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A practical method for improving Diversity, Equity, and Inclusion in Nuclear Science

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After a twenty year Engineering career inventing and operating advanced technology in various private sector and military environments, Jim Olson returned to Academia to formalize and publish the methods and best practices he developed while mentoring and training Early Career individuals in the practical application of STEM concepts. Jim's research if Engineering Education centric and he is currently pursing a Doctorate of Engineering at Rensselaer Polytechnic Institute in Troy, NY

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Dr. Liu is a Professor of Mechanical, Aerospace, and Nuclear Engineering at Rensselaer Polytechnic Institute (RPI). Dr. Liu earned PhD from Massachusetts Institute of Technology (2005). Liu received 2018-2019 ELATE at Drexel Fellowship. He was the recipient of a Faculty Development Grant from the U.S. Nuclear Regulatory Commission, and numerous teaching and research awards from School of Engineering at Rensselaer, as well as the Cozzarelli Prize in Engineering and Applied Sciences from the Proceedings of the National Academy of Sciences. As a Physicist and Engineer by training, Liu's technical research is focused on solving high impact problems associated with energy and the environment through fundamental investigations into the structure-function relationships of materials. For this purpose she is developing fundamental bridges between scattering (neutron, X-ray, and light) spectroscopy and simulations (molecular dynamics and phase field) to investigate materials' response. Moreover, Liu's science based communication/societal research extends into many areas. She works on the emergency management and decision technologies to support preparedness, response, and recovery. Collaborating with financial engineers, she builds economic analysis to measure sustainability of advanced hybrid energy systems and develops new optimization economic/technical model for nuclear fuel cycle. Collaborating with course developers, she discovers innovations for engineering education.

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Malcolm Porterfield is a Ph. D. candidate at Rensselaer Polytechnic Institute (RPI) in Troy, New York, and a GEM Fellow at the Los Alamos National Laboratory in New Mexico. His current research focus is Molecular Dynamics with the long-term goal of unlocking a major breakthrough in Energy Sustainability. More specifically, he is exploring the possibility of thermal-to-electrostatic energy conversion to harvest waste heat.

Raised in Albany, New York, Malcolm graduated from Albany High School before attending Hudson Valley Community College (HVCC) where he earned an Associate of Science Degree in Engineering Science in 2015. While at Hudson Valley, he was on the President's List twice, a member of Phi Theta Kappa, and was on the HVCC Baseball Team.

Malcolm transferred to RPI after completing his degree at HVCC. At RPI, Malcolm earned a Bachelor of Science degree in 2017 in Mechanical Engineering before beginning his graduate studies during which he earned a Master of Engineering degree in Mechanical Engineering in 2019. Throughout his time at RPI, Malcolm has been involved with the Track & Field program, first as a student athlete and later as an assistant coach. He was a champion of the hammer throw at the 2018 Liberty League Outdoor Championship. In addition to his academic and athletic endeavors, Malcolm was the treasurer of the Black Graduate Students Association of RPI where he planned and executed team events and managed the finances of the group.

Prior to accepting a position as a GEM Fellow, Malcolm completed four Graduate Assistant Research Assistant internships at Los Alamos. In addition to his Ph. D. studies, Malcolm continues to pursue available opportunities in learning by auditing courses such as Fusion Energy at Princeton Plasma Physics Laboratory and earning certification in courses such as, Neutron Scattering at Oak Ridge National Laboratory, and Lean / Six Sigma at RPI.

A Practical Method for Improving Diversity, Equity, and Inclusion in Nuclear Science

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Background and Motivation

Rensselaer Polytechnic Institute (RPI) is the oldest operating private school of science and school of engineering among those that were established in any English-speaking country [1]. Starting with civil engineering in the 1820's, RPI has continually evolved available curricula to meet societal goals. Since the early 1990's, societal progress enabled by alumni from institutes of higher learning and compulsory education was so effective that a societal challenge emerged; the general diffusion of scientific knowledge into compulsory curricula was no longer sufficient to maintain an adequate labor force. Leaders from all aspects of society began to focus on the quality of science, technology, engineering, and mathematics (STEM) education in regulated curricula [2].

In 1960, the Nuclear Engineering Department at RPI was one of the first Nuclear Science and Engineering (NSE) programs officially formed in the country. Until the Three Mile Island Accident in 1979 halted Nuclear Industry Growth, the NSE program at RPI expanded to include state of the art infrastructure and had earned an excellent reputation as a talent pipeline for Nuclear Engineers.

