MedLab Final Evaluation Report

SIMLAB: Using Patient Simulation for Student Exploration of Community Health Issues

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Executive Summary

In 2012, the Museum of Science and Industry (MSI) began work on a National Institutes of Health Science Education Partnership Award (NIH SEPA, Award # R25 RR026013-01A1) to develop SIMLAB (publicly named MedLab). MedLab aimed to create museum programs and online products that provide STEM interactive learning experiences for Chicago-area middle and high school students, especially those from low-resourced areas. The MedLab project had three goals:

- **Knowledge**: to build interest in and knowledge of health sciences;
- **Attitude**: to increase awareness of and interest in medical careers;
- **Behavior**: to increase participation in activities that contribute to the betterment of a community health issue.

This external evaluator final report summarizes the outcomes and impacts of the five-year (2012-2017) funding compared to project objectives. The aim of the project was to use in-person and online curricula, including a humanoid patient simulator (iStan®), to build interest in and knowledge of health sciences and health careers, with a particular focus on local community health concerns. An additional goal was to promote literacy in the scientific process by diagnosing and devising a treatment solution for a patient's illness.

The Front-End Evaluation in the first two years of the project featured three main activities: 1) a scholarly literature review of STEM learning and health science literacy that could be used to support curriculum development with teens at the museum or online; 2) development of a protocol to assess and address the risks of students' potentially adverse reactions to the MedLab programming coupled with an 8-hour IRB training for MedLab staff on protection of human subjects in research and MedLab staff adherence to the human subject protection protocol; and 3) pilot testing of health topics to be presented by the program with Chicago youth.

The Formative Phase of the evaluation in years 2 to 4 included a longitudinal phenomenological study of emotional responses to student interactions with iStan®. It involved a pre- and delayed-post-program impact study of students' opinions, knowledge, interests, and behaviors and assessed possible long-term negative impacts of the learning experience with the simulator. In parallel to the external evaluators' work, MSI conducted formative evaluation of the curriculum during its development phase. MSI's formative evaluation results are not reported here.

The Summative Evaluation in Year 5 consisted of three studies to assess the outcome and impact of MedLab's programming: 1) a comparative study of the opinions, knowledge, interests, and behaviors of students who participated in MedLab with students who only visited the museum; 2) an assessment of the utility of the online learning products; and 3) a teacher feedback study on their and their students' experiences with MedLab. The teacher study did not receive sufficient response for any conclusions to be drawn.

Results

The evaluation revealed outcomes for students' knowledge, attitudes, and behaviors around community health issues and general healthy living principles. A range of middle and high school students from Chicago Public Schools and nearby school districts participated in the study, suggesting these results could be applicable to a range of settings.

The program **increased students' knowledge of community health issues and how health sciences address those challenges**. Teens enjoyed the hands-on aspects of the lab activities and could recall their learning several months after the session. Even though students thought the program helped them know how to assist others experiencing health crises, the program did not appear to influence students' tendency to share health information with others. The program also did not contain modeling for how a student might share this information, which may be an area for program development in the future. Although we were unable to test outcomes due to the late launch of the online

product, the MedLab Online program appeared to support knowledge gain about the health sciences.

The program **increased students' awareness of and interest in medical careers** related to the specific medical science topics and the technologies involved in diagnosis. Several months after the programs, they showed interest in health science professions, particularly nursing and physician roles, and could remember many of the less traditional roles, such as lab or ultrasound technicians. We note that some of the participating students were enrolled in health science tracks through their school, which may have had an impact on some outcomes as well. Low participation in delayed post studies limit the ability of the evaluators to make more specific comments on impacts. Although we were unable to test outcomes due to the late launch of the online product, the app appeared to support knowledge gain about the health science professions as well.

The MedLab program supported more health-conscious behaviors among participants. Delayed post interviews and summative evaluation results revealed that students valued and were more inclined to pursue healthy behaviors months after program participation. The MedLab online product did not seem to address behavioral outcomes, but the study of the online learning product was inconclusive given the late date of testing and the few classrooms available to assess the product.

Risks with Robotic Simulator Programs

Monitoring of 685 students attending three in-person programs at MSI showed that the program, the realistic nature of the robotic patient simulator, the simulation of medical situations, and the curriculum posed little to no risk to middle and high school students. A few students were initially reluctant to interact with the simulator, but those reactions quickly dissipated. Students overwhelmingly reported very positive experiences, often citing the simulator as the most engaging aspect of the lab.

The assessment showed that younger or middle school students were more likely than high school students to exhibit stress reactions when approaching or working with the stimulator. The evaluators suggest that these results were likely due to the relatively mild observable reactions programmed for the simulator. We suggest that future programming for older students could take greater advantage of the simulator's capabilities by creating more intense simulation of medical events to assess if these situations stimulate greater learning outcomes.

Finally, two initial concerns of realistic simulation of medical events were that programs might trigger a stress reaction in students who have Blood Injury Injection Phobia, or they might trigger past trauma for students who have a history of medical treatment trauma. Of all the students observed in the programs, none exhibited a phobic reaction. We recommend that students who have a traumatic medical history consult with parents and teachers before participating in medical simulations.

As noted in the proposal*, iStan is a computer-driven, full-sized mannequin that delivers true-to-life biomedical scenarios that swiftly change to meet the user's goals. The ultra sophisticated and highly versatile iStan blinks, speaks and breathes, has a heartbeat and a pulse, and accurately mirrors human responses to such procedures as cardiopulmonary resuscitation, intravenous medication, intubation, ventilation, and catheterization.* The scenarios developed for MedLab used modulated breathing, heartbeat and pulse, that did not reveal any elevated emotional response in youth.

The difference in health topics developed for the online version of MedLab led to limited opportunity to explore how online and live museum experience contribute individually and in combination to learning outcomes. The preliminary nature of the online experience and its focus on medical procedures and diagnosis had limited utility for understanding the role of learning in self-efficacy in medical situations or health behavior practices.

Conclusion

The evaluation of the MedLab live-programming shows it achieved success with its intended outcomes for students across knowledge, attitude and sustained behavioral choices months after the program. Teacher outcomes and outcomes for the online learning tool were not able to be assessed for this project.

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Introduction

In 2012, the Museum of Science and Industry (MSI) started work on a five-year National Institutes of Health Science Education Partnership Award (NIH SEPA #R25 RR026013-01A1) to develop two inquiry-based learning experiences: 1) hands-on MedLab programming around iStan®, a human-like patient simulator, which is part of MSI's ***You! The Experience*** exhibition, and 2) interactive online learning about public health topics for distance learning. With robotic simulators widespread in medical education, MedLab was among the first efforts to create museum programming using a patient simulator as a learning experience for middle and high school students.

In collaboration with science teachers and health educators from Chicago Public Schools (CPS) working as advisors, MSI had a three-pronged goal:

1. **Knowledge**: to build interest in and knowledge of health sciences;
2. **Attitude**: to increase awareness of and interest in medical careers;
3. **Behavior**: to provide context for behavioral changes related to community health issues by creating emotionally positive and productive learning experiences for teachers and youth.

The proposal noted that the Project's target population in CPS contains more underrepresented minorities than the general population of Chicago, students from racial and ethnic groups that have been shown by the National Science Foundation to be underrepresented in health-related sciences, individuals from disadvantaged backgrounds, and with physical and developmental disabilities. The project anticipated that students involved in the proposed work would reflect CPS at-large; and thereby serve a significant fraction of minorities underrepresented in STEM careers.

The Evaluation

NewKnowledge Organization Ltd. (NewKnowledge) served as the external evaluator on the MedLab project after the Institute for Learning Innovation, the original contractor on the NIH-SEPA grant, closed in 2012. NewKnowledge was the Institute for Learning Innovation's successor non-profit research organization, under the direction of the same evaluation team. As independent evaluators, NewKnowledge used a mixed-methods strategy to assess MedLab's effectiveness in meeting the project goals. The evaluation team worked closely with MSI's leadership team to ensure all indicators, instruments, and measures aligned with the team's strategy and goals, and that students served by the program met the target criteria.

The evaluation strategy also recognized that there was some risk of emotional distress both from the uncanny valley effect when students confront a human-like patient simulator, and/or from trauma related to previous personal or family medical issues. To ensure the protection of students, NewKnowledge appointed clinical psychologist Dr. Kin C. Kong (Illinois Clinical Psychologist License # 071-006881) as a Research Fellow to lead external oversight of protection of human subjects in this study. Dr. Kong's academic training, and clinical and professional practice focus on children and adolescents. She also served as a member of the Institutional Review Board (IRB) at the Chicago School of Professional Psychology for several years.

Dr. Kong led a training for MSI project staff in the rights and protections of project participants and collaborated on the development of a literature review related to in-person and online STEM learning that could be used by MSI in program development (Kong et al., 2013). She advised on the data collection instruments and protocols, which in turn were reviewed under the auspices of the MSI IRB, with additional review and oversight from CPS's Research Review Board.

Dr. Kong and her doctoral students monitored students' encounters with the simulator during MedLab sessions to determine if any encounters with the humanoid simulator led to stress, phobic reactions, or triggered past trauma for students. They were also there to determine and implement appropriate responses should such reactions occur. To

ensure there were no delayed or residual negative reactions to iStan®, Dr. Kong also conducted follow-up interviews with randomly selected students and with students flagged for atypical responses during MedLab. All data related to protection of human subjects were anonymized. For monitoring purposes, identifiable data were only collected for students who exhibited unusual reactions or reported a moderate level of distress during MedLab. This information was used to contact students for follow-up interviews after MedLab. Several students were flagged for follow-up interviews and the results revealed no long-term negative consequences, echoing the results from the random selected students.

Choosing Community Health Issues

Decisions about the health topic case studies to develop for the MedLab programming, which would be tested through several iterations, were based on several factors. These factors included research carried out by MSI staff, NewKnowledge's research and literature review, MSI's Advisory Committee discussions, formal and informal feedback from teachers and students from partnering CPS schools, feedback from Chicago medical students, the Chicago Department of Health's Healthy Chicago initiative, and the 12 Priorities for a Healthy Chicago.

Since most of the Museum's MedLab participants came from the Chicago Metro area, drawn most heavily from the CPS's, the six topics chosen for case studies also fell within the 12 priority areas highlighted in the Chicago Department of Public Health's *Transforming the Health of Our City: Chicago Answers the Call* (2010). These priority areas were: tobacco use, obesity prevention, HIV prevention, adolescent health (exercise, nutrition, sexual health, including prevention of sexually transmitted diseases), cancer, heart disease/stroke, mental health, maternal and child health (including teen births, infant mortality, low birth weights), communicable diseases (TB, meningitis, etc.) and HPV vaccinations, healthy homes (lead poisoning, asthma, etc.), violence prevention, and public health infrastructure.

