "Science Possible Selves and the Desire to be a Scientist: Mindsets, Gender Bias, and Confidence during Early Adolescence," published in *Social Sciences*, uses a series of multivariate logistic regression models to examine how boys and girls differ with respect measures related to pursuing science (Wonch Hill et al., 2017). A "fixed mindset" about academic ability refers to seeing that ability as innate rather than something that can change and grow with effort. We found that having a fixed mindset is associated with thinking that boys are better than girls at science ("boy-science gender bias"), and that older girls have more boy-science bias than younger girls. In addition, we also found that fixed mindsets and boy-science bias are both associated with lower likelihood of having a science possible self (thinking that one could become a scientist), and this was true for both boys and girls. Confidence in one's own science ability and having a science possible self are both associated with higher likelihood of wanting to become a scientist. Thus these biases negatively impact how both boys and girls see their potential for science pursuits. These findings suggest some possible interventions that may help widen participation in science careers. For example, encouraging youth to see that it is possible to develop science abilities (they are not fixed), and providing stories about successful women scientists and biomedical practitioners could help shift current implicit images of science as male. These results helped to inform the images in the "Occupied" comic (the science teacher is an African American woman) and the comic "Carnival of Contagion" (the physician is a woman of color) in which the "bad guys" are white males.

The project team continues to work on publications and manuscripts using the rich data gathered via the Biohuman project. One of the current papers underway was also presented as a poster at a professional conference in the Fall of 2017, and is tentatively titled, "Disseminating science identities through afterschool science: Peer group effects." Drawing upon data collected in Wave I of the Science Identity Study, this paper uses social network items based upon youth nominating others in the school as friends and then answering questions about whether or not the friend is a science kind of person, whether the friend sees the survey participant as a science kind of person, and if the two do science activities together. The goal of the paper is to assess how youth and friend participation in afterschool science clubs influences youth science identity. The paper seeks to answer the question: do youth who participate in afterschool science clubs have higher science identities than youth who do not? Do youth with more friends who participate in afterschool science clubs have higher science identities than youth with fewer friends who participate? Social network analyses provided evidence that afterschool science programs are associated with disseminating science identities. Short-term outcomes associated with participating in afterschool science include increased academic performance, engagement, enjoyment, and interest. Science clubs compete with other activities, however, and are not available to everyone (e.g. those who need to care for younger siblings). Preliminary results from this analysis show that, as expected, youth who participate in afterschool science have higher science identities. After controlling for youth science identity, however, we see that the number of friends a youth has in afterschool science also increases youth science identity. We find the same effect even for youth who do not participate in afterschool science at all; the more friends a youth has in afterschool science, the higher the youth science identity of those who do not participate. The social network analysis provides powerful evidence that having an afterschool science program in a school may positively impact youth science identity for many youth in the school, not just those who attend.

The second major paper in progress was submitted for consideration as a presentation for a professional sociology research meeting in August 2018, and is tentatively titled, "Gendered science identity changes during the progression through a U.S. middle school." Guided by identity and social cognitive theories, we model within person change in perceived other and self-science identities for up to four waves over two years among 792 youth from a diverse lower income Midwest middle school. Similar to our cross-sectional research we measure both how much youth see themselves and how much they think others see them as a science kind of person or not. We pay particular attention to convergence and divergence between boys and girls in science identities over time. We find that at most time points during middle school, boys have higher science identities than girls, yet for both groups, changes in science identities respond to changes in at least some science relevant characteristics. The changes in science identities over time suggest that youth science identities respond to experiences with others and with science activities and topics. Increases and decreases in science identities time to time suggest responsiveness to exposure to interesting and relevant science experiences, as well as to people who recognize and tell youth that they are good

at science. These findings support claims that middle school is a vital time for interventions to increase youth science identities. They also suggest that creating relevant and interesting science stories, such as comics, has the potential to increase science identities.

A third research paper currently in development focuses on middle school youth's participation in informal science to explore the extent to which youth engage in different informal science opportunities, in what combinations, and how their engagement differs by level of family resources. Engaging with science outside of the formal classroom can provide youth with an opportunity for more open-ended, self-directed, and independent exploration of science ideas. Currently, little is known about typical youth engagement in out-of-school science activities. In our study of a diverse sample of youth from a large urban middle school, we found that the vast majority of youth report to have engaged in at least one kind of informal science in the past year. Indeed, most youth engage with multiple kinds of informal science activities, including visiting zoos and museums, watching science programming, attending after school and out-of-school time clubs, and participating in summer programs and science fairs. As would be expected, youth in families with more resources participate in a higher number of activities and at higher frequencies. Using the theoretical lens of science capital, our exploration of how access to resources and social capital are associated with informal science activity participation in this diverse sample suggests that there may be different approaches to increase informal science exposure and content by social class. We believe these findings will provide avenues for informal science educators to pursue so that they may reduce class-based disparities in access to authentic/engaging/high quality informal science experiences, in order to both widen participation in the STEM career workforce, and to broaden public understanding of science.