Following the Three Mile Island accident, NSE programs nationwide were being eliminated, campus-based reactors were being decommissioned and NSE undergraduate enrollment was at historic lows. In response to declining enrollment, the Nuclear Engineering Department head at RPI initiated a collaborative partnership with a local U.S. Navy training facility. The program, known as the RPI Navy-Malta program enabled enlisted Navy personnel to earn the same Bachelor of Science degree in Nuclear Engineering offered to on-campus students by completing a curriculum designed to accommodate the needs of the target population [3]. During the now defunct collaborative partnership, approximately 200 active duty military students successfully completed the program and as a result RPI had some of the largest Nuclear Engineering graduating classes in the nation [4]. For the purpose of technological synergy with other disciplines, the Nuclear Engineering Department at RPI was eventually combined with the Mechanical and Aerospace Engineering Programs to form the Mechanical, Aerospace, and Nuclear Engineering (MANE) Department.

The Navy-Malta Program provided unprecedented access to demographics historically underrepresented in Engineering Education. The success of the program motivated a small group of Engineering Education Researchers to maintain and expand this unprecedented access after program termination. Initially focused on NSE fundamentals to broaden participation in Nuclear Engineering Education, the Engineering Education Researchers began to focus on improving multidisciplinary collaboration among Mechanical, Aerospace, and Nuclear undergraduate and graduate students in pursuit of various research goals. As the focus on Diversity, Equity, and Inclusion in Engineering has continued to grow, efforts shifted to the development of a novel pre-college system of teaching STEM fundamentals, that is independent of student proficiency in math or reading, to broaden participation in STEM education and careers, including NSE.

The purpose of this paper is to document the practical methods used by Engineering Education Researchers at RPI to broaden participation in STEM education and careers, with an emphasis on Engineering Education, by disrupting underrepresentation in various demographics. These methods include an efficient theoretical framework of STEM fundamentals and best practices in lesson plan development and execution. Demonstration and documentation of the effectiveness of these methods occurred at a pre-college program hosted by RPI, Black Family Technology Awareness Day (BFTAD). Established more than twenty years ago, RPI invites families from across the world to participate in BFTAD to perform hands-on STEM activities, learn how to prepare for college, and meet with students and faculty to discuss ongoing research. A request for BFTAD 2022 Program Proposals was received by the authors on December 9, 2021. The third author volunteered to facilitate a BFTAD session for the purpose of broadening participation of Black or African American students in NSE education and careers.

Literature Review

There exists a persistent general agreement that regulated education plays a critical role in society. Written evidence for debates about the role of public curricula can be found as early as fourth century BC. The need for a regulated curriculum emerges "when it is no longer self-evident what should be taught" [5]. Over time, various rules and regulations associated with standardized curricula emerged as societal needs have evolved. In ancient times, schools like those established in Athens provided education to a relatively small number of people. These intellectuals often produced innovative insights that resulted in societal gains such as more efficient means of production. More efficient production led to improved human quality of life of the general population. Eventually, the means of production evolved to the point where it was no longer self-evident what the general labor force should be taught. Compulsory curricula were introduced to ensure the general population was able and prepared to be productive members of society.

What can be considered the first compulsory curriculum in the U.S. was established in the Massachusetts Bay Colony on June 14, 1642 by Puritan elders [6]. The curriculum, limited to the essentials necessary for children "to read and understand the principles of religion and the capital laws of the country" [6], was established out of necessity for the survival of the newly established community in the wilderness. Compulsory education regulations were subsequently established across the U.S. and continued to evolve until the 1970s. A legal challenge to compulsory education was initiated by an Amish community in Wisconsin. In *Wisconsin v. Yoder*, the Amish parents were granted a religious exemption to compulsory education beyond the eighth grade and set a precedent for other states to establish their own limits. The current US compulsory education system is essentially 50 individual sets of regulations as each state has its own requirements regarding minimum and maximum required grades, ages, etc.