The original plan called for seven health topics to be developed for MedLab, two in Year 1 and five in Year 2. This timeline proved to be overly optimistic. Instead, after a year of planning in Year 1, three public health issues connected to student lifestyles and potential for behavior changes were selected for case study development for the MedLab program in Years 2 to 4. The diabetes (related to obesity) case study launched in Year 2, heart disease in Year 3, and asthma in Year 4. MSI reported that their formative studies with 15 CPS teachers surveyed for Heart Disease found the topic relevant to their students and to their classroom curriculum. MSI also reported that of the 17 teachers surveyed for three scenarios ranking the relevance of health topics - cancer, substance abuse, STIs, asthma, and tuberculosis, these teachers ranked asthma the highest. Based on these data and how the team felt iStan® could most effectively be used in order to enhance student and teacher learning, the team identified three well-suited topics. The three topics met MSI's design criteria: they could be easily programmed into iStan®; worked well for diagnostic purposes; and afforded students a "cool" experience with the patient simulator as well as a hands-on, simulated medical diagnosis experience. Throughout the evaluation, questions about diabetes, heart disease, asthma, health and wellness were included in the student assessment survey, as well as other piloted public health issues (bipolar disorder, depression, blood pressure, cancer, and cholesterol). Sexual health was excluded based on teacher rankings in learning priorities.

The online version of MedLab was to be drawn from the simulation experience, and was scheduled for rollout in Year 4. Several factors resulted in a delay in launching the online platform until the end of the final year of funding, Year 5. These included: a change in MSI staffing, the need to produce materials for three to four additional topics, technical difficulties in developing the platform and a change in web developers, following low performance by the first contracted company. In addition, the focus moved away from lifestyle health topics, to ones that related to balancing diagnostic information with relatively easy to understand and engaging content for student classroom learning and discussion. MSI reported that the classroom version was meant to be used as part of a health sciences unit that should include personal health. Staff identified lead poisoning as a point of interest because the Flint, Michigan water crisis had high newsworthiness. Meningitis, and tuberculosis were also

selected by staff and happened to be priorities in *Transforming the Health of Our City* (2010).

Some students in the pilot phase and a few Advisory Committee members had advocated for one of the case studies to be an EMS-like situation (from accidents and/or violence) as it reflected the reality of students' lives and was thought to have the highest potential for engaging them. In addition, trauma also could demonstrate iStan®'s many capabilities. A simulated trauma scenario might have provided researchers with a broader set of dimensions from which to assess emotional reactions of potentially vulnerable students or empathy for the simulated patient in a medical scenario, and do so in a safe and supportive environment. MSI did not pursue development of trauma scenarios, deeming these scenarios too risky because they might trigger significant stress reactions in participants and an inadequate amount of live program time for students to resolve negative reactions. Staff also felt that operational cost of fluid clean up or chest compression (i.e. CPR) experiments might cause excessive wear and tear on the simulator.

All of the topics selected afforded ample opportunity for students to engage in inquiry-based science investigation. Due to the late launch of the beta version of the online platform, we were unable to adequately assess its value. MSI reports that they have budgeted for continued development and evaluation of that program beyond NIH funding.

Evaluation Challenges

There were three main challenges NewKnowledge encountered in carrying out the evaluation of this project: pedagogy issues, low teacher/student participation rates, and the late development of online scenarios.

The different health topics for the online version of MedLab led to limited opportunity to explore how online and live museum experience contribute individually and in combination to learning outcomes. The online experience also focused primarily on the scientific process and therefore had limited utility for understanding the role of learning in self-efficacy related to medical situations or health behavior practices.

Second, beginning with the pilot studies in the first year of funding, participation from teachers and students was unexpectedly low and inadequate for comparison measures as originally envisioned in the grant proposal. MSI had a viable list of schools and teachers who brought their students to MSI regularly, as well as a list of infrequent visitors, but few teachers agreed to participate in the studies or withdrew from the studies after attending programs. Meanwhile, some Chicago Public Schools' Research Review Board restrictions placed on teachers restricted participation to only out-of-school hours, which contributed to very few responses after extensive recruiting efforts. Lack of continued teacher interest in later years and reported lack of free time hindered involvement. Many students were excluded from the evaluation because they did not have signed parental consent forms. Of note, MSI also discontinued their teacher training workshops after continued low turnout. Few teachers took advantage of the pre- and post-visit online resources, another situation that MSI adapted to in onsite programming in later years.

Third, we were unable to evaluate the utility of the online program due to a late launch in May 2017 and technical difficulties in the classrooms where the launch was being staged. The late launch meant none of the schools that were observed had experience with the platform, and technical difficulties resulted in only one classroom being able to successfully connect to the internet to use the platform as intended. Consistent with the CPS teacher response to the live program development, there were also few schools willing to participate in this study. Therefore, there were no viable comparisons that permitted assessment of the in-person simulation model and online platform, even if the platform had operated correctly.

The evaluators and their contract clinical psychologist felt that new information on the degree to which more emotionally complex interactions with a simulator demonstrating medical reactions or trauma situations might provide valuable information to the health science learning field. Given the careful controlled settings for this work, the external evaluation team felt the experimental situation was ideally suited to careful study. However, the low-risk scenarios created for the simulation meant that the role

of an elevated emotional response by participating youth as a contribution to health related learning was not available for study.

Staffing & Advisement

There were staffing changes at MSI after the second year that caused some loss of historical knowledge and how decisions were made. The main impact on program development was a shift in teacher engagement at MSI. Initially teacher pairs (health and science educators) were involved as a group in program development and topic selection, whereas after Year 2, individual teachers were contacted for input. For the most part, the staff changes did not significantly alter the program, and program leadership remained the same.

The project advisory committee composed of medical professionals and medical technology experts remained the same over the life of the project. The committee met bi-annually and were instrumental in acquisition of hardware and software development, and provided input into narrowing the case study topics.

Program Participants

The initial project plan aimed to enroll 5,160 disadvantaged youth in grades 8 to 12 to participate in the program. At the conclusion of the program, 7,127 students had participated in 258 labs (153 diabetes labs, 73 heart disease labs, and 32 asthma labs), 38% more than projected. About 60% of these classes (*n* = 155 teachers) were repeat attendees, bringing multiple classes to labs over the life of the project. The online version aimed to reach 334 educators, but only five educators had participated by the conclusion of this funding support. Again, we note that MSI reports they have allocated additional funds to support the online effort beyond the life of the NIH support.

This Report

This final report summarizes results of the five-year MedLab evaluation.

In Year 1, NewKnowledge developed and implemented the IRB human subjects training, produced a literature review of key themes related to the use of a patient simulation with youth, developed the human subjects' protection protocol, and created, tested, and modified the survey evaluation instruments in collaboration with MSI.

In Years 2 to 4 NewKnowledge's formative evaluation assessed changes in students' health knowledge, health attitudes, health behaviors, interest in health careers, healthy living, and feedback on the MedLab health case study as it rolled out. The diabetes curriculum was evaluated in Year 2, heart disease in Year 3, and asthma in Year 4. On-site risk assessments of students who attended MedLab were conducted for each curriculum and discontinued after statistical analysis suggested that relatively limited negative emotional threat was anticipated for the target audience.

In Year 5, the summative evaluation consisted of three studies to assess the impact of all MedLab programming: 1) a comparative survey study of MedLab vs non-MedLab students' attitudes, behaviors and knowledge of health topics, careers and healthy living; 2) focus group interviews with teachers about the program's value from their perspective; and 3) an assessment of the online program of the three additional health topics (lead poisoning, meningitis, and tuberculosis). NewKnowledge also informally interviewed key MSI members about how they felt students received the program and challenges that they faced.

Literature Review & Protection of Human Subjects Training

As an initial step in the research and evaluation for MSI's MedLab, NewKnowledge in collaboration with Dr. Kin Kong and students at the Chicago School of Professional Psychology produced a preliminary guide to scholarly literature on health and other topics. These topics were chosen due to their potential to inform curriculum development and protection of human subjects in STEM and health-related learning for teens at MSI or online. This review was updated in the final year of funding. The review addressed:

- Explaining and Predicting Health Behavior
- Participation, Risk, and Mitigation
- Stress, Coping, and Engagement
- Developmental Neuroscience and Social Experiential Learning
- African American Studies and Storytelling in Learning Experiences
- Online Learning Theory, Supplement and Stand Alone Experiences

Each section of the literature review featured an annotated bibliography and explanation outlining how that particular topic might apply to MedLab. They are detailed below.

Topic 1. Explaining and Predicting Health Behavior

A review of literature related to explaining and predicting health behavior revealed four distinct, albeit convergent, ways of focusing on the topic of positive health behaviors. The first addressed possible models, such as the Health Belief Model (HBM), Social Cognitive Theory (SCT), Theory of Planned Behavior (TPB), Social Ecological Models, and Diffusion Theory, for explaining and predicting health behavior, especially as it relates to chronic diseases (i.e. obesity, asthma, HIV) among youth. The second approach to handling positive health behaviors focused on culture and health beliefs as they overlap with health behavior. In general, the studies in this section point to the importance of social cultural variables in health, including the use of narrative by some cultures to promote health practices.

Overall, the studies suggested that health decisions are usually negotiated at the group level, developed from shared experiences and social reinforcement, rather than at the individual level.

The third topic considered the specific issues that have emerged from the study of African American and Latino-Hispanic adolescents in relation to health topics. This area suggests that the family be involved when trying to change youth behaviors. The fourth topic addressed issues of health behavior change and positive psychology, giving weight to positive reinforcement as a support for intrinsic motivation over the traditional negative, fear-focused messaging. It addresses the potential positive outcomes when youth engage in challenging problems of their choosing and that they have some measure of control over finding solutions.

Topic 2. Participation, Risk, and Mitigation

Very little literature on the potential risks to adolescents participating in a medical simulation learning setting was identified. Literature on phobic responses to some medical settings or procedures raises the possibility that medical stimulations could trigger a phobic reaction, such as fainting. Literature on trauma and PTSD similarly raises the possibility that medical simulations could trigger a re-experiencing of trauma for those with traumatic medical histories. Adolescents may try and mask their anxiety with apathy or joking. There may also be delayed responses as adolescents fully take in the situation or study. Literature on how to minimize trauma for children undergoing invasive medical procedures suggest that preparation material in advance of the visit may minimizes anxiety.

In summary, the literature in this section suggested that the students' current health issues (e.g. blood, injection, injury [BII] phobias) and medical history might increase the risk that the student would react negatively to MedLab. The literature further suggests that preparation might help minimize such risk.

Topic 3. Stress, Coping and Engagement

This review reaffirmed that one size does not fit all with respect to youth engagement, stress triggers, or coping strategies. Both cultural heritage and individual experience influence how engagement is fostered and when stress can produce positive outcomes rather than avoidance. Self-efficacy, competence, pro-social norms, family, community, and school all play a part in successful outcomes. The MedLab "scientific process" of problem solving and working hard can provide an opportunity for adolescents to practice their coping strategies and improve their efficacy for future, more stressful situations.

Topic 4. Developmental Neuroscience and Social Experiential Learning

The literature in this section described the development of the limbic system, which influences emotion and social cognitive function, as abrupt and faster growing in adolescents than the frontal cortex that regulates planning, decision-making, risk assessments, and other executive functions. This review concluded that socially based experiential learning (i.e., shared learning and co-participating in activities) in programs that target adolescents will be the most effective. The research also offered the explanation for risk-taking in adolescents that adolescents engage in risky behavior, not because of a sense of invulnerability, but rather because they do not deem the behavior as very risky. These studies, like the ones in the healthy behavior section, highlight the importance of challenging work and how overcoming those difficult tasks builds an adolescent's self-esteem and decision-making abilities.

Topic 5. African American Studies and Storytelling in Learning Experiences

Literature found for this section was deemed useful as a planning guide for culturally responsive programming. In particular, it suggested using moral, narrative-structured storytelling for African American youth, rather than the single-focused arc of stories or epic structures generally used for Caucasians. Several of the studies also touched on the differential risk among different ethnic groups for certain diseases and what accounts for the differences.