Taken together, these studies help us better understand the influences of gender, race, and friendships on youth science identities. They contribute to our ultimate goal of ameliorating gender and race/ethnicity gaps in science participation at every level by shedding light on some of the complex social, psychological and developmental changes during adolescence that impact how youth see themselves and each other. These studies are important steps in understanding the kinds of changes in afterschool programs, science materials, in-school and out-of-school science experiences, teacher preparation, access to resources and other personal influences that might help shape a future with science gender parity.

This research has resulted so far in three peer-reviewed articles in the sociological literature, in addition to other peer reviewed publications (see full list of published articles in section on Overall Impacts, page 42). Presentations of the social science research studies at local, regional, and national conferences by members of the project team reached hundreds of scientists, researchers, undergraduate students, and pre-service, classroom and informal educators.

LIST OF CONFERENCE AND OTHER PRESENTATIONS

McQuillan, J. & Hill, P.W. (August 2018). *Gendered Science Identity Changes during the Progression through a U.S. Middle School.* Presentation at the American Sociological Association (ASA) Annual Meeting, Philadelphia, PA.

Hill, P.W. (March 2018). *World of Viruses/Biology of Human: Engaging Teenagers with Science Through Comics.* Presentation at SciComm 2018: A Conference on Effective Science Communication: Lincoln, NE.

Hill, P.W. (March 2018). *The science of self: how gender bias & mindsets influence the inner scientist.* Presentation at UNL 2018 SciPop Talk Series: Lincoln, NE.

McQuillan, J. (August 2017). *How can we discover science kinds of people?* Lincoln Youth TEDx Presentation: Lincoln, NE.

McQuillan, J. (February 2017). *Blinded by science.* Learning Research Presentation at the UNL DBER's Group STEM Education Seminar, Lincoln, NE.

Ledesma, J., Hill, P.W., Gauthier, G., McQuillan, J., Spiegel, A.N., & Diamond, J. (October 2017). *Disseminating science identities through afterschool science: Peer group effects.* Presentation at the 2017 Annual Conference of the Computational Social Science Society of the Americas (CSSSA), Santa Fe, NM.

Yang, Y. L., & McQuillan, J. (August 2017). *Variations in Science Identity: Exploring Race/Ethnicity and Science Experiences Among Middle School Youth.* Poster presentation at the University of Nebraska Research Fair, Lincoln, NE

McQuillan, J., Hill, P.W., & Diamond, J. (December 2016). *Disseminating science identities.* Presentation at the Nebraska K-12 Science Education Summit. Lincoln, NE.

Gauthier, G., McQuillan, J., Hill, P. W., Spiegel, A.N., & Diamond, J. (August 2016). *The potential scientist's dilemma: Gender differences in the salience of science in same-sex adolescent friendships.* Presentation at the American Sociological Association (ASA) Annual Meeting, Seattle, WA.

Hill, P.W., Gauthier, G., & McQuillan, J., (March 2016). *The potential scientist's dilemma: The social salience of science in U.S. boys' and girls' same-gender friendships.* Presentation at the Population Association of American (PAA) Annual Meeting, Washington, DC.

McQuillan, J., & Hill, P. W. (March 2016). *Biology of Human Project Social Science Research.* Presentation at the UNL, UNMC & UNO Sciences, Engineering and Medicine (SEM) Research Retreat. Lincoln, NE.

McQuillan, J. (February 2016). *Trying on identities: Science engagement among adolescents.* Symposium moderated at AAAS Annual Conference, Washington, DC.

McQuillan, J. (October 2015). *From discovery to identity: Exploring ways to engage all youth in science*. Plenary presentation at the Midwest Regional Noyce Connections Annual Conference. Omaha, NE.

McQuillan, J. (October 2015). *Adding value to science communication through partnering with social scientists.* Presentation at UNL SciComm 2015: Symposium on Effective Science Communication, Lincoln, NE.

McQuillan, J., Hill, P. W., Spiegel, A.N., & Diamond, J. (August 2015). *Social inequality in science identity among middle school youth.* Presentation at the American Sociological Association (ASA) Annual Meeting, Chicago, IL.

Smith, K.D., & Hill, P.W. (August, 2015). *What is science? Exploring middle school perceptions of the nature of science and science identity.* Presentation at the American Sociological Association (ASA) Annual Meeting, Chicago, IL.

Talbert, E., Hill, P.W., & McQuillan, J. (August 2015). *Growth mindset, traditional gender science beliefs and the gender gap in STEM*. Presentation at the UNL Undergraduate Research Symposium, Lincoln, NE.

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Diamond, J. (May 2015). *So you want to make an app? Mobile aps for biomedicine and health outreach.* Presentation at the National Institutes for Health (NIH) SciEd 2015 Conference. Washington, DC.

