Association of Environmental Engineering and Science Professors Foundation (AEESP) Foundation Grant Final Report

Microbiome of the Built Environment

Be-MICROBIOME

South Dakota School of Mines and Technology
501 E. Saint Joseph St., Rapid City,
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Project Summary

The project aim was to provide scientific knowledge and training for the K-12 students, specifically to help them study and understand the importance of microbiome of the built indoor environment (***Be-Microbiome***). The training included lectures, hands-on training, and sample collection from indoor environment including school buildings and deep subsurface environment of the Sanford Underground Research Facility (SURF). Training materials included lecture notes and information sheets. They focused on key air quality parameters including temperature, humidity, gases and microbial community (mainly bacterial population), all in responses to changes in the ambient conditions of built environments. We trained nearly ~200 students from Spearfish, South Dakota, USA. Hands on training was provided for students to measure the indoor air quality including microbial diversity analysis. We have developed questionnaires to gauge their level of their understanding before and after the training. We have used an assessment metrics that was previously developed by the SD EPSCoR office for ongoing projects funded by National Science Foundation. The study outcome was promising, and the feedback from students and teachers were used to improve the lecture contents and training activities for future outreach programs. Using this pre-pilot project outcomes and accomplishments, we are preparing an NSF-SD EPSCoR SEED funding application to expand this outreach activity for other schools within South Dakota region.

Project Team

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Project Location

South Dakota is the seventeenth largest by area, but the 5^{th} least populous in the United States For more information: https://www.sd.gov/cs

South Dakota Mines (Formerly known as South Dakota School of Mines and Technology): The South Dakota Mines (SD Mines or SDSM&T) is a public university in Rapid City, South Dakota. It is governed by the South Dakota Board of Regents and was founded in 1885. The campus is in the center of Rapid City, on the northern slope of small foothills of the Black Hills. South Dakota Mines offers degrees in 20 engineering and science fields, as well as 18 master's degree programs and 9 Doctorate programs. For more information, see https://www.sdsmt.edu/

AEESP Education Outreach Activity: The team visited two different schools from Spearfish, which are 50 minutes away from Rapid City, namely; (a) Spearfish Creekside Upper Elementary School; and (b) Spearfish High School. Spearfish is in the Northern Black Hills. It represents one of the most broad-based economies in western South Dakota. With roots in education, health care, tourism, mining and timber, the economy has grown and diversified substantially. Spearfish School district's mission statement, "Empowering All Students to Succeed in a Changing World," is a goal. The Spearfish School District provides quality programs for all ranges of academic learners. The Spearfish School District is a positive, productive learning institution with a history of high expectations and student success. The staffs are experienced, talented, and dedicated to the success of our students. The school system and community place a high value on the education of our youth, and that expectation serves as a catalyst for student success in a rigorous learning environment. For more information, see https://www.spearfish.k12.sd.us/

Supporting Staffs/Team members

1. Dr. Srivatasan, Jayaraman Sridharan – Research Scientist, Mining Engineering and Management, South Dakota Mines, Rapid City, SD, USA
2. Mrs. Elizabeth McGee – Founder & Senior Consultant, LEAP Consulting Services, Sioux Fall, SD, USA
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4. Grace O'Connor, Biology Teacher, Creekside Elementary School, Spearfish, SD, USA
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1.0 Project Background:

1.1. Overview: Built Environments are man-made or modified landscapes that enclose human activity, including living, working, and recreational (***Be-Microbiome***). It can be indoor or outdoor within the urban/industrial area. These built environments influence the person's mental and physical health (Perdue et al., 2003). With the COVID-19 spread, the importance of both in-door and out-door air quality was significantly discussed at all levels (Reshetnikov et al., 2021). As of today, 6 out of 10 people who live and work in built environments are likely exposed to a diverse set of microorganisms that pose potential health risks (Gianfredi et al., 2021). Several studies reported the importance of *Be-Microbiome* structures and methods to study their differences (Adams et al., 2015; Peccia et al., 2016; Parkpour et al., 2016). The fact is that the *Be-Microbiome* is influenced by the air circulation/ventilation, humidity, temperature, and other interacting surfaces/exposed materials. Therefore, it is essential to study and compare the *Be-Microbiome* from different built environments to develop a strategy and regulate individual exposures. In this outreach activity, our aim was to seed the basic knowledge about *Be-Microbiome* i.e., mainly the indoor microbiome of built environment, its importance, and methods to study among the K-12 students. Our study partners include Mr., Stephen Gabriel from Spearfish High School (SHS), Mrs., Grace O' Corner from Creekside Elementary School (CES), and Mr., Johnson W Andrew from Belle Fourche Middle School (BFM), South Dakota, USA.