Topic 6. Online Learning Theory, Supplement and Stand-Alone Experiences

The literature on digital educational materials indicated that electronic media can be effective for health promotion programs with youth, but care needs to be taken in the development of both content and delivery of online educational materials. For example, narrative media could be used to promote health programs because narratives can evoke vivid mental imagery that might give the reader a sense of direct experience with health outcomes and the behaviors needed to achieve them. In addition, online learning can meet the needs of students' varying learning styles, whether they are visual, auditory, or kinesthetic learners.

A simulation study around public health issues found that simulators motivated students, improved their problem-solving skills, helped in acquiring knowledge, and potentially changed attitudes. Another study in this section focused on the practical aspects of using electronic media in the classroom, noting that whether teachers use online materials depended on factors such as teacher competency in using the materials, number of computers, teacher buy-in regarding the use of the technology for improved student learning, and the pedagogical style of the teacher and learners. The research in this section may help to increase the viability of using online resources in the classroom.

IRB RISK ASSESSMENT PROTOCOL AND TRAINING

Because of the iStan® simulator's realistic attributes and the simulation of medical situations, the project team recognized the potential for participants to experience negative reactions to it, such as the uncanny valley effect, phobic reactions, and the triggering of past medical trauma. While MSI believed the risks to be minimal, clinical psychologist Dr. Kin Kong with specialized training and significant clinical experience with children and adolescents was hired by the external evaluator to develop, implement, and monitor a protocol to assess and address adverse reactions to MedLab programming should they arise. The psychologist carried out post-experience interviews to ensure learning did not yield adverse effects.

As a pre-project step, the same clinical psychologist led an 8-hour refresher session on the results of the literature review

and training in protection of human subjects for the MedLab project staff. The course consisted of three parts: the NIH-developed 7-module online course on the ethical conduct of human subject research; an interactive, Department of Children and Family Services online course on recognizing and reporting child abuse and neglect; and a MedLab-specific course on human subject protection issues. The latter course covered BII phobia and medical trauma, adolescent stress and coping, and assessing and managing risks specific to the MedLab project.

Front-End: Health Topics Exploration & Testing Instruments

NewKnowledge and clinical psychologist Dr. Kin Kong collaborated with MSI staff to collect data from teens between April and June 2013 to learn about their perceptions and opinions of health topics and health-related behaviors. This effort included a baseline intercept survey conducted at the museum, focus groups, interviews, and pilot program observations.

We initially aimed to pilot test instruments and then pursue baseline quantitative data from CPS students participating in MedLab in order to inform program development. At the time of the study, CPS sites for the most part were attended predominately by African American / Black (39%) and Hispanic / Latino (46%) students from underserved communities; 81% of students are eligible for federally funded lunch (Chicago Public Health Department, 2011). Unfortunately, due to low attendance of CPS students at MSI during the survey period, the small dataset precluded quantitative statistical analysis of the results, so we present frequencies.

METHODS

Initial Topic Exploration

Over three meetings in spring 2013, MSI staff and NewKnowledge discussed the program direction and structure to help youth engage in four science-learning goals:

- Increased understanding of humanoid simulators and how they can support learning;
- Increased understanding of community health issues in the Chicago area, in particular: diabetes, heart disease, asthma, and general wellness;
- Increased literacy about human biology; and
- Increased knowledge, positive attitudes, and skills including self-efficacy and advocacy in relation to health professions and health-related careers.

Focus Groups with Health Professionals

Follow-up focus groups with health professionals, conducted by MSI staff, and formal and informal surveys of CPS teachers helped the team further refine the health topics to be included in program development. Based on the focus group discussions and interviews, MSI deemed the original four health topics appropriate for MedLab's iStan® programming (diabetes, heart disease, asthma, and general wellness). The team also supplemented the program strategy with five new or revised topics: cholesterol (originally part of the heart disease topic), cancer, bipolar disorder, depression, and health and wellness in general (formerly general wellness).

Baseline Survey & Interview Study

Based on the revised program direction, NewKnowledge created a quantitative front-end baseline data survey and intercept interview protocol. Together with MSI staff, we pilot-tested the six newly developed survey modules at the museum using a parallel quantitative and qualitative study.

Survey data were collected in two pilot phases. In the first, NewKnowledge collaborated with MSI to hand out surveys over two days to students as they were leaving the Museum, with a final sample of 74 CPS students out of 83 surveys distributed. The second pilot involved a teacher handing out surveys to CPS students at school, for a total of 60 surveys. Total responses from the two pilots resulted in between 21 and 26 responses for each of the six modules. The response rate was too low to attain statistical predictability, but met validity requirements.

Survey Modules

The baseline survey featured six modules exploring different aspects of the MedLab program content and approach. Where possible, we designed the modules based on pre-validated scales. We briefly explain them here, as we

designed subsequent survey studies based on these front-end modules.

Module 1: Familiarity with Health Topics

This module asked students to use a five-point self-knowledge / confidence scale (from *I don't know anything* to *I am an expert*) to assess their own sense of knowledge confidence in the nine health topics outlined above.

Module 2: Empathy towards Robots

The second module was a five-point scale (from *strongly disagree* through *not sure* to *strongly agree*). These scales measured student perceptions of humanoid robots' rights, moral concerns involving simulators, and how such simulators might be employed in reasoning about health and wellness strategies. The module and scale items were based on the laboratory research that investigated the extent to which children accord values to social robots similar to those accorded to humans (Kahn, Gary & Shen, 2012).

Module 3: Norms for Health & Wellness

A third module assessed the incidence of the health issues among family members. The results were intended to allow examination of health topics in relation to students' personal experience and possible links or knowledge that would likely influence the MedLab group learning experience.

Module 4: Self-Efficacy with Health & Wellness

A fourth module was adapted from an adult study (Fraser, 2011), to assess self-efficacy related to health-protective behaviors and pre-arming that may be counter-intuitive for youth, whose mental development generally promotes discounting of risk. The statements about living a healthy life used a five-point scale, from *strongly agree* through *not sure* to *strongly disagree*.

Module 5: Taxonomy of Health Behaviors

A fifth module was based on a taxonomy designed for adult wellness research (Fraser, 2011). This module adapted the metric to explore youth perceptions of the legitimacy of a set of pre-defined wellness pathologies that, in moderation, are alternative ways of considering health risk, but at as extremes can lead to excessive risk taking. The module consisted of 15 statements that students rated on a five-point scale (*not at all, rarely, sometimes, often,* and *not applicable/cannot answer*) based on how true each statement reflected their own recent thought processes about their approach to health.

Module 6: Trust in Sources

The sixth module was a 13-item module, using a five-point scale (from *not at all reliable* through *not sure* to *extremely reliable*) that examined sources students trust for their health and wellness information. This module was used to see whether there were common anchor activities that might influence students' health and wellness beliefs.

Interviews

After piloting the six modules, MSI and NewKnowledge collaborated on interviews with 30 other randomly selected teen visitors at MSI, and then using a revised instrument, with an additional seven youth visitors to MSI. Researchers recorded the approximately five-minute interviews if permission was granted (in two cases it was not granted). Interviews included both the quantitative rating items and qualitative open-ended items exploring healthy lifestyles role models in teens' lives for health-related behaviors.

Pilot Program Observation

MSI led a "Live from the Heart" program featuring footage of open-heart surgery on a TV followed by presentations on the iStan® simulator. The project's psychologists observed 20 eleventh-grade students as MSI staff presented concepts and medical instruments, and then observed those students interacting with the iStan® simulator. The purpose of this evaluation activity was to gain insight into potentially stressful situations for students or evidence of possible stress reactions to the future MedLab program that might require mitigating interventions.

RESULTS

Survey Results

Familiarity with Health Topics

Results indicated that students have little to moderate familiarity with the project's health topics. They reported the least familiarity with bipolar disorder *(M* = 2.24, *SD* = .88) and cholesterol (*M* = 2.52, *SD* = .92), and the most familiarity with cancer (*M* = 3.64, *SD* = .81). Several students mentioned that bipolar disorder, diabetes, and asthma were confusing terms. As a result, NewKnowledge suggested that *Never heard of it* be added as an option to the module.

Empathy towards Robots

When thinking about robots, students indicated they felt limited empathy towards robots overall, with the lowest rated item being that *robots have the same rights as people (M* = 2.31, *SD* = 1.32) and highest ratings for *being scared of robots that look like people (M* = 3.00, *SD* = 1.39). Although inconclusive, moderate correlations showed that those who believed robots could be programmed for feelings were more likely to treat human-like robots as people and to think they might have rights in the future. Compared to girls, boys were more likely to rate humanoid robots as scary.

Norms for Health & Wellness

Results relating to health and wellness norms indicated that at least one student knew someone with one of the health conditions listed in the survey. Despite the small sample, we predicted that a larger sample would follow a similar pattern. We speculated that a student could be considered a trusted source on a particular health condition with their learning group if they have personal experience with that health issue. This familiarity, however, might elevate the risk for students' negative responses to programming, even beyond initial participation.

Responses to questions about self-efficacy with health showed that the item with the highest rating was *It is important for me to learn to stay healthy so I can provide quality care for my family* (*M* = 4.38, *SD* = .88), and the lowest rated item was *I am not concerned with healthy living (M* = 3.00, *SD* = 1.61). Strong correlations were exhibited between *I try to learn how to live a healthier life because it will help to extend my quality of life over a longer period* and the two items *It is important for me to learn about how to stay healthy so I can provide quality care for my loved ones* and *Being healthy allows me to enjoy social experiences with my family.* Despite the small sample size, the two rounds of the pilot and strong correlations between items suggested validity for exploration in the final survey.

Taxonomy of Healthy Behaviors

When considering a taxonomy of health behaviors, teens most highly rated *It is important to keep an active lifestyle* (*M* = 4.40, *SD* = .97) and *It is important to keep an athletic lifestyle* (*M* = 4.29, *SD* = .76). The lowest rated item was *I believe that global travel is a threat to my health (M* = 1.95, *SD* = 1.15). At the suggestion of MSI, three paired statements were explored to see if wording impacted responses. Based on lower skew numbers, *It is important to keep an athletic lifestyle* (skew = -.60) was recommended over *It is important to keep an active lifestyle* (skew = -1.96*).* The item *Living a life of moderation is the path to health and long life* (skew = -.61) was recommended over *Living a spiritual life of moderation is the path to health and long life* (1.51). Lastly, the statement *The lifestyle of the average American today can keep people fit* (skew .13) was recommended over *The lifestyles people keep today can keep people fit* (skew = 1.60). The recommended phrasing was adopted in later surveys.

Trust in Sources

When considering trust in information sources, data suggested that teens rely on parents *(M* = 4.43*, SD* = .87) and doctors *(M* = 4.19*, SD* = .87) the most for health-related information. Correlations between items indicated a few moderate relationships: those who trusted doctors also trusted nurses and medical information websites. Students who trusted parents also trusted other relatives who looked up things on the Internet. Those who trusted newspaper journalists also tended to trust television reporters. Finally, teens who trusted teachers also trusted parents and friends. However, it cannot be assumed there are common prototypes or referents when discussing health or risk behaviors with students, and that may prove challenging in group

discussions if some students view parents or teachers as reliable sources of information, and others do not.