McQuillan, J., Hill, P. W., Spiegel, A.N., & Diamond, J. (March 2015). *Identities in middle school: Lessons from a school-wide social network study.* Presentation at the Annual Meeting of the Midwest Sociological Society, Kansas City, KS.

McQuillan, J., Hill, P. W., Spiegel, A.N., & Diamond, J. (March 2015). *More than competence: Science identity by gender and race among middle school youth.* Presentation at the Sociology of Gender Brownbag (FemSem) at the University of Wisconsin Department of Scoiology, Madison, WI.

McQuillan, J., Hill, P. W., Spiegel, A.N., & Diamond, J. (March 2015). *Activating adolescent science identity: Research and practice.* Presentation at the National Science Teachers Association (NSTA) National Conference on Science Education, Chicago, IL.

McQuillan, J., & Hill, P.W. (February 2015). *Is it still science if you don't call it science? Discovery orientation and science identity among middle school youth.* Learning Research Presentation at the UNL DBER's Group STEM Education Seminar, Lincoln, NE.

Diamond, J., McQuillan, J., & Spiegel, A. N. (February 2015). *Comics, Zombies & Hip Hop: Leveraging Pop Culture for Science Engagement: Engaging Teenagers with Science through Comics.* Paper presented at AAAS Annual Conference, San Jose, CA.

Hill, P.W. (November 2014). *Women, gender and science.* Guest lecture in AGRI/NRES/WMNS385 UNL course. Lincoln, NE.

Diamond, J. & McQuillan, J. (October 2014). *Biology for Human Project.* Outreach presentation at Education Shar-a-Thon Water for Food 2014 Global Conference.

Diamond, J., McQuillan, J., & Spiegel, A. N. (September 2014). *Activating adolescent science identity: Research and practice.* Presentation at the Nebraska Association of Teachers of Science (NATS) Conference, Fremont, NE.

Gamino Torre, B., Hill, P.W., & McQuillan, J. (August 2015). *Growth mindset, traditional gender science beliefs and the gender gap in STEM*. Presentation at the UNL Undergraduate Research Symposium, Lincoln, NE.

Hill, P., McQuillan, J., and Spiegel, A. (July 2014). *Are you a science kind of person? Gender differences in science identity amod middle school youth.* Presentation at STEM Thinktank and Conference, Nashville, TN.

McQuillan, J., Hill, P.W., Spiegel, A., & Diamond, J. (May 2014). *Bringing social scientists in: Extending science education partnerships.* Panel presentation at the National Institutes for Health NIH SciEd 2014: Conference for NIH Science Education Projects, Washington, DC.

Diamond, J. (May 2014). *Human microbiome share-a-thon.* Facilitator and panelist at the National Institutes for Health NIH SciEd 2014: Conference for NIH Science Education Projects, Washington, DC.

Diamond, J. (May 2014). *NIH P-12 STEM and National Science Foundation (Informal Science Education programs).* Presentation at the National Institutes for Health NIH SciEd 2014: Conference for NIH Science Education Projects, Washington, DC.

Diamond, J. (May 2014). *Publish a Paper about Your Project in Curator: The Museum Journal.* Facilitator for breakout session at the National Institutes for Health NIH SciEd 2014: Conference for NIH Science Education Projects, Washington, DC.

Jee, B.D., Uttal, D.H., Spiegel, A., & Diamond, J. (2013). *Students' and teachers' beliefs about the microbiological structure and activity of viruses and vaccines.* Poster presented at the 2013 Society for Research in Child Development Biennial Meeting, Seattle, Washington.

The Science Identity Study (SIS) is a rich data source with information that has the potential to inform several questions that SEPA projects have about how best to increase science knowledge, interests, identities, and careers for all youth. In addition to these BioHuman SEPA team studies on science identity, data collected by the project team has been shared with other researchers conducting work in related or technical methodological areas. For example, colleagues at the University of Nebraska used the social network data component of SIS as the basis for a simulation study to identify how to estimate the effects of interventions in communities with many social connections in which some do and some do not participate in the intervention. A graduate student in the Sociology Department is completing a Master's Thesis on mechanisms associated with math, engineering, and science identities. A student in a social network health disparities NSF Research Experience for Undergraduates (REU) program used the SIS data to explore if there is evidence that Asian youth in a high poverty school exhibit evidence that they believe the Asian model minority myth by having higher science identities than youth in other racial/ethnic groups. Finally, there will be at least one additional paper that will use the two-wave social network data to assess

if changes in social network connections are associated with changes in science identities. These collaborations have resulted in two student publications, one manuscript submitted for publication, and two poster presentations:

Gauthier, G. R., Khan, B., Duncan, I., & Dombrowski, K. (manuscript under review). *Network Evaluation Protocols for Community-Based Participatory Interventions: Dis-aggregating direct intervention effects from the social context.*

Jochman, J., Swendener, A., Novak, L., & McQuillan, J. (in press). *Are Biological Science Knowledge, Interests, and Science Identity Framed by Religious and Political Perspectives in the United States?* The Sociological Quarterly.