1.2. Project Goal: Our goal was to provide basic knowledge and hands-on training for the K-12 students to know about the *Be-Microbiome* and its importance on physical and mental health. Specifically, the students gained the knowledge needed to address the following: (i) what is indoor air quality? (ii) how does that influence mental and physical health? (iii) how can one map the indoor environment air quality? (iv) how the indoor air quality fluctuates with outdoor influences? and (v) what is the role of the microbiome and why it is important?

1.3. Study Approach: The outreach activity included (Figure 1);

Activity 1: Provide the basic knowledge of the *Be-Microbiome* and its importance

Activity 2: Hands-on training to study the *Be-Microbiome*

Activity 3: Demonstrate the differences between *Be-Microbiome* from different built environment

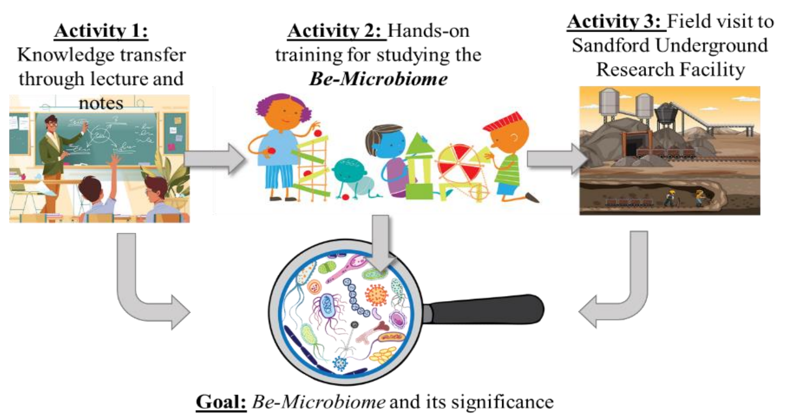

Fig 1. *Study approach for the outreach and training activities for the student participants*

2.0 Project Outcome and Accomplishments:

<u>2.1. School visits</u>: The integrated training approach was proposed by the schools; therefore, the training was given for both the SHS students and CES on April 25, 2022 at CES. The team from SD Mines visited the CES and completed the Activities 1 and 2, i.e., lecture and hands-on training and sample collection from indoor environment (Figure 2). Two different set of questionnaires were used to collect the information's from the students to gauge their level of understanding and interest with the *Be-Microbiome* topic post-training (see section 2.2). The team re-visited the SHS on May 5, 2022 and CES on May 10, 2022 to complete the proposed activity 3 i.e., data presentation and demonstration of *Be-Microbiome* differences from different environment. After the final visits, the feedback forms were shared with the SHS students and CES teachers.

Fig 2. Providing a lecture and hands-on training to the students during the first school visit

<u>2.2. Number of students/teachers attended the outreach activity</u>: There were 9 high-school students (mainly 9-10th graders) and 1 teacher from SHS and 200 elementary school students (mainly 5th graders) and 6 teachers from CES were trained. As shown in Figure 3, there were 49-67% of male and 33% of female students were trained during this outreach activity (based on the data provided). From CES, only 20% of students were willing to provide their personal information i.e., age, name, and grades, otherwise the ratio might look different.