Interview Results

Focusing on items related to health and wellness self-efficacy and a taxonomy of health behaviors (corresponding to survey Modules 4 and 5), we conducted both sets of interviews with students visiting MSI with their parents or teachers. Results indicated that teens see parents as the go-to source for health-related information *(n* = 30 students, *M* = 4.56, *SD* =. 57). The seven teens who gave their parents a high rating also reported that their parents were concerned with healthy eating and exercise. Celebrities were also mentioned by most teens as role models, but teens didn't necessarily emulate their healthy lifestyles. Rather, they relied on more local role models.

Observation Results

Independent observers did not identify visible signs of stress among students as they interacted with the iStan® simulator and measured iStan's various body functions during a simulated asthma attack. Similarly, they did not exhibit distress when MSI staff demonstrated how to suture a wound using a model followed by student practice of that procedure with yarn. The observations were inconclusive regarding potential stress reactions that might emerge if there were a more dramatic change in the iStan® simulator, such as suffering a visible health condition rather than the simple labored breathing replicating an asthma attack. We recommended that staff manage the views available to passersby from outside the MedLab program area if presenting more emotionally laden content.

DISCUSSION

The front-end evaluation offered evidence that the survey modules were reliable and comprehensible to the target audience, and offered relevant constructs for formative evaluation of MedLab program impacts. The strong results from the *Trust in Sources* module, in combination with interview data, highlighted the trusted role of parents and teachers for imparting health information to teens. The observations of students interacting with the iStan® simulator and the *Empathy towards Robots* module suggested implications for the role of simulation in learning outcomes.

Results from early pilot testing of human biology programs, including interactions with iStan®, showed that programming is unlikely to produce negative stressors for most students. Formative and summative studies further explored this phenomenon.

Formative Study: Testing the Curriculum

The Formative Phase of the evaluation aimed to use the instruments that were validated during the Front-End Phase to measure the impact of MedLab programs over time. To this end, NewKnowledge completed a pilot impact survey in spring 2015, and based on those initial findings, the impact survey was slightly revised. This revised survey was then administered in 2016 with middle and high school students who had participated in the MedLab programs on heart disease or diabetes in the previous year. The results of this study served as a comparative, retrospective, and current account of students' health-related attitudes, knowledge, and behavior.

METHODS

The study used a retrospective pre / delayed-post comparison survey to understand changes in students' opinions, knowledge, interests, and behaviors between before and after participating in the MedLab programming. We used a delayed retrospective method rather than surveying students immediately following the program in order to capture learning retention and to detect lasting negative symptom onset that might have arisen or lingered after the program. The retrospective pre / delayed-post design also enabled students to assess their pre- and post-responses at the same time, using the identical frame of reference (Howard 1980), which is an effective method for measuring program impact versus the traditional pre-survey at one point in time and post-survey at another.

The impact survey featured topics similar to those of the front-end baseline study and focused on four areas, with a slightly expanded exploration of interest in health careers. The topics included:

- Students' health and wellness self-efficacy;
- Students' health information sharing patterns with those in their (offline) social networks;
- Health science literacy;
- Awareness of health career options; and
- Awareness of medical technologies and technical careers.

Participants & Data Collection

In the spring 2015 study, NewKnowledge asked all teachers who had participated in the heart disease and / or diabetes curriculum at MedLab in spring or fall 2014 to distribute the retrospective pre / post survey to their students. A total of 19 seventh to ninth grade students from four classes completed the impact survey. Most (n = 12) self-identified as Black / African American, while five students identified as Hispanic / Latino, and one as White / Caucasian. Due to the low survey completion rate, these data were not considered representative of the total sample frame, and could not offer insight into whether students engaged family members who supported learning about STEM and research, more generally. It did suggest that engaged students with supportive family members willing to sign a consent form were likely to discuss the program with their family.

In the spring 2016 study, three of the nine teachers who had attended the heart disease and / or diabetes MedLab curriculum in that school year agreed to participate in the retrospective pre / post impact study. Only two teachers ultimately submitted data. In all, 41 students were represented in the survey data. Of the 40 students who indicated their grade, most of the students were seventh graders (n = 30) or twelfth graders (n = 9), with one tenth-grade student. Most of the students identified as Hispanic / Latino (n = 28) or Black / African American (n = 10), and one identified as White / Caucasian.

Modules

The survey instrument used for the formative surveys was divided into six modules, each focusing on a different topic and containing at least one measure. Each module consisted of five to nineteen items that students answered based on their recalled experiences before and after participating in MedLab. Most modules consisted of a five-point Likert scale from *strongly disagree* (1) to *strongly agree* (5). Module 2 was a familiarity scale using on a six-point Likert type range, including: *I never heard of it* (1), *I don't know anything* (2), *I*

know very little (3), *I have some knowledge* (4), *I know quite a lot* (5), and *I am an expert* (6).

Some modules in the formative study's survey were amended based on results from front-end baseline survey. Module 6 was a new addition, developed after the front-end study in order to focus on students' self-perception as social actors able to support family and community in their pursuit of health information.

The formative survey modules were:

Module 1: Opinions about robotic simulators and their use as teaching tools

NewKnowledge adapted these items from an original instrument developed in Peter Kahn's Human Interactions with Nature and Technological Systems Lab to study how robots impact the moral and emotional development of youth (Kahn, Gary, & Shen, 2012). For MedLab, the instrument focused solely on youth familiarity, understanding, and comfort with the engineering aspects of robotic tools. This approach inverted Kahn's work on the uncanny valley effect, where the appearance of human-like traits in a robotic entity may be off-putting to humans (Tinwell, 2014). We opted for this approach based on findings from the preliminary monitoring (Kong, Fraser, & Lo, 2014).

Module 2: Familiarity with specific health issues and general wellness

During initial project development, NewKnowledge identified eight potential health topics for MedLab programming. We retained these items throughout the project to facilitate comparisons between the front-end baseline survey and later phases of the project.

Module 3: Knowledge about MedLab topics

NewKnowledge developed a five-item Likert scale focused on measuring student understanding of biological systems and recollections of MedLab content delivery and interactive experiences. Items asked about body systems, how to maintain a healthy body, and comfort with using medical technologies.

Module 4: Opinions about healthy lifestyles

NewKnowledge drew this scale from a larger front-end study of self-efficacy related to active engagement in health and wellness practices in a museum exhibit setting (Fraser, 2011; Fraser & Gupta, 2013).

Module 5: Interest in health science careers

Original items for this scale were developed by Tyler-Wood, Knezek, & Christensen (2010) and explored how curriculum interventions created through National Science Foundation-funded research have direct impact on youth. The scale includes three subscales measuring: perceptions of a supportive environment for pursuing a science career, interest in future studies that help toward securing a career in science, and perceived importance of a science career.

Module 6: Tendency to share science knowledge with others

This new instrument was developed by modifying a pre-validated self-perception and self-efficacy scale (Gupta, Shane-Simpson, Rank, Hannah, & Fraser 2014) to focus on students' self-perceptions as social actors able to support family and community in their pursuit of health information.

Analysis

For data analysis, NewKnowledge assessed the differences between the *before-MedLab* and *after-MedLab* responses in each scale using paired sample t-tests. Significant differences were evaluated at the $p < .05$ level. For significant levels of $p < .10$ for any change, we noted trends towards significant differences.

The internal consistencies of each standardized measure were also calculated to identify scales that were not appropriately reliable measures ($\alpha > .70$; Nunnally & Berstein, 1994). When scales were identified as reliable, we calculated the average score across all items within a scale to generate an average aggregate value. Due to the nature of items in Module 2, we did not conduct reliability tests, and instead treated each item separately since each item covered familiarity with different health topics.

RESULTS

Opinions about Robotics

In 2015 students' opinions about robotic simulators and their use as teaching tools were more positive after their MedLab experience than before. However, due to the small sample size, we could not assess statistical significance. In the 2016 survey, however, this topic was significantly more positive after their MedLab experience than before ($t(32) = 2.62$, $p = .013$).

Familiarity with Health Issues & General Wellness

In the 2015 study, students' self-reported knowledge of cholesterol, asthma, blood pressure, cancer, bipolar disorder, and depression indicated an increase after the MedLab program based on the numerical values; however, this could not be assessed for statistical significance again for the small sample size ($n = 19$). The numerical values in before- and after-program knowledge of diabetes, heart disease, and general health and wellness did not suggest a change. In the 2016 survey, the change in knowledge significantly increased across all health topics after attending MedLab programming, except for knowledge of diabetes. Further research is needed to understand why knowledge of diabetes did not change over time. Possible explanations could be that students had prior knowledge of the topic from other sources, that MedLab had not covered new material for students, or that students may have lacked interest in diabetes because they didn't think it pertained to them or anyone they knew.

We also speculated that the prevalence of heart disease and diabetes health issues in the students' communities might have made the teens more familiar with these topics. We could only speculate that the MedLab program may not have gone deep enough into the topic to measurably advance knowledge for those who responded to the survey.

Knowledge of MedLab Topics

In 2015, students' self-reporting of knowledge of MedLab topics (e.g. biological systems, how to stay healthy) after MedLab indicated an increase, but could not be assessed for significance difference. However, the 2016 students self-reported more knowledge about MedLab topics after participating in MedLab than before ($t(34) = 3.05$, $p = .004$).

Healthy Living Behaviors

The 2015 study did not suggest change in students' feelings about living a healthy life before and after MedLab. In the 2016 study, we were able to verify that there was no significant change in students' feelings about how to live a healthy life after MedLab. It is likely students already had a strong understanding of healthy living habits.

Interest in Health Science Careers

In 2015, no difference was suggested in students' interest in health careers before and after the MedLab program. In 2016, students reported being significantly more interested in health science careers after they attended the MedLab program than before ($t(33) = 4.37$, $p < .001$).

Sharing of Science Knowledge

In both the 2015 and 2016 studies, student interest in sharing their health science knowledge was low overall for before and after MedLab (ranging from around 2.96 to 3.12). The 2016 data verified statistically that there were no significant changes after attending MedLab.

DISCUSSION

These formative impact studies suggest that the MedLab program achieved its goals in strengthening teenagers' understanding of and interest in community health-related issues common in the Chicago area and in health careers. The program built teens' understanding of and appreciation for robotic simulators as learning tools. The program also increased students' knowledge of a range of health issues common in their community, especially for the less familiar topics of cholesterol and bipolar disease. In addition, students self-reported greater literacy about human biology after their MedLab experience.

These formative studies, combined with the front-end study, indicated that teens generally had a strong initial understanding of and appreciation for a healthy lifestyle. As a potential consequence, the MedLab program appeared to have little impact towards advancing students' familiarity with

healthy living behaviors. Finally, the program built students' interest in health professions, but did not appear to affect their efficacy in sharing health information with others.

The positive results at the $p < .05$ significance level in the 2016 study compared with findings from 2015 may be a result of the larger sample sizes that could provide more reliability in the analysis. The lack of knowledge change in either year for diabetes was surprising given that this topic along with heart disease was most frequently identified as a focal topic covered by MedLab. We speculated that the program might not have explored these topics with enough depth for students attending the program, which resulted in an inability of the program to build on students' pre-existing knowledge. The subsequent summative survey instruments with matched samples of students attending or not attending MedLab were then meant to clarify and potentially validate these initial results.