Kesselring, K. (2017). *Mechanisms explaining gender differences in science identity.* Ogle Fellowship Presentation at UNL, Lincoln, NE.

Swendener, A. (2017). *Examining Inequalities in Science Literacy by Religious Affiliation Among Adults.* The Nebraska Educator 4:47-63.

Yang, Y. L. (2017). *Variations in Science Identity: Exploring Race/Ethnicity and Science Experiences Among Middle School Youth.* Poster presented at the UNL Undergraduate Research Symposium, Lincoln, NE.

OVERALL IMPACTS, OPPORTUNITIES AND LIMITATIONS OF BIOHUMAN SEPA PROJECT (2012-2017)

The goal of the BioHuman SEPA project as initially envisioned in the proposal was "to increase awareness of and understanding about new biomedical research developments pertaining to human biology." The project proposed to "provide a sophisticated science education outreach package for students aged 11 to 15 and adults" and to "leverage the latest biomedical information and innovations, a dynamic suite of educational and dissemination strategies, and research-driven approach grounded in social psychology to broadly educate youth and adults about human biology." The project focused on three specific aims:

- Stimulate interest in and understanding of biomedical research's importance to diverse individuals' health, communities, and environments.
- Establish partnerships among science educators, biomedical researchers, science journalists, and others to create dynamic educational resources focused on biomedical research developments and human biology.
- Increase youths' interest in biomedical science.

As the results from the numerous evaluation and research studies have demonstrated, the BioHuman SEPA project remained focused on these key elements and strategies. Through the four integrated components, these aims were addressed through multiple means. The educator professional development included emphasis on NGSS, connections with diverse resources, researchers, and institutions, and delivering information from BioHuman SEPA social science research that was relevant to classroom teaching. The creation of the science learning deliverables used a research-based development approach utilizing front-end and formative evaluation, learning and social science research findings, feedback from teachers, librarians, virologists, and teens and were disseminated through diverse means, many of which will continue to be available after the grant funding ends. The museum and public outreach activities attracted broad participation from elementary age youth to adults through a diverse series of events. Though most were brief in duration, attendance at the events were consistently high and feedback indicated that they were successful in sparking interest in the selected science topics. Finally, the social science research delved into fundamental questions about the gender gap in science participation and addressed questions on the cutting edge of research on adolescent science identity and its role in youths' science career aspirations. Together, these varied activities contributed to the general public's awareness of and understanding of the microbial world and how microbes interact with human health, indicating successful fulfillment of project aims and goals.

Five published books resulted from the BioHuman SEPA support:

Hall, B., West, J., Zimmer, and Diamond, J. (2017). *Carnival of Contagion*. Lincoln, NE: University of Nebraska Press.

Allison, L., Smith, R. and Diamond, J. (2016). *Watch Your Mouth! And Discover your Amazing Microbes*. Altadena, CA: Bitingduck Press.

Diamond, J., Horn, M., and Uttal, D. H. (2016). *Practical Evaluation Guide: Tools for Museums and Other Informal Educational Settings.* Revised 3rd edition. Lanham, MD: Rowman & Littlefield Pubs.

Zimmer, C. (2015). *A Planet of Viruses: Second Edition.* Chicago, IL: University of Chicago Press.

Diamond, J., Floyd, T., Powell, M., Fox, A., Downer-Hazell, A., and Wood, C. (2012). *World of Viruses.* Lincoln, NE: University of Nebraska Press.

Spanning a broad audience demographic, these books represent contributions to the evaluation literature, children's literature, young adult graphic stories about science, and adult science literature. All of these continue to be available to the public to interest and educate people of ages about viruses.

Finally, some of the most important and enduring outcomes of the project are contributions to literature through peer-reviewed articles in social science, informal education, and science education journals. The following eight articles are the direct result of BioHuman SEPA project activities:

Hill, P. W., McQuillan, J., Spiegel, A.N., & Diamond, J. (2017). Discovery orientation, cognitive schemas, and disparities in science identity in early adolescence. *Sociological Perspectives.* doi:10.1177/0731121417724774

Hill, P.W., McQuillan, J., Talbert, E J., Spiegel, A.N., Gauthier, G.R., and Diamond, J. (2017). Science Possible Selves and the Desire to be a Scientist: Mindsets, Gender Bias, and Confidence during Early Adolescence. *Social Sciences 6*(2), 55. doi:10.3390/socsci6020055.

Gauthier, G. R., Hill, P. W., McQuillan, J., Spiegel, A.N., & Diamond, J. (2017). The potential scientist's dilemma: How the masculine framing of science shapes friendships and science job aspirations. *Social Sciences 6*(1), 14. doi:10.3390/socsci6010014

Diamond, J., Martin, L., and Weiss, M. (eds.) (2016). Museums, health, and medicine. *Museums and Social Issues, 11*(1). Walnut Creek, CA: Left Coast Press, Inc.