U.S. higher education, defined here as any formal education not required by regulation, evolved independently of compulsory education regulations. Founded in 1636, the College at New Towne (later renamed as Harvard University) is widely regarded as the "oldest institution of higher learning in the United States" [7]. Patterned after English universities, the institution established formal admission requirements nineteen years into its history as follows: "When any scholar is able to read Tully or any like classical Latin author, *ex tempore,* and make and speak true Latin in verse and prose (*suo ut aiunt Marte*), and decline perfectly the paradigms of nouns and verbs in the Greek tongue, then may he be admitted to the college; nor shall any claim admission before such qualification." [8]. The establishment of other institutions of higher learning would follow.

Until the early nineteenth century, higher education curricula was generally classified as natural history or natural philosophy. While these categories are not rigorously defined, what was then known as the physical sciences (astronomy, physics, chemistry, botany, and geology) were subsets of natural philosophy. Instruction in these courses were typically given by lectures, sometimes supplemented by experiments performed by the teacher. The growing market value of the natural sciences, resulting from the Industrial Revolution, prompted increased focus on formal scientific instruction in the form of higher education and a general diffusion of scientific knowledge in compulsory settings [1].

In the early 1800s, three schools were established in the US for the purpose of teaching science. Of these three, only RPI has maintained a continuous operation. Initially called the Rensselaer School, RPI was established by Stephen van Rensselaer "for the purpose of instructing persons, who may choose to apply themselves, in the application of science to the common purposes of life" [9]. In his 7th Order, van Rensselaer stated that chemistry students "are not to be taught by seeing experiments and hearing lectures, according to the usual method. But they are to lecture and experiment by turns, under the immediate direction of a professor or a competent assistant. Thus by a term of labor, like apprentices to a trade, they are to become operative chemists" [9]. In his 8th Order, van Rensselaer stated that the chemistry certification exam "…is not to be conducted by question and answer, but the qualifications of students are to be estimated by the facility with which they perform experiments and give the rationale" [9]. Considered the beginning of Applied Sciences or Engineering education in the U.S., additional Engineering schools were subsequently founded, and Engineering curricula were established at already existing higher learning institutions.

During the mid-1900's, the pursuit of military dominance during and after World War II prompted a shift towards research-centric higher education programs. Research focus on emerging technology derived from newly developed scientific theories of the atom "emphasized science over practice while pushing the humanities and social sciences aside" [10]. These research-focused programs relied on educational approaches that were vastly different than the apprenticeship style programs established in the US throughout the nineteenth century. The establishment of formal Nuclear Science and Engineering (NSE) curricula started with the Manhattan Project and evolved to primarily focus on power generation as the commercialization of the nuclear power industry began. By 1975, eighty nuclear engineering departments had been established in US higher education institutions nationwide. Growing concerns about radiation and environmental impacts combined with the accidents at 3 Mile Island (1979) and Chernobyl (1986) slowed and later reversed NSE program growth [10]. NSE programs around the nation were eliminated, including decommissioning of campus-based reactors, as student enrollment sharply declined. In response to low enrollment and limited research funding, NSE programs across the nation merged with other programs such Environmental Engineering or Physics.

While leaders can agree that a regulated curriculum that effectively teaches STEM concepts is important, there is no clear agreement on how STEM education is defined. The National Center for Education Statistics (NCES) is the primary federal entity that collects and analyzes data related to compulsory and higher education. The NCES uses Classification of Instructional Program (CIP) codes to provide a taxonomic scheme to provide accurate tracking and reporting of statistics related to available fields of study. According to the NCES Frequently Asked Questions, every agency that uses CIP codes to define STEM has its own definition and some maintain a list of CIP codes considered to be STEM fields.

The current U.S. STEM education system emerged from the convergence of two independent education systems: 1) compulsory education, defined as systematic learning required by law and 2) higher education, defined as systematic learning not required by law. Each of these systems predate the U.S. itself and each system was founded for different reasons. Higher education has historically been a system intended for leaders of society to be trained in the knowledge necessary to sustain and progress society. Compulsory education in the US was founded to ensure citizens were trained in the knowledge necessary to be productive members of society. The production of technologists has historically been associated with compulsory education. The production of scientists and engineers has historically been associated with higher education. In recent years, the production of advanced technologist has been associated with higher education.

A novel conceptual framework for STEM Education is necessary to achieve the societal goal of broadening participation of improving education outcomes, including disrupting persistent underrepresentation of various demographics, in STEM. A novel conceptual framework was developed by Engineering Education Researchers at RPI for this purpose and is described in the sections that follow.