Formative Study: Assessing Risk with Robotic Simulator

The MSI staff generally believed that students would report only positive effects from program participation with the robotic simulator. However, because of the potential for stress or negative reactions from students as they interacted with a human-like robot exhibiting health issues, and in compliance with NIH regulations, both the MSI IRB and the CPS Research Review Board's (RRB) Office of Accountability reviewed and approved the study's human subject protection protocols to ensure that appropriate safeguards were in place for participating students.

Dr. Kin Kong, clinical psychologist, and the rest of the external evaluation team worked with MSI staff to monitor student reactions and ensure human subject protection during each of the MedLab sessions. This monitoring assessed 1) MSI's compliance with the approved protocols; and 2) any instances of student negative or stress reactions. If there were indications a student might be experiencing stress related to the programming, the external evaluation team, MSI staff, and the teacher observed and monitored the student during the lab and intervened with the student if necessary. The teacher further observed the student after the program, and flagged the student for a follow-up interview.

NewKnowledge offered continuous feedback on the compliance and risk monitoring efforts (see References for list of reports). In these reports, we offered recommendations for program delivery staff to ensure risk conditions were minimized and monitored. This chapter summarizes the risk assessment results.

METHODS

The formative phenomenological monitoring study began in April 2014, following approval of the study protocols by MSI IRB in November 2013 and CPS RRB in January 2014. Overall, evaluators, the clinical psychologist, and her doctoral psychology students monitored 685 students attending MedLab programs. The protocols adhered to the NIH standards for monitoring human subject protection. The protective protocols were five-fold, as follows:

Parental Consent and Student Assent Forms

Prior to participation, parents and students were sent and asked to sign informed consent / assent forms, emphasizing that students had the right not to participate or to withdraw from participation in the MedLab program at any time without repercussions. A screening question also advised those students who had a history of personal or medical trauma to seek advice from their parents and teachers as to whether they should participate. We were unclear if that screening question was ever adopted. Teachers were also reminded that they needed to obtain signed forms from all students participating in MedLab while the program was in development.

Pre-Lab Review

At the beginning of each lab, MSI staff reminded students that they could opt out of participating in the experiential parts of the program at any time without repercussions. They explained to students about the range of emotions that they might expect when interacting with iStan® and encouraged them to share their experiences, positive or negative. They were told to let MSI staff or their teacher know if they had any moderate to strong negative reactions during their program participation.

During Lab Monitoring

The protocol called for MSI staff to check with any student who seemed reluctant to participate or who was exhibiting any other explicit (e.g., crying, fainting, verbal outbursts) or subtle (e.g., inappropriate or sudden change in behavior) negative reaction to see if they were okay. If the student appeared reluctant or showed signs of a negative reaction, their teacher was notified by Dr. Kong or MSI staff so the student could be monitored post-program for any persistent or delayed reaction. They were also tracked for delayed post follow-up interviews by Dr. Kong on behalf of the NewKnowledge team.

Post-iStan® Student Quick Survey

During each MedLab session, MSI staff administered a quick survey post-interaction with iStan® to assess students' emotional responses and stress reactions to the activities involving the stimulator. This survey included two questions:

1. At this moment, how stressful is the interaction with iStan® for you?
2. At this moment, how upsetting is the interaction with iStan® for you?

Students were asked to respond to these questions on a five-point Likert scale ranging from 1 = *not stressful / upsetting* to 5 = *extremely stressful / upsetting*. If students rated the experience as *very* or *extremely stressful / upsetting*, following protocol, trained staff from MSI spoke individually with these students to assess students' functioning and to see if the students need additional assessment or help. The students' names were also noted for follow-up interviews.

Delayed Post-Program Follow-Up Student Interviews

Several months after the MedLab experience, Dr. Kong and her clinical psychology doctoral students, conducted delayed-post interviews with a sample of students from each program type. This sample included: 1) students who were flagged for atypical responses in the experience monitoring protocol, such as anxiety, or those who gave elevated ratings on the real-time quick survey; and 2) a random sample of students who participated in the sessions but had not demonstrated an atypical or stressed response.

Including students in this second group for follow-up interviews helped protect the flagged students from stigma that could have been associated with participating in the follow-up monitoring. The interviews planned to ask these students about their experience and reactions to MedLab and simulator, with some questions assessing negative experience.

If students stated that they had a negative reaction, worries, feelings of discomfort, or unanswered questions and they were still experiencing any of these reactions, they would be administered the Revised Child Impact of Event Scale (*Perrin, Meiser-Stedman & Smith, 2005),* a trauma screening tool. If the total score on the Revised Child Impact of Event Scale (CIES-8) was 17 or higher, the student was then tagged and referred for mental health services.

RESULTS

Diabetes Curriculum

NewKnowledge staff and Dr. Kong and doctoral students under her supervision observed 194 students who attended MSI's MedLab diabetes program. Observations revealed no immediate, significant negative reactions. A few students indicated elevated responses on the quick survey, but observations and follow-up interviews revealed no lingering negative responses. One student chose not to participate in the interaction with the simulator. The delayed follow-up interview revealed that student was uncomfortable due to the novelty of the experience and she stated the lab ***was actually kinda nice***.

In April 2014, Dr. Kong and her students interviewed 15 students (five eighth graders and ten eleventh graders) who had attended MSI's MedLab diabetes programs in November 2013. Students unanimously found the experience positive. The only negative comments focused on time: four students felt they did not have adequate time and one felt the orientation was too long. Beyond initial trepidation and nervousness around interacting with the simulator that were quickly dispelled, students said they had no negative emotional responses. Rather, they felt the experience with iStan® heightened their learning and one claimed the experience inspired an interest in a possible career in medical technology.

Based on observations, student responses to the quick two-question survey, and follow up interviews, it was concluded that the diabetes curriculum, as implemented, posed little to no psychological risks to student participants.

Heart Disease Curriculum

In April / May and October 2015, NewKnowledge staff and Dr. Kong and her doctoral students observed 215 middle and high school students attending the heart disease MedLab program, who also completed the 2-item quick survey. Researchers conducted follow-up interviews with 27 students. Although no students exhibited observable negative reactions

to the curriculum, a small number of students reported on the quick response survey that they felt a mild level of discomfort.

Observations and follow-up interviews found these few negative reactions to be short-lived and related to either not doing as well on the lab exercise as they had wanted or a discomfort present prior to interacting with the simulator. Only three or four students were hesitant about approaching the simulator, but eventually did and did not report any stress associated with the simulator interaction. In the class in which the teacher had shared online MedLab resources with her students before the visit to MSI, students demonstrated familiarity with the material during the MedLab heart disease program.

In the fall 2015 program, MSI instructors also engaged the students in a discussion about what a patient could do to maintain their heart health. Students suggested actions such as *eat healthy, exercise, don't smoke, don't drink, avoid caffeine,* and *take medication.* These responses indicated students' awareness of healthy living behaviors, which corroborated the results of the front-end and formative survey studies.

Based on observations, results of the quick survey, and the follow-up interviews, we concluded that the heart disease curriculum, as designed and implemented, posed minimal to no psychological risk to the youth participants.

Asthma Curriculum

In February and March 2016, Dr. Kong or her doctoral students observed 276 middle and high school students attending the asthma program. As with the other health content curricula, most students did not exhibit hesitation or adverse reaction to interacting with the simulator. In fact they appeared to find the experience enjoyable.

Some participants, mostly middle school students, had relatively strong reactions when observing the simulator's human-like features, wheezing breathing and erratic pulse, and were particularly concerned when its pulse stopped and they thought iStan® had died. The instructor's explanation of the mechanical nature of the simulator calmed them and they recovered quickly and exhibited no further unusual responses. Researchers observed that younger students also tended to handle the simulator less respectfully than older students did. Several of the students recounted their own experiences with asthma. These reactions appeared to be typical non-stressful reactions and were not flagged for specific follow-up.

The several dozen students who indicated they were mildly affected by the interaction with the simulator on the quick survey showed no outward signs of negative impact by the experience. They exhibited normal range of affect, behavior and interactions. Of the few students who said they were moderately stressed or upset on the survey, most were younger students who reported to MSI staff or their teacher that they were fine upon check-in. One student who stated he was moderately upset and stressed was a wheelchair user. He told the instructor his own experience and memory of health issues had triggered his reaction, but that he did not need help. Following the quick survey, neither he nor the other students exhibited affects, behavior, or interactions outside the normal range relative to their earlier presentation. All students who indicated they were moderately stressed or upset were flagged for follow up and their teachers informed and agreed to monitor the student post lab for lingering negative reactions.

In spring 2016, under her supervision, Dr. Kong's doctoral students, conducted interviews with 44 students as a follow-up to their February or March MedLab sessions. The nine students who were tagged based on their unusual or atypical responses during MedLab were included in these interviews. Researchers were unable to conduct a follow-up interview with the wheelchair user despite several attempts. None of the interviewed students reported having a negative experience and the majority (86%) reflected that the MedLab asthma program was a positive experience, using phrases like ***fun***, ***good***, ***interesting***, ***enjoyable***, ***awesome***, ***it was perfect***, and ***learned things*** to describe it. Six middle school students noted that they had initial discomfort because the simulator was so life-like, but their discomfort disappeared as they began interacting more with iStan®. Two eighth-grade students said they were worried about the robot's health since their MedLab visit. No students were considered in need of taking the CIES-8 assessment.

Based on observations, the two-item quick survey results, and follow-up interviews, the vast majority of students had no negative reactions to the asthma curriculum. Of those who expressed a mild or moderate negative reaction, their reactions were not sustained. Thus, it was concluded that the asthma program posed little to no risk to the participants. Based on the results of this study, the observing psychologist recommended that younger students should be prepared for what to expect regarding the simulator's pulse and breathing. We also suggested teachers who know of students with a severe or traumatic medical history should consult their family before the visit to MSI.

DISCUSSION

Based on observations, the two-question survey, and follow up interviews, the monitoring phenomenological studies indicated the approved human subject protocols were in place and being followed. The heart disease, diabetes, and asthma curricula posed no significant nor sustained emotional risk to youth 13 years of age or older. Younger students and those with existing health issues tended to react more strongly to the problems with the simulator's vital signs and life-like features, but those reactions were short-lived. Most students, including those initially reluctant to participate, had positive, enjoyable experiences with iStan® and the new ultrasound equipment, and appreciated the hands-on opportunity.

Based on the risk assessment findings in the front-end and formative phases of the study, we concluded that the program may spark minor to moderate stress in a small proportion of students, but these feelings proved short-lived and did not threaten students' emotional health. Overall, the diabetes, heart disease, and asthma curricula, as presented to students, did not appear to pose a significant nor sustained risk to the students. Nevertheless, we recommended that the current protocols of observation monitoring, interviews, and impact assessments continue throughout the summative phase of the project. In addition, we felt that any initial reluctance students might have to interacting with iStan® could be minimized if students knew what to expect during their visit. To this end, we recommended that:

- MSI staff continue to encourage students to ask questions about iStan® to allay concerns or anxieties they might feel about interacting with a patient simulator; and
- Teachers, especially middle school teachers, review the curriculum with students prior to visiting MedLab, and alert them to some of the human-like symptoms (e.g. wheezing, labored breathing, weak pulse, dilated pupils) the simulator might exhibit.