Diamond, J., McQuillan, J., Hill, P.W., Spiegel, A. N., Smith, R., West, J., and Wood, C. (2016). Viruses, vaccines and the public. *Museums and Social Issues 11*(1): 9-16. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4980086

Diamond, J., Jee, B., Matuk, C., McQuillan, J., Spiegel, A. N., and Uttal, D. (2015). Museum monsters and victorious viruses: Improving public understanding of emerging biomedical research. *Curator 58*(3): 299-311.

Jee, B., Uttal, D., Spiegel, A. and Diamond, J. (2015). Expert-novice differences in mental models of viruses, vaccines, and the causes of infectious disease. *Public Understanding of Science, 24*(2):241-256.

Spiegel, A.N., McQuillan, J., Halpin, P., Matuk, C., and Diamond, J. (2013). Engaging teenagers with science through comics. *Research in Science Education, 43*(6): 2309-2326.

The unique contribution of scholarly research that was integrated across the project probed fundamental questions relevant to increasing access to science for youth from underrepresented groups, and understanding how innovative materials, such as comics, can support these efforts.

Overall, the coordinated approach of the different components effectively addressed project goals. Opportunities both created by and exploited by the project to forward the education and outreach agenda included the following:

- Building upon work of the principal investigator's prior SEPA project extended and increased the impacts of deliverables and activities.
- Taking advantage of collaborative opportunities with other researchers, educators, funded projects, and institutions enhanced the visibility and impacts of the project and expanded the distribution of deliverables.
- Open communication and collaborative planning with the Nebraska Department of Education and the Lincoln Public Schools ensured that the BioHuman SEPA professional development programs were relevant to the needs of local teachers, addressed meaningful content, and leveraged resources effectively.
- The high-quality and diverse deliverables were well received, spanned a wide target audience, and will continue to be disseminated after the funding period of the project ends.
- Experienced educators embraced using the "unique" and "engaging" deliverables and were able to creatively extend and supplement the content with a variety of related materials.
- Youth programming enabled the project staff to trial materials, interact on a regular basis with the target age group, and gather rich research and evaluation data to further project goals. At the same time, it provided fun and enriching experiences for participating youth.
- The museum programs, informal outreach, and other means of engaging the public with the BioHuman SEPA content reached millions of people in both modest and substantial ways.
- The social science research agenda to examine how to increase broad audiences' interest in and knowledge of human biology and biomedical careers was successfully enacted, resulting in the multiple, distinct publications in peer-reviewed academic journals.

Some limitations of the project activities and strategies can also be noted:

- The professional development workshops did not provide a sustained, consistent model of delivery. Choosing a flexible and lower-cost model of design and delivery that was adapted to local needs precluded the development and use of an intensive, iteratively refined program focused on student achievement.
- Although materials were distributed through multiple channels and means, evaluation feedback on use of project deliverables indicated limited visibility of the different resources across the project. In other words, people who used one of the resources developed by the project were not always aware of the other related resources available through the BioHuman SEPA project. This may be because each deliverable was introduced individually as it became available for distribution rather than all the deliverables presented to a potential user at once as a suite of resources. In addition, the target audiences varied by deliverable, in that the target age group was different for each of the print materials.
- By design, the deliverables were not intended to fit a specific course of study nor accompanied by any curriculum. While this is an advantage in enabling wide latitude and application of their use, it also means that educators must adapt and accommodate the integration of their use in instruction.

The BioHuman SEPA project reached a broad, diverse audience, increasing their awareness of and understanding about microbes and human health. The multi-pronged strategy of four distinct but integrated components resulted in efficient use of resources to deliver effective professional development, create high-quality, engaging deliverables, and author meaningful contributions to the professional literature on increasing science participation, particularly for youth from underrepresented populations.

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APPENDICES

Appendix A: June 2015 Teacher PD Workshop Agenda and Goals

Appendix B: June 2016 Teacher PD Nebraska Vision for Science Agenda

Appendix C: June 2017 Teacher PD Course Syllabus

APPENDIX A: JUNE 2015 TEACHER PD WORKSHOP AGENDA AND GOALS

UNIVERSITY OF NEBRASKA STATE MUSEUM

SEPA SCIENCE EDUCATION PARTNERSHIP AWARD
Supported by the National Institutes of Health

UNIVERSITY OF Nebraska Lincoln

Explore Students' Science Identity &
Inquiry-based Investigations of Biology

WORKSHOP SCHEDULE

Monday June 15

5 pm Planetarium shows: Supervolcanoes 5-5:25; Sunstruck 5:30-5:50
6 pm Dinner in Elephant Hall, University of Nebraska State Museum, Parking stickers for the central lot for the entire week will be handed out next to Archie from 4:30 to 6pm.