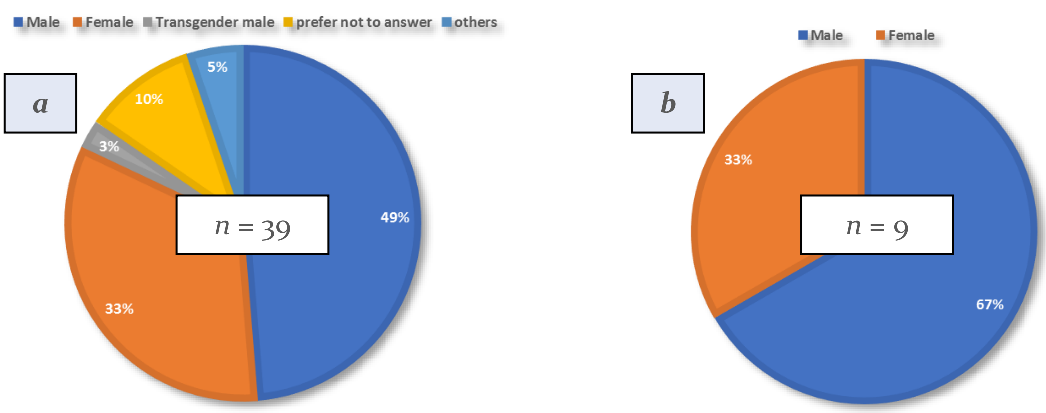

***Fig 3.** Gender distribution of participants*

***2.3. Training Questionnaire*:** We have used a training questionnaire for high-school students (https://survey.alchemer.com/s3/6834120/2022-IAQ-High-School-Survey) and Elementary (https://survey.alchemer.com/s3/6842375/2022-IAQ-Elementary-School-Survey) students after completing the activities 1 and 2. We have used two different questionnaires, since to meet their standard and level of understanding to respond to the questions. The high-school students were provided with more detailed questionnaire with a total of 16 questions (Q1-Q16; Table 1). For elementary school students, we included only 6 questions (EQ1-EQ6; Table 2). We adapted a pre-existing platform (i.e., Alchemer) that was previously developed by the SD EPSCoR office and study approach to administer the questionnaire and data processing. The high-school students were asked to report on scale of 1-10 (don't aware to aware), their responses to several statements about indoor air quality before and after training. All 9 students were returned the survey during our visit that was 100% success rate. The Elementary school students were asked to choose the best answer. Out of 200 students, only 82 students responded to the online survey questionnaire and that was 41% success rate.

Table 1. *Set of questions used to measure the knowledge transfer in high-school students*

Question #	Questions
Q1	How much do you know about IAQ?
Q2	What is IAQ mean to you and what level you think its important?
Q3	Do you know there is US-EPA regulation for IAQ?
Q4	Do you know there are biological pollutants (i.e., bacteria, virus, etc), other than particulates and chemical components in indoor air?
Q5	Do you know IAQ humidity level of 30-50% is recommended for homes to control or minimize the biological pollutants (e.g., mold formation)?
Q6	Do you know the biological pollutants affect your mental/physical health?
Q7	Do you know minimum ventilation requirement is set as 0.35 air changes per hour, but not less than 15 cfm per person for IAQ to reduce health risk?
Q8	Do you know indoor plants improve the IAQ?
Q9	Do you know pets affect the indoor biological pollutant levels?
Q10	Do you know the carpets and other unwashed mats affect the biological pollutant levels in IAQ?
Q11	Do you know there are air cleaners available for improving the IAQ?
Q12	Do you know air-fresheners change the IAQ?
Q13	Do you know cooking, smoking or grilling indoor will change the air quality?
Q14	Do you know fresh paintings and floor waxing alter the IAQ?
Q15	Do you know HEPA filters remove 99.97% of indoor pollutants?
Q16	Do you know OSHA can help to test your IAQ?

Table 2. *Set of questions used to measure the knowledge transfer in Elementary school students*

Question #	Questions
EQ1	Do you know the air that we breathe contains bacteria and viruses?
EQ2	Do you know ventilation is important to reduce bacteria and viruses from indoor air?
EQ3	Do you know indoor plants improve the indoor air quality?
EQ4	Do you know pets affect the indoor air quality?
EQ5	Do you know filters/air purifiers improve the indoor air quality?
EQ6	Did you like learning about this topic?