Summative Evaluation

In the fifth and final year of the evaluation, NewKnowledge designed three separate studies to understand MedLab's contribution to a positive and productive learning experience around health and health topics of interest to teens living in the Chicago area. The first study was a comparative survey of students to assess health knowledge gain by students who participated in MedLab versus those who did not. The second study, compared MedLab and non-MedLab participating students' use of the online component of MedLab to understand the online component's utility as a long-distance learning tool in classrooms. The third study explored teachers' perspectives of their own experience and that of their students with the MedLab program.

OUTCOMES FOR MEDLAB & NON-MEDLAB STUDENTS

This study summarizes the impact of the MedLab program on participating middle and high school students in the Chicago area, as compared to a matched sample of students who visited MSI but did not attend the MedLab program. The value of the MedLab program to students was measured in four areas: 1) increased awareness and knowledge of community health issues (some mentioned in MedLab, others not) and healthy lifestyles; 2) increased interest in STEM careers and STEM topics; 3) potential changes in healthy behaviors, as measured by increased consumption of fruits and vegetables (a proxy for a healthy diet, Garriquet, 2009) and physical activity; and 4) psychosocial predictors of healthy behavior changes.

Methods

The aim was to compare a sample of 82 MedLab students for each lab to 82 non-MedLab students. Pulling from MSI's roster of schools and teachers, we asked 10 teachers / schools who participated in MedLab and 13 teachers / schools who visited the Museum but did not use MedLab programs to participate. These schools represented 287 and 332 students, respectively. Eleven teachers agreed to participate but ultimately only six were able to complete the study. Others agreed, but due to time or lack of parental consent forms were unable to participate. Ultimately, between March – May 2017, only 105 middle and high school students across six schools completed surveys for the summative evaluation. 60 of these students participated in the MedLab program during their visit to MSI, while the remaining 45 only visited the museum.

The survey instrument was divided into five sections: 1) perceived knowledge gains; 2) interest in subject matter; 3) perceived and measured behavioral change; 4) change in psychosocial predictors of behavior change; and 5) demographics. To be able to compare findings with those of previous years, some MedLab questions were the same as those used in the formative studies, and where possible we validated relevant items at that time. Previously validated measures with upper elementary and middle-school students were used for the healthy diets and healthy physical activity questions. For dietary intake measures, see Neuhouser, Lilley, Lund & Johnson (2009) and measures for changes in physical activity, see Thiagarajah et al. (2008).

Participants

Of the 105 students included in the survey, 60 had attended MedLab that day and 45 had not. Almost two-thirds of the MedLab students who reported their sex (n = 54) were female (n = 34) 19 were male and 1 student selected 'Other'. The average age of students who participated in MedLab was 15.7 years. 21 of the students were in eighth grade, 7 were in lower high school (ninth or tenth grade), and the remaining 26 respondents were in upper high school (eleventh or twelfth grade). The remaining 6 did not report their grade.

Half of the MedLab students reporting on their heritage (n = 54) reported being African American, and slightly less than half were White (n = 25). The small remainder were Hispanic (n = 4), one student was Middle Eastern and one was Pacific Islander. Six students selected multiple ethnicities.

Unfortunately, we were unable to capture the demographics for the students who did not attend MedLab due to a missing

page in the distributed survey. Additional survey responses were submitted but parental consent was not included and therefore the data from 62 non-MedLab students (over three-fourths from one school) could not be included.

Schools with MedLab students comprised one CPS site, one public school in a nearby town, and one community high school near Peoria. Of the classes, which visited MedLab, two participated in the heart disease program and one in the asthma. Schools with the non-MedLab students consisted of two CPS sites and one public school in a nearby town.

Analysis

Researchers analyzed demographic data using basic descriptive statistics (frequencies and means). They used content analysis to generate common themes for open-ended questions, and SPSS for statistical analysis of paired pre / post cases. Using the standardized Cronbach's alpha compared at the .70 level (Nunnally & Bernstein, 1994), all *before* and *after* module items were found to be reliable. Average totals were then calculated across all items within a scale to generate the average aggregate value. We conducted paired samples t-tests to assess differences in some responses on scales (or items) in the before condition and immediately after their MedLab experience or *before* and *after* non-MedLab museum visit experience. Data were assessed at the $p < .05$ significance level.

Results

Interest in Activities

Of the MedLab students reporting which session they attended during their visit, the majority attended the heart disease session *(n* = 32) or the asthma session (*n* = 19). Only two students in the study said that they had attended the diabetes session. All MedLab students were asked what they enjoyed most about their lab session from a list of items using three-point scale, with 1 = I enjoyed it, 2 = I didn't enjoy it, 2 = I don't remember it / we didn't to cover it. This list included, *taking vital signs, performing urine analysis test, learning to recognize / assist in a heart attack, wearing protective equipment, performing blood plasma tests, learning about healthy exercise, learning about healthy foods, learning to recognize /assist in an asthma attack, learning about asthma triggers, and learning to recognize/assist in a diabetes attack.* Across all of the MedLab sessions (*n* = 60), almost all of the students stated that they enjoyed taking the patient's vital signs (*n* = 54) and all enjoyed performing at least one of the other lab tests (*n* = 60). Fifteen said they did not like wearing the protective equipment.

We looked at various activities by session attended, and found students who attended the heart disease session (*n* = 32) stated they most enjoyed taking the vital signs and performing the lab tests compared to groups in the other sessions. These students also liked learning to recognize and assist someone experiencing a heart attack (*n* = 30). Responses to learning about healthy exercise and healthy foods were mixed, with more than half (*n* = 18) of the students in the heart disease session enjoying learning about exercise, and 12 of the students not remembering it being covered. In this group, 12 students enjoyed learning about healthy foods, while over half (*n* = 18) did not remembering the topic being covered. Students attending the heart disease session were more likely than students in other sessions to dislike wearing the protective equipment.

Of the asthma lab students (*n* = 19) almost all reported enjoying taking iStan®'s vital signs (*n* = 18), and learning about asthma triggers (*n* = 18). The same number (*n =18)* enjoyed learning how to recognize and what to do in the case of an asthma attack. Half of the asthma lab students did not remember doing urine analyses or blood plasma tests. Approximately two-thirds of these students also liked learning about healthy exercise, while one-third did not remember learning about it. These numbers were reversed when asked about healthy foods, with one-third stating they liked learning about them and two-thirds not remembering the healthy foods topic being covered.

There were only two usable survey responses for students who attended the diabetes sessions, so we are unable to generalize about their satisfaction and learning outcomes.

We asked the 45 non-MedLab students about the exhibits they visited. Thirteen students said they explored the Science Storms exhibit, 12 students saw the Numbers in Nature exhibit, and 10 reported going to the You! The Experience exhibit.

Perceived Knowledge Gains

Comparable to questions asked in the formative phase in 2015 and 2016, students were asked about their knowledge on a list of health-related subjects after their visit to the museum and/or MedLab program and to retrospectively reflect on their knowledge of these topics before their visit. Responses were based on a five-point Likert scale (1 = Never heard of it, 2 = I don't know anything, 3 = I have some knowledge, 4 = I know quite a lot, and 5 = I am an expert).

MedLab students showed a significant increase in their knowledge about *healthy lifestyles* after their engagement with the program as compared with before ($t(58) = -2.38$, $p = .02$). Non MedLab students also showed an equally significant increase in their knowledge about *healthy lifestyle* after the program as compared with before ($t(41) = -2.44$, $p = .02$). Only non-MedLab students self-reported having a significant gain in knowledge in other health topics after their museum visit, namely *depression, asthma,* and *blood pressure*. There were no other significant differences in knowledge gains in either group among the other topics. Students at the museum were least familiar with *depression*, *asthma*, *blood pressure*, *food deserts* and *cholesterol*.

MedLab students self-reported that they knew more about each of the health topics even before they attended MedLab than their non-MedLab counterparts reported. Similarly, MedLab students were more likely to self-report that they also knew more after participating in the program. MedLab students on average reported knowing most about *healthy lifestyles* both before ($M = 3.82$, $SD = 1.00$) and after their visit ($M = 4.00$, $SD = 0.95$). These students knew the least about *bipolar disorder* both before ($M = 3.57$, $SD = 0.95$) and after ($M = 3.54$, $SD = 0.88$) their session. Before their visit, Non-MedLab students reported knowing the most about *cancer* ($M = 3.44$, $SD = 0.91$) and least about *cholesterol* ($M = 3.00$, $SD = 0.93$) before their visit to MSI. After their visit they felt the most competent about *healthy lifestyles* ($M = 3.79$, $SD = 0.94$) and least competent about *bipolar disorder* ($M = 2.95$, $SD = 1.11$).

The finding that students who attended MedLab did not show any significant gains in knowledge after participating in the program, except for healthy lifestyles, contradicts the results of the 2016 study, and to a certain degree results from 2015 as well. Several potential explanations could be: students had good preparation in the health topics before coming to the MedLab session; or it may be that the MedLab program was too brief or did not go deep enough into the topics to instill a significant amount of new information. Irrespective of these findings, teachers interviewed for the project were pleased that the program focused on the scientific method since this was a priority in their teaching.

Using a five-point Likert scale (from 1 = Not at all to 5 = Very true), students were also asked to reflect on their beliefs about the impact of eating healthy foods and being physically active to improve their wellbeing. MedLab students on average had a greater understanding of the importance of eating healthily and exercise on their health than non-MedLab students did (Figure 1) ($t(42) = 4.519$, $p=.04$).

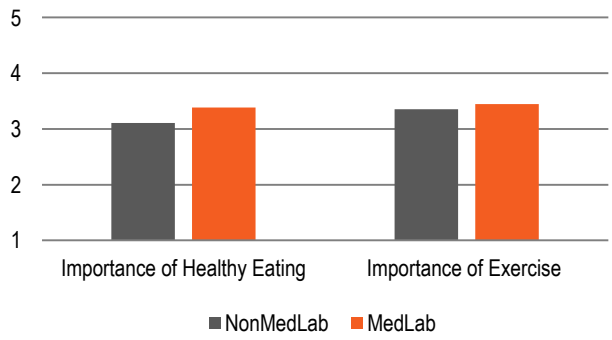

Figure 1. Importance of healthy eating and exercise on wellbeing.

Interest in STEM Topics & STEM Careers

All students were asked how interesting they found science and technology, and to what degree they would be interested in pursuing a career in the health care field. Responses were based on a five-point Likert scale from 1 = Boring to 5 = Very interesting, after being reverse coded. MedLab students seemed more likely to find science interesting and consider a career in healthcare than were non-MedLab students but these results were not statistically significant. Both MedLab and non-MedLab students were equally interested in technology (See Figure 2).

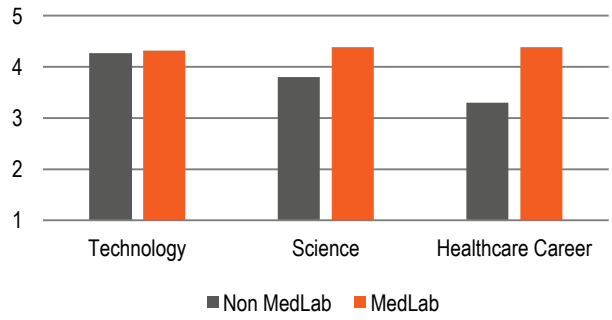

Figure 2. Interest in topics.