Tuesday June 16

8:30 am Meet at Archie to walk to Sociology Rm 707 Oldfather Hall.
8:45- 9:15 am Review schedule and handouts. Breakfast foods available.
9:15-11:15 am Science Identity investigations.
11:15-12:15 Bag lunch provided.
12:30 pm Meet by Archie for van and cars to Gut Microbe Lab (East Campus).
1:00-5:00 pm Gut Microbe Investigations.
5:00 pm Van pick up at Dairy Store to return to the Museum.

Wednesday June 17

8:30-11:30 am Science Identity Investigation in Sociology Rm 707 Oldfather Hall; breakfast foods available.
11:30-12:30 Bag lunch provided.
12:45 pm Meet by Archie to split into TWO groups: 1) Walk to Parasitology Division, Nebraska Hall. 2) Take van to Morrison Virology Center.
1:00-5:00 pm Parasitology and Virology Investigations.
5:00 pm Van pickup from Morrison Center to return to Museum.

Thursday June 18

8:30-11:30 am Science Identity Investigation in Sociology Rm 707 Oldfather Hall; breakfast foods available.
11:30-12:30 Bag lunch provided.
12:45 pm Meet by Archie to split into TWO groups: 1) Walk to Parasitology Division, Nebraska Hall. 2) Take van to Morrison Virology Center.
1:00-5:00 pm Parasitology and Virology Investigations.
5:00 pm Van pickup from Morrison Center to return to Museum.

Friday June 19

8:30-9:30 am Meet at Morrill Hall Rm 126 for evaluation with Dr. Amy Spiegel; breakfast foods available.
9:30-12:30 Discussion with Dr. James Blake, LPS Science Curriculum Coordinator.
12:30-1:30 pm Buffet lunch provided.

Social Science Investigations: Exploring Science Identity

The goals of this 3-day morning workshop were to have teachers 1) understand the usefulness of social psychological concepts in their efforts to help youth become more interested in science; 2) learn to use a sociological lens to identify how social structural forces influence youth identification with science; 3) identify ways to use identity theory concepts and principles to enhance youth science identities; 4) create tools to integrate what they've learned about science identity into education practices. To reach these goals we invited participants to take the survey that we used in our research with middle-school youth, asked teachers to answer the question "who am I?" to explore their "selves"; and invited participants to take an implicit bias test on gender and science. We provided information on the sociological imagination, and social psychological concepts on identity theory, implicit bias, and stereotype threat. To better understand how majority "white" and minority boys and girls could differ in the sense that others see them as a science kind of person, we had participants do content analyses of the science textbooks used in local middle schools. They completed coding sheets on the gender, race, activities, and roles of the people pictured in the books. We provided data on local, national, and international participation in science and other careers by gender and where available race/ethnicity. We explored the association between discovery orientation and science identity through enjoyment, relevance, messages from parents, teachers, and general others by gender and race. Teacher participants collaborated with the sociologists to create tools that teachers can use in their classes to facilitate higher science identities in their students.

Science Research Investigations: **Inquiry-based Investigations of Human Biology**

June 16, 2015 Gastrointestinal Microbiota with Prof. Amanda Ramir-Tait and Post-doctoral fellow in Bioinformatics, Dr. Rohita Sinha.

Investigations to convey: 1. Microbial population have tremendous capability to manipulate our physiological state (disease vs non-disease state); 2. Once we understand this, then the question is how do we study a microbial environment: 2A: Then we explain the ways to study microbial environments; 2B: Show examples of the studies, which have used these methods to differentiate the microbial population of disease vs non-disease states. 3- In the hands-on practice we simulate "obese" and "lean" microbiome input files and ask them to run (RDP classifier) and compare the two microbial profiles. Workshop activities include an introductory lecture and discussion about gut microbiota; Tour of UNL Gnotobiotic Mouse Facility; Discussion of using data science to understand gut microbiota diversity; Designing gnotobiotic mouse experiments to test associations discovered using data science (mock isolator activities, mouse tissues and microbiome images); Wrap-up, questions, and discussion of how to incorporate gut microbes into the classroom.

June 17-18, 2015 Parasitology with Prof. & Curator Scott Gardner and Collections Manager Gabor Racz

Teachers will be exposed to parasites from several perspectives including investagating life cycles of tapeworms, nematodes, and trematodes. Then teachers will learn about actual specimens by looking at infected mammals and they will dissect beetles that have tapeworm larvae (all non pathogenic and not infective to people). Objectives: Understand where tapeworms fit into the tree of life (and try to add an unknown species into the tree); Study how tapeworms live; Understand the life cycle of tapeworms; Observe dissection of rodents (rat and gopher) to search gastro-intestinal tract for parasites; Discover, fix, stain, mount, and study a cestode (discovery of morphological characters; build character matrix, use matrix to build phylogenetic tree to determine location of species on tree of life). One Day 1, the teachers studied the basic biology of Cestode; Discuss the life cycle of tapeworms; different hosts at different parts of the life cycle; how can humans get involved; Dissection of rat and gopher to find tapeworms; Find, relax, fix, stain tapeworm to prepare to mount it on a slide, and then identified characteristics necessary to measure and/or find in order to place a species on a phylogenetic tree and, ultimately, the tree of life. On Day 2, the teachers finished mounting tapeworm slide; Build character matrix for unidentified tapeworm species by observing slides under microscopes; Upload matrix into software programs (Mesquite; TNT) to build phylogentic tree – to determine ancestor-descendant relationships of the tapeworms of interest.