***2.4. Lecture and knowledge transfer*:** The team developed a lecture material in form of a PowerPoint presentation. The lecture lasted for ~30 min and was geared to provide insights about the importance and methods to study *Be-Microbiome* from indoor environment. Specifically, the optimum humidity levels, factors influence the microbiome structures, ventilation requirements and methods to improve the indoor air quality were detailed. The information was well received by the students and was reflected from the post-training survey. As shown in Figure 4, the high-school students (n=9) strongly agreed that their fundamental knowledge about the *Be-Microbiome* were improved ~ 45% and individual responses were compiled in Annexure 1. (please check the lecture material here: https://www.researchgate.net/publication/360537346_Pre-training_Microbiome_of_Built_Environment_Lecture-April_2022)

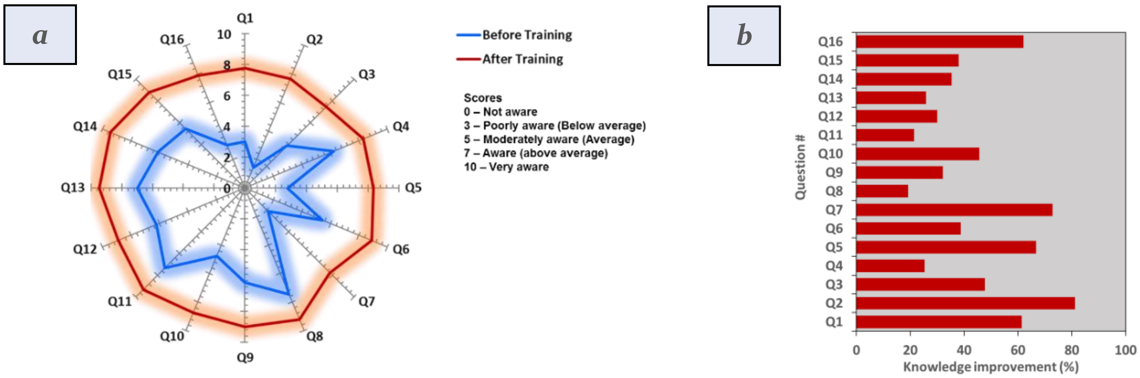

Fig 4. *In reflecting our outreach activity, the level of Knowledge transfer is calculated for high-school students; (a) a radar graph that shows the average scores (n=9) before and after training; (b) fundamental knowledge improvements for specific questions was shown in percentage.*

The elementary school students from CES were asked to share their opinion about the outreach activity and training by stating how strongly they agreed or disagreed with various statements (Figure 5a-b). Overall, 82% of the respondents were liked the lecture and hands-on training about indoor air quality and *Be-Microbiome* topic (Figure 5a). Most respondents choose the one or the other options for EQ1-EQ5 as "I learned about this topic today" or "I knew about this subject before but learned more today" (Figure 5b). Only 2-13% of the respondents choose I don't know about this subject. The study outcome suggested that the students are better aware of the *Be-Microbiome* topic, but additional information's and training activities were helpful for them to better understand about the importance of the additional training.