Conceptual Framework

The origins of modern NSE theory can be traced back to Ancient Greece. Leucippus of Miletus claimed the world was made from a combination of imperceptible matter and a void separating them. Plato argued that reality existed in the human mind in the form of experience and therefore any effort to quantify imperceptible matter was futile [11]. These same basic claims are still inherent in modern NSE theory. Nuclear Science tends to deal with the abstract theoretical quantification of imperceptible matter while Nuclear Engineering tends to deal with the more practical application of available theories.

For as long as NSE theory has existed, the philosophical debate about how to interpret experimental results have persisted. The Cat Paradox proposed by Erwin Schrödinger in 1934 [12] is a famous example of counterintuitive implications suggested by atomic particle experiments. From an Engineering Education perspective, these abstract concepts are drastically different than those taught in compulsory education. The mastery of NSE fundamentals in Nuclear Engineering Undergraduate education can be difficult to learn and teach. Additionally, multidisciplinary collaboration with other disciplines, such as Mechanical or Aerospace Engineers, are hindered by the inconsistencies in the philosophical frameworks.

In response to declining student enrollment in NSE, and for the purpose of improving Diversity, Equity, and Inclusion in NSE education and careers, a novel conceptual framework was developed to broaden participation. Initially intended for NSE only, practical demonstrations of curricula developed using the novel conceptual framework suggested potential improvements in teaching relevant fundamentals in a broad range of STEM topics. In order to maintain consistency with existing STEM frameworks, a two-part STEM Learning Model was developed. The first part is an empirical cognitive model, the Human Learning Model to maintain philosophical consistency with Plato's claim that reality exists in the mind. The second part is a reduced set of scientific theories, Small-To-Big Physics that align with relevant STEM fundamentals to maintain philosophical consistency with Leucippus' theory that the world consists of quantifiable components. Accommodation of both legacy interpretations of reality maximizes consistency between the proposed and mainstream theoretical frameworks.

Human Learning Model Development: Development of the Human Learning Model began by exploring numerous theories in Cognitive Psychology, with an emphasis on Human Cognitive Architecture. Cognitive Load Theory (CLT) [13, 14] is an influential theoretical framework that provides guidance for instructional design to improve learning outcomes. CLT emphasizes the management of cognitive load of a learner's working memory [15] to maximize learning outcomes. CLT achieves this goal by describing the components and characteristics of the memory system and aims to quantify the working relationship of the components that are attributable to human learning: sensory input, working memory and long-term memory. The limited practical CLT guidance focused on STEM learning required an empirical approach for model development.

Empirical model development of the Human Learning Model began by modifying a typical five-part Human Communication Model to align with common components in education systems. A theoretical framework was established that enabled iterative test-and-learn in practical settings in various academic, military, and private sector engineering education environments. A descriptive comparison of Human Communication Model and Human Learning Model components are included in Table 1 below.

Human Communication Model Components	Human Learning Model Components
Sender: Message Originator	**Knowledge Resource:** Any fact, information, or skill that may be acquired by a student
Receiver: Message Recipient	**Student:** Any individual seeking to assimilate information contained within a knowledge resource
Message: Information to be conveyed by the Sender to the Receiver	**Education:** The complete process of 1) transferring information from a Knowledge Resource to a Student and 2) Student assimilation of knowledge.
Feedback: Confirmation from the Receiver that the message from the Sender was received	**Evaluation:** Evidence that proper assimilation of knowledge by the student has occurred.
Interference: Any distraction that inhibits transmission of the message between Sender and Receiver.	**Barrier:** Anything that inhibits Education. Barriers may be environmental (excessive noise, etc.), resource (malnutrition, etc.), or systemic (persistent legacy factors, etc.)

Table 1: Description of Human Learning and Human Communication Model Components

The compartmentalization of the learning process into core components allowed Education Researchers to methodically apply various troubleshooting techniques to maximize learning outcomes. Through a systematic process of isolating variables, the key factor limiting the ability to achieve desired learning outcomes was attributed to three conflated variables: Knowledge Resource, Student and Barrier. In order to separate these components into independent variables, development of a novel human cognitive model was necessary to segment the knowledge assimilation process that occurs in the human brain into three discrete entities: knowledge delivery process, knowledge assimilation process, and external factors. This additional effort produced the empirical Human Cognitive Model shown in Figure 1.