June 17-18, 2015 Virology with Dr. John West and HIB Laboratory Manager, Danielle Shea

One of the most important aspects of virology, and of microbiology in general, is the ability to apply quantitative assessments to biological phenotypes or genotypes. In virology, this often takes the form of titrations, plaque assays or focus-formation assays. However, molecular detection using the polymerase chain reaction (PCR), provides the capacity to enumerate viral copy numbers, or numbers of infected cells, safely, accurately, and in real-time. In this workshop, teachers used extracted genome DNA from a cell line called 8E5 that contained a single integrated HIV-1 copy (defective) for quantitative real-time PCR to produce standard curves for number of human genomes sampled and the number of HIV-1 copies per human genome. A patient sample was run in parallel to compare to the curve and determine the HIV-1 burden in the patient DNA sample. The concepts and application of real-time PCR to our specific project, and to other applications, were explored through activities and discussion, including pipetting technique instruction and experience, PCR plate preparation and introduction to DNA analysis technology. At the end of the first day, teachers toured the Level 3 facility in the Virology Center and on the second day, learned about the NIH-funded virology research being conducted in Africa while working in the lab.

June 19, 2015 Assessment and Applications with Dr. Amy Spiegel and James Blake, Lincoln Public Schools Science Curriculum Specialist.

8:30-9:30 Written evaluations with Dr. Amy Spiegel

9:30-10:30 Workshop with James Blake. Teachers do a whip around and share-out the answers to select questions from Amy's evaluation with the rest of the workshop staff present.

10:30-11:30 Orientation to Next Generation Science Standards Practices Activity and Discussion. Discussion with Dr. Judy Diamond on future workshop plans.

11:30-12:30 Plus, Minus, Delta activity with LPS Curriculum Objectives (or State Standards if non-LPS) with the context of their week of "authentic science."

12:30-1:30 Buffet Lunch

APPENDIX B: JUNE 2016 TEACHER PD NEBRASKA VISION FOR SCIENCE AGENDA

Nebraska Vision for Science

Professional Development Schedule for June 27, 2016

Join teachers from across the state for a full day of 3-dimensional learning. This event promises to be a great opportunity with national and state leaders in science to explore the future of Nebraska science education. We will help bridge the gap between current educational research and practice using hands-on experiences. Facilitating this event will be special guests and authors of "*A Vision for Science Teaching and Learning*," Rodger Bybee, Brett Moulding, and Nicole Paulsen.

7:30 am	Registration at Innovation Campus, University of Nebraska – Lincoln, 2021 Transformation Drive, Lincoln. Parking is available in lot directly north of Transformation Drive.
8:30–8:45	Welcome – *Judy Diamond, Sara Cooper, James Blake, Deb Paulman*
8:45–10:15	Vision for K-12 Science Education as Described in the Framework – *Brett Moulding*
10:15–10:30	Break
10:30–11:45	Breakout Session I* (Repeated in Breakout Session II) 1. Disciplinary Core Ideas in the Classroom (LINKS participants pick another session) 2. Implications of the Framework for Standards and Classroom Instruction 3. Supporting Science Understanding through Literacy 4. Engaging Students in the Science & Engineering Practices (LINKS participants pick another session) 5. Engineering Practices Consistent with the Framework
11:45–12:45	Lunch
12:45–2:00	Breakout Session II* (Repeat of Breakout Session I)
2:00–2:15	Break
2:15–3:15	Using Crosscutting Concept Prompts to Engage Students in Structured Responses *Brett Moulding*
3:15–3:30	Nebraska EPSCoR Presentation – *Lindsey Moore*
3:30–4:00	Evaluation – *Amy Spiegel*
4:00–5:00	Break
5:00–9:00	Reception at the University of Nebraska State Museum, Morrill Hall, 14th and Vine Streets. Parking available in lot A/F3/C in front of the museum. Guest can park in any spot and pick-up a parking pass at the visitors services desk inside the museum.