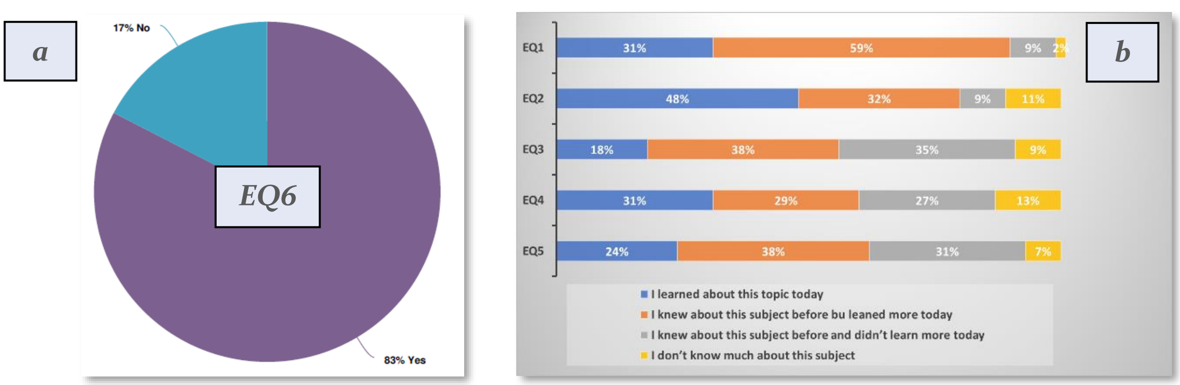

Fig 5. *In reflecting our outreach activity, the level of Knowledge transfer is calculated for Elementary school students (n=82) after training. Please refer to Table 2 for EQ1-AQ6; (a) interest towards the topic among the students; (b) responses towards their understanding about the topic.*

***2.5. Hands-on training and Data collection*:** The team used different quality monitoring instruments and provided hands-on training to characterize the indoor air quality and *Be-Microbiome*. We grouped the students into different teams and each team had 10 elementary school students and one high-school student. High school student was heading the team and identified a specific study location within the CES building (Figure 6a). Each team was provided with the R2A bacterial agar plates and trained to collect the air samples on the specific location. The plates were incubated at room temperature and students were counting the bacterial colony over the incubation period of 5 days (Figure 6b). A teacher and a supporting team member (Dr. Srivatsan) visited the specific location and trained the students for monitoring the other air quality parameters such as temperature, humidity, carbon monoxide (CO), Nitrogen dioxide (NO_2), methane (CH_4), hydrogen sulfide (H_2S), Carbon dioxide (CO_2), oxygen O_2 levels and barometric pressure (Figure 6c).