Behavioral Outcomes

Impact of Museum & MedLab on Health Considerations

Students were asked whether their visit to MedLab or MSI changed how they thought about their own health or their eating and exercise habits. Over half of the MedLab students reported that their visit influenced how they thought about their own health, whereas less than half of non-MedLab students thought it had an impact. On the other hand, slightly more than half of both visiting groups stated that their visit inspired them to eat better and exercise more, with MedLab students feeling slightly stronger about this than the non-MedLab group

Thirty-Two MedLab and 19 non-MedLab students thought their visit had an impact on how they thought about their health. Teens shared that the experience increased their awareness of how certain activities and decisions directly impact their health (14 MedLab and 5 non-MedLab students) and that they now know how to take better care of their bodies (10 MedLab and 3 non-MedLab students). Of the 32 MedLab students, 5 stated they would eat better, whereas ten of the non-MedLab students shared they would eat better and six shared they would exercise more frequently, a comment not heard from the MedLab students.

Healthy Lifestyle Choices

Students were asked to think about the level of importance that they personally place on living a healthy lifestyle, and how they see themselves making healthy decisions into the future. Students rated their level of agreement with each statement on a five-point Likert scale from 1 = Strongly disagree to 5 = Strongly agree, after reverse coding.

Students in both the MedLab and non-MedLab groups felt strongly about the importance healthy decisions play in their lives, and expressed a strong desire to incorporate healthy behaviors into their lives for the long-term. MedLab students rated all of these items higher than did non-MedLab students but these results were not statistically significant.

Fruit and Vegetable Intake

Students were asked about their intake of fruits and vegetables as a proxy to measure how conscious they are of their health, and how much they are reducing health risks through consuming a healthy diet. Students were asked to report the frequency eating of a variety of fruit and vegetable items per week. Responses were measured on a five-point scale (1 = 0 times, 2 = 1-2 times, 3 = 3-4 times, 4 = Every day, 5 = 2 or more times every day).

Students in both groups reported consuming a lot more fruit products and dark greens than other vegetables. Most commonly they ate these items between one and two times per week. While the consumption of these foods were nominally higher for MedLab students, the results were not statistically significant.

Career and Future Plans

Post-High School – We asked students about their current job status, plans for attending college, and other professional plans. The MedLab and non-MedLab groups were mostly similar in these categories. Currently, almost half of the MedLab students reported they are working, compared to less than one-fifth of the non-MedLab students. The high majority of both groups overwhelmingly envision attending college after high school. One third of both MedLab and non-MedLab students shared they may have to work full-time, and approximately one-fifth of each of these groups expressed plans to raise a family.

Both groups of students responded similarly on a five-point scale with 1= strongly disagree and 5 = strongly agree, about the importance of getting a good job after high school. Both

MedLab (*M* = 3.60, *SD* = 0.78) and non MedLab (*M* = 3.54, *SD* = 0.78) groups thought it was moderately important.

Legacy – Most students come from families that have attended college: 48 of MedLab students came from families that have attended college; 30 of the non-MedLab students had college-attending family members. Three of MedLab students will be the first one in their family to graduate high school, while the same is true for 4 of the non-MedLab students.

Professions – As noted earlier when reporting about behaviors, students who attended the MedLab program (*n* = 60) learned more about health-related careers and expressed interest in these positions than students who just went to MSI. Almost half recalled hearing most about the profession of lab technician and nurse (45%), while about a third remembered learning about ultrasound technician and nurse practitioner. These students were most interested in careers in traditional fields: nurse *(n* = 37*),* doctor *(n* = 23*),* or nurse practitioner *(n* = 22*).* About one in five MedLab students also expressed an interest in careers as a physician's assistant, lab technician, medical secretary, physical therapist, or forensic scientist. Those who selected *other* also included an interest in learning more about pediatricians, anesthesiologists, and surgeons. Non-MedLab students remember hearing most about the professions of doctor (*n* = 17) and lab technician *(n* = 10*)* during their visits. We do not have data on non-MedLab students' career interests due to that page of the survey not being included during distribution.

Summary

As we found in the Formative Evaluation, MedLab students felt strongly about the importance of living healthily and incorporating healthy behaviors into their lives for the long-term. While non-MedLab students also had strong feelings about living a healthy life, and both groups noted significant changes in their knowledge after their MSI experiences of what it means to live healthy lives, MedLab students' responses were consistently higher than non-MedLab students.

While both MedLab and non-MedLab groups expressed an interest in technology subjects, MedLab students expressed more interest in STEM and healthcare subjects, and were more likely to consider a career in healthcare. Careers MedLab students mentioned most were being a nurse, doctor, or nurse's assistant. We speculate that the high interest in nursing professions may have been skewed by gender due to the MedLab group being more heavily attended by females 2:1. However, many of the group members also expressed interest in other careers such as physician's assistant, lab technician, medical secretary, physical therapist, or forensic scientist.

The influence of the MedLab program was less obvious when we evaluated students' knowledge gain in health topics. MedLab students came to the program with more knowledge around community health issues than students who did not attend the MedLab program. However, these students did not show any statistical change in their knowledge after their experience, a finding that differs from the results of the Formative Phase studies. It is possible that teachers who chose MedLab for a fieldtrip were already teaching the topic in the classroom, and thus students had a solid basis for their experience. It is also possible that the sample size was too small, both in numbers and types of schools included to reveal small incremental gains. In the Formative Phase surveys, students all came from the Chicago Public Schools, but in the Summative Phase survey the mix of school types may have skewed the data.

Of course, other explanations for the lack of change in MedLab students' knowledge categories could be considered. The program itself, because of time constraints, focused more on engaging students' in exciting hands-on activities, rather than on in-depth discussions of health topics. Another explanation is that the time lapse between students attending MedLab and taking the Summative Phase survey was too long for people their age and hence did not allow students to accurately assess what they knew and when. As a note, the time lapse in the Summative Phase survey was longer than the lapse in the Formative Phase surveys.

THE ONLINE MEDLAB COMPONENT

The Summative Evaluation of the online MedLab component sought to assess the program's utility as a distance-learning tool by students. Designed to be used on tablets, MSI plans

for the MedLab Online program to be available online in 2017.

For the online MedLab product, MSI designed three scenarios around lead poisoning, viral meningitis and tuberculosis, with each lesson guiding students through an inquiry-based process of diagnosing a patient. Each lesson began with an introductory video of a doctor and patient, discussing the symptoms that caused the patient to visit the doctor. From there, students (in pairs or alone) could record symptoms relating to the patient's chart, virtually take the patient's vital signs, engage in relevant diagnostic tests, and use a list of diseases with those symptoms to diagnose the patient's illness and select a treatment plan. Teachers controlled the content and timing via a dashboard.

Methods

The initial methodology called for 10 classroom visits (five classes which had visited MedLab in person and five MedLab online only students). During classroom visits, researchers were to observe students using the online platform and conduct "Think Aloud" sessions with students regarding their learning that day and pervious learning using the platform. The purpose of the visits was to understand online product utility and see if it differed between classes that had attended a physical MedLab and those which had not.

Because of the delayed launch of the online programming to May 2017, there were no schools that had previous experience with the online program before our scheduled observations. Therefore, NewKnowledge revised the evaluation methodology.

Two researchers visited each classroom to observe the 50-116 minute MedLab sessions. At the beginning of each visit, the lead researcher told the class the reason for the visit, and obtained written consent from parents and written assent from students to participate. He or she then explained the evaluation process of observation and subsequent class discussion about their engagement with the online scenario.

Participants

Unfortunately, MSI's attempts at recruitment resulted in only six classroom teachers agreeing to participate, with one dropping out the day before the scheduled observation visit. In all, five classrooms (*N* = 109 students*)* were included in the study of the online MedLab product: two classrooms had previously participated in onsite MedLab programming at MSI, two had not, and one that had some students who had participated in MedLab programs and some who had not.

Three of the classrooms were in CPS schools and two were in suburban schools outside of the CPS system. Two of the classrooms were also designated as medical pullout classes with a focus on nursing and medical skills. 34 students were boys and 75 were female.

Results

Due to technical issues, the platform only worked as intended in one classroom. Two classes had non-teacher guided access to the platform and two classes had more challenging technical limitations causing them to only see parts of the lesson and not complete it. Based on these complications and reduced sample of students engaged in the online MedLab component, comparisons of MedLab versus non-MedLab students was not feasible. However, we were able to make some observations:

- Students found the platform absorbing and capturing of their full attention;
- Students repeated tests when the outcomes reached were not the ones desired;
- Students read the directions and Help section to learn how to navigate the program, rather than simply using trial and error to learn the program;
- Students worked collaboratively by figuring out tests together;
- Students processed information aloud, speculating on how far to insert a needle, wondering why the patient was moving, and making a diagnosis based on one set of symptoms and being curious about the other symptoms that were not a fit for the chosen diagnosis.

Classroom discussions revealed that students had learned several key health science concepts. These included:

- Identification of various diseases, based on symptoms, and their treatment plans;

- Knowing the differences between negative and positive tests; and
- Having an understanding that different diseases can have similar symptoms.

When asked about their iPad experience, students most often compared it to real life and noted the difference. One said, ***It would have taken longer in real life to perform the tests.*** Other students pointed out that since some of the tests, such as a spinal tap, were painful or expensive, they may not have initially used them if other diagnostic tests clearly indicated the diagnosis. Recognizing the difference, students were enthusiastic about the platform as a learning tool as they identified the experience and tests were not something they could replicate either with a dummy or in real life.

Students were asked to compare learning opportunities on the online platform with the MedLab iStan® simulator or a hypothetical generalized idea of a dummy. Students were able to clearly articulate the advantages of one over the other.

- The simulator felt / hypothetically felt more realistic to students, allowing for a true visual and tactile experience;
- The iPad allowed students to perform experiments on their own and engage in many different scenarios, see internal organs, make and correct mistakes, manipulate the patient into different positions, and get a sense of many more diagnostic tests that can be performed in order to determine a diagnosis.
- The major criticism of the platform, beyond functionality issues, was that it was ***too programmed***, giving them answers and providing some test results when they would have liked to have perform all the tests and figure out the diagnosis on their own, without the correct answer being so obvious. In essence, they wanted more complexity, and to experiment and feel challenged.

Summary

Because of the small number of classrooms that could fully utilize the platform, the results of the platform utility are neither generalizable, nor can comparisons be made between those students who had attended a physical MedLab and those who had not. Moreover, since the students were seeing the platform for the first time, the study of the online MedLab product was more formative than summative in nature.

Students were enthusiastic about the platform, and were actively learning about health issues, their causes, symptoms, and treatments. The inquiry-based scientific process held their attention, allowing them the opportunity to experiment, repeatedly if necessary, in order to arrive at the correct diagnosis. The online platform also provided them with additional information, such as details about internal organs and various other tests, which the iStan® simulator was not equipped to handle. They wished the online MedLab product could have been more open-ended and less obvious in its solution so they could figure out the diagnosis on their own.

The technological aspects of using the online platform, especially in schools with firewalls and other security measures could restrict use. We support MSI's plans to continue testing and evaluating the platform after the conclusion of this NIH-funded study.

RETURNING TEACHER PERSPECTIVES

The final component of the Summative Evaluation was an interview study with teachers who had one or multiple experiences with MedLab programs. The goal of this study was to assess how educators leverage the MedLab offerings and their aspirations for future use of MedLab.