**Breakouts subject to minor changes.*

Nebraska Vision for Science Sponsors

Biology of Human NIH-SEPA project
University of Nebraska State Museum
Nebraska Center for Virology
Nebraska EPSCoR
LINKS Nebraska MSP
Lincoln Public Schools
Nebraska State Dept. of Education
Colleges of Agricultural Sciences and Natural Resources, Education and Human Sciences, Arts and Sciences, and NebraskaSCIENCE
College of Engineering
Dept. of Sociology
Vice Chancellor for Research & Economic Development

Thanks to STEMscopes for graciously providing lunch for this event

APPENDIX C: JUNE 2017 TEACHER PD COURSE SYLLABUS

Soc 898: Special Topics:
Social Psychological Processes in the STEM Classroom: Activating STEM Identities

University of Nebraska –Lincoln

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Learning Objectives:
1. Teachers will understand the usefulness of social psychological concepts in their efforts to help youth become more interested in STEM.
2. Teachers will learn to use a sociological lens to identify how social structural forces influence youth identification with STEM.
3. Teachers will identify ways to use identity theory concepts and principles to enhance youth STEM identities.
4. Teachers will create tools to integrate what they've learned about STEM identity into education practices

Description:
This class covers a broad range of social psychological topics and processes to help teachers better understand how social context impacts STEM learning. Students will learn about social inequality in STEM fields, and the individual, interactional, and institutional barriers to developing a science identity for youth from a variety of social locations (rural/urban, gender, race/ethnicity, Socioeconomic Status, ELL).The class will learn about implicit bias, stereotype threat, and identity theory, and how they impact formal and informal social interactions and learning in the STEM classroom. They will learn and help formulated practical strategies to reduce their negative impact in order to broaden and widen student engagement in STEM.

Assessment

1. Fact Sheet: Science Translation & Communication that translates a social science concept/theory finding FOR teachers in a format that facilitates understanding (each class participate will have a unique topic) (10% draft due July 14th; 10% draft presentation due July 20th, 10% final due July 21st)
2. Intervention/Action plan: Develop a plan of action to alter teaching/classroom/activity that is new that will help to activate stem identities for all youth, or will engage all/more youth with STEM (integrating identity into education) with a plan for evaluating if the action was effective for reaching the intended goal (and no unintended consequences) (each class participant will have a unique action plan) (10% draft due July 14th; 10% draft presentation due July 20st, 10% final due July 21st)
3. Journaling/reactions/questions/ideas (20%)
4. Effective and constructive class participation (20%)

Class Structure – Schedule
Our classroom time together will loosely follow this structure. There will be breaks every hour, with a longer coffee break at around 2 o'clock.

Meditation – Journal Reflection – Introduction of Content
Video – Lecture - Classroom Discussion
Reading Presentation/Discussion
Project worktime (Groups/Peers/Individual)

Readings

Reading 1: Cast, D. Alicia and Jan E. Stets. 2016. The Self. *Handbook of Contemporary Sociological Theory.* Ed. S. Abrutyn. Springer International Publishing. Switzerland.

Reading 2: Tan, E. & **Calabrese Barton A.** (2007). From peripheral to central, the story of Melanie's metamorphosis in an urban middle school science class. *Science Education* 92(4), 567-590.

Reading 3 **Carlone, H.B**., Scott, C., & Lowder, C. (2014). Becoming (less) scientific: A longitudinal study of students' identity work from elementary to middle school science. *Journal of Research in Science Teaching, 51*(7), 836-869.

Reading 4: Brickhouse, N. W., Schultz, K., & Lowery, P. (2000). What kind of a girl does science? The construction of school science identities. *Journal of Research in Science Teaching, 37,* 441-458.

Reading 5: Archer, Louise, Emily Dawson, Jennifer DeWitt, Amy Seakins, and Billy Wong. 2015. "Science Capital": A Conceptual, Methodological, and Empirical Argument for Extending Bourdieusian Notions of Capital Beyond the Arts. *Journal of Research in Science Teaching*. 52:7:922-948.

Reading 6 **Tan, E**., Calabrese Barton, A., Kang, H., & O'Neil, T. (2013). Desiring a career in STEM fields: Girls' Narrated and Embodied Identities-in-practice. *Journal of Research in Science Education*, 50(10), 1143-1179.

Reading 7: Hill, Patricia Wonch, Julia McQuillan, Eli Talbert, Amy Spiegel, G. Robin Gauthier, and Judy Diamond. 2017. Science Possible Selves and the Desire to be a Scientist: Mindsets, Gender Bias, and Confidence during Early Adolescence. *Social Sciences*. 6:55.

Reading 8: Gershenson, Seth, Stephen B. Holt, and Nicolas Papageore. 2015. Who Believes in Me? The Effect of Student-Teacher Demographic Match on Teacher Expectations. *Economics of Education Review*: 52:209-224.

Reading 9: Wilson, Kimi. 2016. Exploring an Integrative Lens of Identity for a High School Mathematics Teacher. *Journal of Urban Learning Teaching and Research*. 12:164-173.

Reading 10: Avraamidou, Lucy. 2014. Studying Science Teacher Identity: Current Insights and Future Research Directions. *Studies in Science Education*. 50:2:145-179.