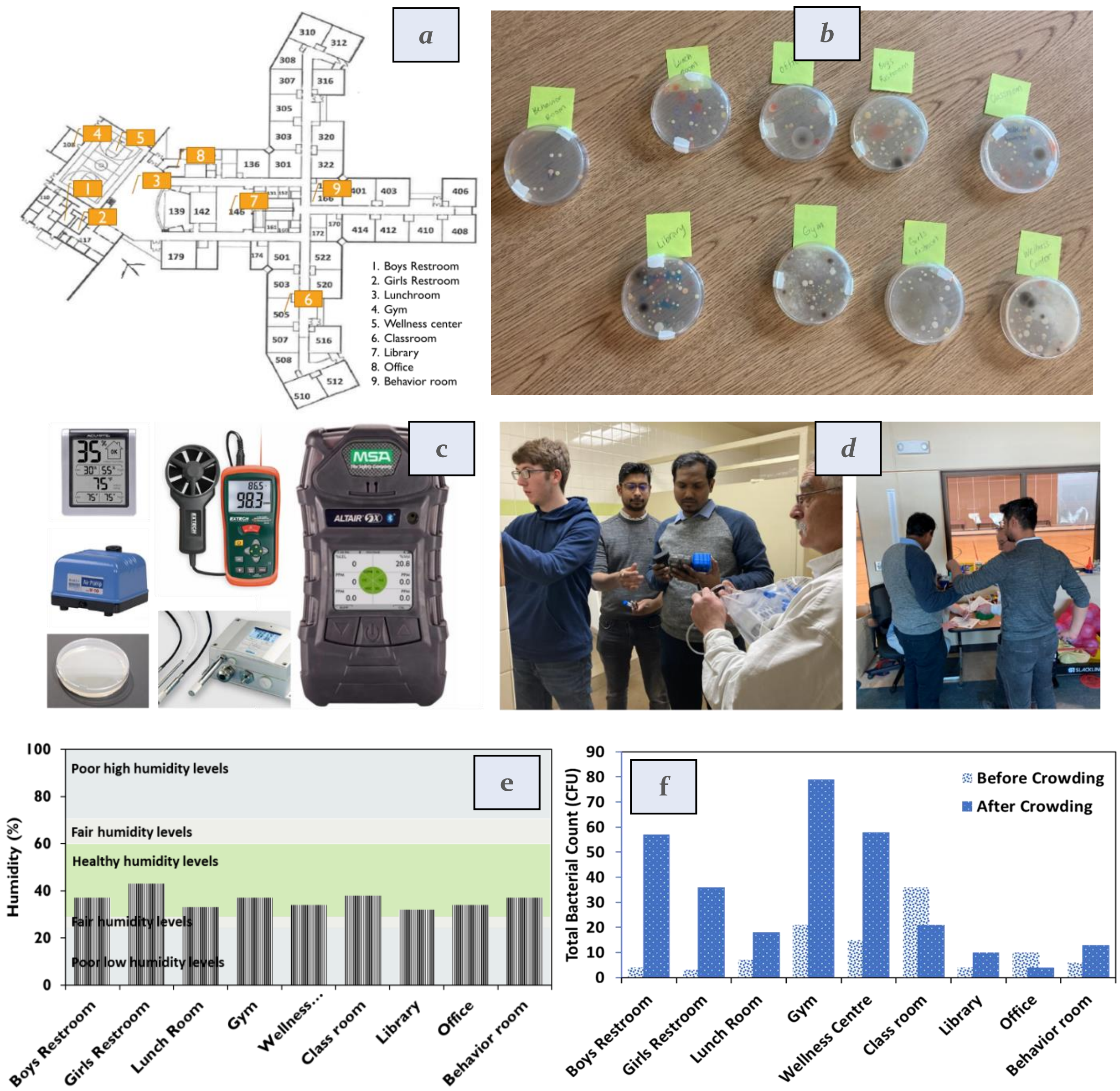

Fig 6. *Hands-on training and data collection; (a) Indoor air quality monitoring locations; (b) Microbial diversity from different locations; (c) air quality monitoring instruments used for the training activity; (d) providing hands-on training and data collection from individual locations; (e) Humidity level and (f) total bacterial counts from different sampling locations.*

The teams were provided with the data sheets to record specific air quality parameters at designated locations (Figure 6d). The humidity was measured using humidity meter. The typical levels were found to be within recommended value of in-between 30 and 60% for healthy environment (Figure 6e). The data on total bacterial count was compared among different locations (Figure 5f). The maximum count was from Gym and minimum was from office, library and behavior room, respectively. Other indoor air quality data sets were presented in Annexure 2. The SD Mines team also visited the Sanford Underground Research Facility (SURF) to collect the samples from 4850 ft level. The underground mine air quality data including microbial data were compiled along with the other data sets for final presentation. The SURF indoor air quality data sets were not compiled in this report due to data confidentiality and sensitivity of topic.

<u>2.6. Re-visits and wrap-up sessions</u>**:** The PI compiled all the results and prepared a presentation to share it with the K-12 students. The PI re-visited the SHS on May 5, 2022 and CES on May 10, 2022. The results were shared with the students and discussed (Figure 7). We have asked the students/teachers to provide a feedback for the overall training and outreach activity using set of questions as below; Most participants indicated the merits of the outreach activity and student engagement. The students/teacher's responses were highlighted below; Most of them suggested to have a at least 3-4 different visits for lecturing, training, sample collection and data presentations, while few liked the integrated training approach with elementary school kids.

1. **If you had to change one thing about the session, what would you change and why?**

"Do the sampling at the high school. Logistically easier"

"I wish we had more things to do with the kids. Maybe more time or activities"

2. **What parts of the session contributed most to your learning about this subject?**

"I enjoyed the presentation, it really helped develop my understanding of the topic"

"Being able to visualize the bacteria growth"

"When you brought up how moisture levels can affect the number of bacteria in the air, it really made me consider what other aspects of my lifestyle influence the number of bacteria I'm exposed to. How many types of bacteria am I exposed to every day? Does the carpet in my room hold a large number of bacteria? How can I keep my hands and face clean throughout the day?"