Methods

NewKnowledge conducted three 60-minute online group interviews with seven teachers who had brought their classes to MedLab sessions at MSI. In compliance with the CPS RRB guidelines, these interviews took place during after-school hours. One NewKnowledge interviewer conducted all the interviews, using a semi-structured interview protocol, and coded the discussions according to recurring themes.

The semi-structured protocol was divided into three sections:

- Section 1 asked participants to comment on different ways that teachers have engaged with the MedLab program and the aspects of MedLab they value the most for their students;

- Section 2 asked teachers to comment on the benefits and challenges of the MedLab program; and
- Section 3 asked participants to comment on their long-term use of the MedLab.

Participants

This study intended to engage 18 teachers in 3 group interviews of 6 teachers each, who had repeatedly used onsite MedLab programs with their classes. Using MSI's multi-visit teacher listserv, MSI emailed 66 teachers asking if they would participate in the study. Of these, 12 teachers (18%) completed the survey indicating their interest in participating. Ultimately, only five of those teachers ended up participating in the group interviews.

Because of the low number of participating multi-visit teachers, MSI and NewKnowledge agreed to supplement the group with teachers who had attended the MedLab program only once with their students. Of the nine teachers in this category, two agreed to participate in the online group interviews, bringing the total number of study participants to seven teachers.

Prior to participating in the group interviews, the seven teachers filled out a short demographic survey. The results indicated that three teachers were male and four female, with teaching experiences ranging from 4 to 25 years. The teachers taught either middle school or high school students in various science fields, including chemistry, anatomy, biology, medical sciences, and physiology. One teacher taught in a school with a health sciences career track. Three teachers identified as Black / African American, two as White / Caucasian, one as Arabic, and one as mixed ethnicity (Black / African American and Native American / Pacific Islander). Two teachers and their students reported attending one MedLab session, three reported attending three to five sessions, and the other two teachers reported being involved in eight or more MedLab sessions.

Results

The Value of MedLab

The main benefit of MedLab cited by all seven teachers was MedLab's power to link classroom learning with the real world. MedLab provided students with hands-on opportunities to explore health topics that are relevant to their lives, such as diabetes and asthma. They felt MedLab also provided a setting that gave students insights into various career opportunities in the STEM fields and an understanding of lab work. Related to that was the problem-solving, scientific inquiry aspect of the program, which they credited by enabling students to use evidence to think critically. Another benefit noted was the importance of MSI's resources to students, especially students from low-resourced schools. Teachers saw the iStan® simulator and ultrasound technology as unique and essential to student learning outcomes.

About half of the teachers (n = 4) had hoped their students would come away from the MedLab experience with a better understanding of career options in the sciences. One teacher hoped students would have a more deeply changed mentality towards healthy habits, although some other teachers felt a health outcome was secondary.

If MSI could make changes, various teachers suggested MedLab should develop take-home scenarios (case studies) as a follow-up exploratory exercise.

Benefits & Challenges of MedLab Programming

Teachers cited that they pursued MedLab programming for its hands-on activities, especially with the iStan® simulator and pre- and post-MedLab resources. Two teachers, in contrast, said they chose MedLab based on fit with their school schedule and did not use the resources.

Despite grant funds for transportation, some teachers still found the cost of the program an issue. Sometimes scheduling was also an issue. A solution, at least from some of their perspectives, would be for MedLab to come to the school instead, although they expressed hope that an online MedLab product might be an alternative. Two other teachers wanted to expand their students' learning with scenarios to take home and / or by doing more with the simulator. Some teachers expressed a great desire for an online version of the program so that more students in their school could have access to the program as cost and out of school time were constraining factors for attendance.

Long-Term Use of MedLab

The responses to these set of questions echoed what we heard in the previous sections. Teachers said they made repeat visits to MedLab because it offered more than they could provide in the classroom, i.e., hands-on experience that was relevant to the students' lives and integrated with their classroom curricula. Others also said the students' enthusiasm for the program rejuvenated their students and themselves.

When asked what additional support they would like to see from MSI or MedLab, the responses mostly focused on follow-up / take-home case studies from which the students' can continue to learn and an online element for both students attending as well as a more general student population.

Summary

Teachers unanimously viewed the MedLab hands-on experience as important and irreplaceable. It exposed students with real-life science application and familiarity with career options that they cannot offer in the classroom. The particular health content knowledge was important but deemed of secondary value. Teachers believed, however, that students would use the knowledge gained and share it with others. They also felt it would stay with their students for long-term learning outcomes related to health practices and health science career opportunities.

All of the teachers praised the MedLab program and expressed an interest in either more or new MedLabs, including more extension programming to enrich their students' learning experiences.

Conclusion

The MedLab program provided a valuable and enjoyable hands-on experience to middle and high school students. It enabled them to practice an inquiry-based approach to learning about health topics that affect students and their families. Although students self-reported only moderate knowledge gain about community health issues from MedLab overall, within each program students felt they had learned to recognize the symptoms of a heart attack or asthma attack and how to help the person.

They also thought, and teachers agreed, that the program exposed them to new career options to explore in the healthcare field, and peaked their interest in technology and science topics. Most importantly, the program afforded students a greater understanding and value of leading a healthy life, and that how they eat and exercise now will impact their health in the future. Across the board, students expressed a desire to change to more healthful habits.

Discussion: What We Learned from 5 Years of MedLab

SIMLAB set out to create school teams, consisting of a science teacher and a health educator from schools in disadvantaged neighborhoods, to work with Museum of Science and Industry (MSI) education personnel to develop customized applications, primarily for ninth grade students, using a patient simulator. Through this initiative, MSI sought to create innovation by applying patient simulation technology for what was believed to be the first time in a museum education program setting. SIMLAB further aimed to support the NIH's goal of encouraging the development of future scientists by disseminating the program through the greater Chicago Public School system via an interactive online experience based on the in-person learning lab structure as outlined in Table 1.

At the conclusion of the project, the majority of the aims outlined in the funding proposal were met for the in-person program. Due to a variety of converging challenges, the online learning opportunity took a great deal more effort to complete, and could not be assessed for impacts on the intended audience. Irrespective of the delivery technique, however, it appears that the learning program more then met the intended learning goals and reached more students than originally anticipated.

CURRICULUM

The results of both formative and summative curriculum assessments conducted during live programming at a science museum resulted in positive outcomes across the range of

Table 1. Proposed Program Impacts and Indicators

Category	Impact	Indicator
Knowledge	Understanding of, and interest in, a range of health and science careers that impact community and individual health	**Students:** • Ability to identify a range of health and science careers, and their major areas of activity. • Expressed increased levels of interest in health and science careers. • Increase understanding of medicine, physiology and anatomy.
	Increase understanding of medicine, physiology and anatomy.	**Students & Teachers:** • Increased understanding of medical, physiological and anatomical conditions of a specified community health.
	Increase understanding of how personal choices impact community health issues.	**Students:** • Identified a personal health decision and accurately described its relationship to a specified community health.
Attitude	Feel empowered to take initiative in their personal, family and / or community health.	**Students:** • Reported high levels of confidence in ability to create positive change towards personal health. • Reported intention to create positive change towards personal health.
Behavior	Increase participation in activities that contribute to the betterment of a community health issue.	**Students:** **1.** Self-reported positive changes made towards a healthier lifestyle. **2.** Increased interest in science and medicine related career paths. **3.** Increased selection of classes / areas of study related to science and medicine. **Teachers:** **4.** Increased integration of health curriculum into classroom teaching practice

indicators initially imagined for the program. These results accrued for students whether they were in middle school (younger than originally anticipated in the original grant proposal) and for those in their senior year of high school (older than originally anticipated in the original grant proposal). In all cases, interaction with the patient simulator, iStan®, and in later years with an ultrasound training torso helped them understand the lived experience measuring vital signs and the professional use of diagnostic tools to determine a simulated patient's illness.

Results demonstrate that program outcomes were achieved with students' knowledge outcomes increasing across all three areas of assessment. Furthermore, their medical knowledge about health issues in their community demonstrated attitudinal outcomes that suggest they would be willing to take initiative if the opportunity arose.

The evaluation also assessed the initial version of an online medical science learning product that simulates the process of working with a patient. That platform shows promise for helping youth understand the role of medical diagnosis. It also suggests that using the interactive platform helps them imagine themselves in medical careers.

The proposal goals outlined in Table 1 suggested that the live programs and online platform would all contribute to teacher outcomes, both for their own knowledge and also in support of their in-class use of MSI assets to advance medical science learning opportunities. Of the three medical subject curricula developed for lab experiences at MSI, all three successfully helped teens build their understanding of the medical topic, imagine themselves in medical careers, and explore medical technologies that were novel in their experience. The programs also significantly contributed to attitudes toward healthy lifestyle choices. We note that MSI staff claim that the MedLab program is very popular and was the second-most requested program by schools.

Unfortunately, both the Chicago Public School's RRB policies that limited use of tools during class time and the teachers' prescribed curriculum seemed to limit engagement during preparation for the live experience and follow-up activities. Due to the limited nature of teacher response, our evaluation data cannot confirm any teacher outcomes originally planned.

We note the live-experience proved to be very popular with teachers and was considered a highly motivating experience for their students. A number of teachers signed up for more than one experience and were likely to return each year pending funding restrictions. The program appears to be stable and well-received.

REACH & REPLICABILITY

The results suggest that MSI could share the curricula with other museums and that the learning outcomes could be replicated in other sites if they had access to similar equipment. We note that adaptation, if the equipment is not available, could be tested on more limited patient simulator interactive equipment and may produce similar results.

We were unable to study generalizable results regarding the utility of the online product due to a late launch in May 2017 and technical difficulties in the classrooms where the launch was being staged for the evaluation. In spite of the limited data, preliminary results suggested the online product could support curiosity and interest in STEM learning and health sciences, and possibly students' self-guided inquiry.

Conclusions

MSI's investment from the National Institutes of Health Science Education Partnership Award (NIH SEPA, Award # R25 RR026013-01A1) developed MedLab, live museum programs and online products to support Chicago-area middle and high school students, especially those from low-resourced areas.

The evaluation achieved the anticipated outcomes for increases in students' knowledge, attitudes, and behaviors around community health issues and general healthy living principles. Specifically, the program **increased students' knowledge of community health issues and how health sciences address those challenges**. The program did not contain modeling for how a student might share this information, which may be an area for program development in the future. The online MedLab Online program appeared to support knowledge gain about the health sciences.

The program **increased students' awareness of and interest in medical careers** related to the specific medical science topics and the technologies involved in diagnosis. Several months after the programs, students still showed interest in health science professions, particularly nursing and physician roles, and could remember many of the less traditional roles, such as lab or ultrasound technicians.

As designed, the MedLab programs **created a supportive environment for considering healthy behaviors**. It appeared that students' willingness to pursue healthy behaviors may be one the strongest lasting effects of the program.

Student outcomes were achieved as anticipated in the original grant proposal and the live in-person program was more popular than expected. Due to low response from teachers, we could not conclude if any changes in teaching strategies or understanding were achieved.

Risks with Robotic Simulator Programs

Monitoring of 685 students attending three in-person programs at MSI showed the program and its curriculum posed little to no risk to middle and high school students. Middle school students were more likely than high school students to have minor stress reactions when working with the stimulator, but these reactions were short-lived and manageable.

Replication and Dissemination

The in-person programs appear appealing and show promise that others could replicate the models and curricula developed by MSI.

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