3. **What recommendations would you provide the facilitators in doing sessions of this kind to other high school students? What would make it the best it can be?**

"Training on the equipment and lecture on a day prior to sampling. Maybe sample collection during training. Separate day for taking samples"

"I think that more high schoolers could benefit from this information, so maybe open up to a broader audience-maybe only other high schoolers but on a larger scale"

In addition, we have also shared the outreach activity details with Dr Mel Ustad, Project Director - SD EPSCoR and got his feedback as below

"Thank you for the note. This sounds like a great activity. My suggestion for potential Track 1 future support would be for them to submit a Seed grant proposal this summer. If you do the Seeds application, you might want to consider working with the TCUs and Discovery Center for additional outreach activities in South Dakota. Hopefully this is helpful. "

Fig 7. *Wrap-up sessions and data discussion with student participants*

3.0 Success metrics:

The success metrics of this program were calculated based on the followings.

- Number of K-12 students engaged/benefited on the topic: More than 200 students were trained for the Be-Microbiome topic during this outreach activity.
- Survey feedback from students (and their parents) on the topic: Different survey questionnaires were developed and used during this outreach activity. The overall success was gauged from the feedbacks and specific scores.
- Data presentation in AEESP forum or other workshops/conference: The data will be compiled and submitted for the AEESP newsletter.
- Education material development and dissemination: The education materials i.e., lectures and data sets will be shared with the schools for their use in curriculum. Also, we are communicating with other schools to further expand this activity and use the education materials for training more K12 students.
- Possible future collaborations with the schools and funding opportunities: We are planning to submit a SEED grant application to NSF SD EPSCoR funding.

4.0 Conclusion and Future works:

More than 200 students from elementary and high-school were trained under the AEESP funding on the project topic *Be-Microbiome*. The response during and post-training was clearly showed that the students were able to understand the importance of indoor air-quality on mental and physical health. From the hands-on experience on air-quality monitoring and microbial plate count studies, the students were able to understand the air-quality of different indoor environments from the schools. Specifically, the microbial diversity differences from Cafeteria and Toilets had provided them the importance of disinfection requirements of different indoor environment to protect their health. Post-training lectures given few insights and recommendations to the students and teachers who were all part of the training.

This funding fostered (i) a new collaboration between the faculty from mining and environmental engineering departments at SD Mines; (ii) The future funding opportunities (e.g., SEED grant) for us to expand this outreach program within the SD state. To further expand the scope of this outreach activity, we are communicating with Mrs., Hemalatha Bhaskaran, Science Supervisor from Wicomico County Board of Education to train K12 students for remote training through zoom calls. Based on the feedback from students and teachers, the future program will include following additional activities.

- Engage small group of students for training.

- Include more details pertaining to the specific sampling methods and selection criteria.

- Microscopes and other lab equipment's for *Be-Microbiome* testing could be more detailed.

- More hands-on training could be included and different building settings could be tested.

5.0 Acknowledgement:

We acknowledge the funding support from Association of Environmental Engineering and Science Professors Foundation (AEESP; letter dated March 28, 2022). We acknowledge the funding support from the National Science Foundation (NSF; Awards # 1920954, #1849206). We thank SD EPSCoR and LEAP Consulting services for their technical support on administering the survey questionnaires. We also thank all the school teachers and supporting staff members, especially Dr Srivatsan Jayaraman for helping us to complete this activity on-time.

6.0 References:

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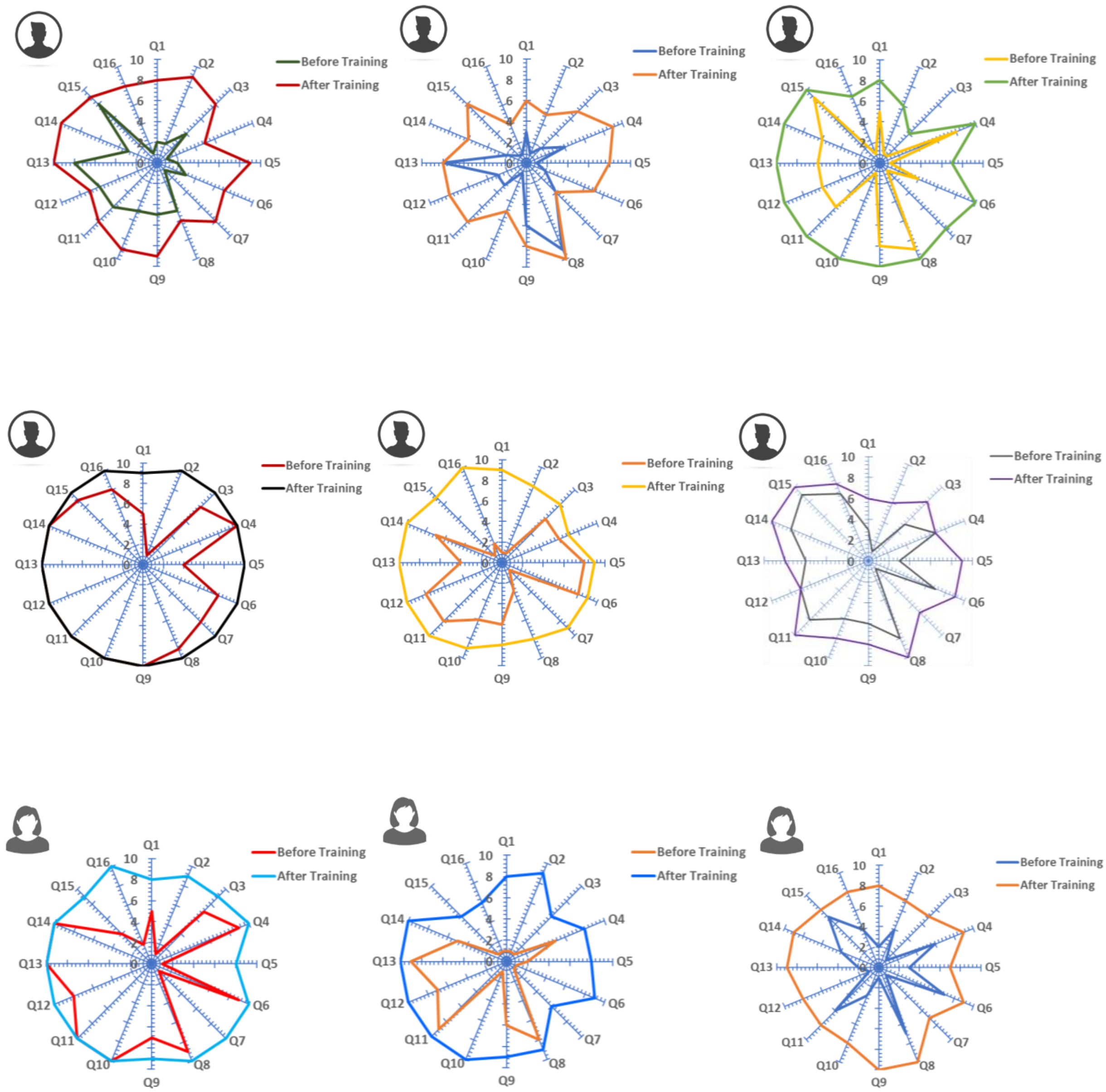
7.0 Annexures:

Annexure – 1: Individual response and level of agreements from the high-school students about the lecture and training on the topic Be-Microbiome. (check Table 1, for Q1-Q16).



Annexure – 2: Indoor air-quality datasets from the SUE.

Sampling Locations #	Specifications	Temperature (°F)	Oxygen (ppm)	CO (ppm)	H_2S (ppm)	CO_2 (%)	NO_2 (ppm)	Barometric pressure	Methane (%)
1	Boys Restroom	79	20.8	0	0	0.03	1.6	88.5	0
2	Girls Restroom	81	20.8	0	0	0.08	1.3	88.9	0
3	Lunch Room	81	20.8	0	0	0	0.6	88.4	0
4	Gym	82	20.8	0	0	0.03	0.6	89.9	0
5	Wellness Centre	81	20.8	0	0	0.07	1	88.9	0
6	Class room	79	20.8	0.26	0	0.28	1	88.9	0
7	Library	79	20.8	0	0	0.07	0.2	89.9	0
8	Office	81	20.8	0	0	0.04	0.4	88.9	0
9	Behavior room	77	20.8	0	0	0.14	0.7	89.9	0