Including the empirical Human Cognitive Model within the Knowledge Resource and Student components of the Human Learning Model provided new areas of interest to focus on. For example, tactile lesson plans could be developed to compare the effectiveness of various combinations of sensory input in achieving learning outcomes. Additionally, reduced learning outcomes resulting from external factors, such as cultural and resource barriers, could be allocated to Barriers rather than the teacher or student. For example, malnutrition in low socio-economic status students is modeled as an external factor rather than an inherent student constraint. In subsequent iterations, researchers took deliberate actions to ensure external factors were accounted for in assessing student performance. These efforts resulted in the current best practice of partnering with existing programs dedicated to resolving external factors that are persistent barriers to STEM education and careers.

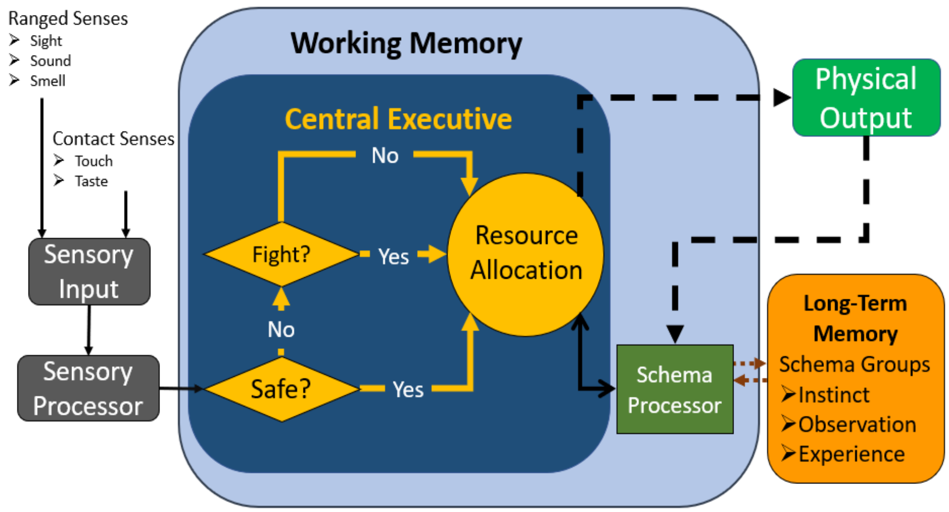

Figure 1: Empirical Human Cognitive Model

After seeing improvements after accounting for variations in external factors, persistent reduced outcomes in NSE curricula were noticed when compared to other STEM subjects such as chemistry, mechanics, or electrical theory. The development of a novel scientific framework was necessary to segment the knowledge assimilation process that occurs in the human brain from the type of information that the brain is attempting to assimilate. This additional effort produced the Small-To-Big-Physics framework.

Small-To-Big-Physics Development: The general trend for STEM education in US compulsory education curricula is to introduce concepts in the chronological order of scientific discovery. This chronological order is referred to as Big-To-Small Physics based on the sequence of scale that natural phenomena were quantified; early scientific progress was based on observations of celestial motion, followed by terrestrial mechanics and later atomic physics and quantum mechanics. US compulsory curricula follows the Big-To-Small Physics sequence by first introducing students to planets and earth ecosystems, then geology and climate cycles, followed by biology, chemistry, and physics.

Big-To-Small Physics as a foundation for standardized STEM curricula is inherently inefficient. In the same way scientists are constantly making new discoveries that render prior theories obsolete, student learners are taught STEM concepts that have already been displaced by subsequent STEM concepts introduced in higher courses. For students that do not attend higher education, modern STEM concepts are never introduced and therefore never displace legacy theories learned in compulsory education settings. Additionally, as the total amount of available human knowledge continually increases, the amount of time necessary to chronologically teach all known STEM concepts to students also increases; there is a natural point where the amount of available knowledge exceeds the human capacity to acquire all of it.

Since many scientific advancements include complex mathematics, a persistent assumption is that proficiency in math is a prerequisite for success in STEM. Math is so important to the Big-To-Small Physics STEM education framework that pre-college proficiency can be used as a predictor for an individual student's long-term earning potential [16, 17]. Since NSE concepts exists outside the range of natural human sensory input and are primarily mathematical frameworks, the Human Learning Model and other human cognitive architecture theories offered no practical guidance to improve learning outcomes beyond improving mathematical proficiency.

Instead of focusing on novel methods to teach mathematics, the authors decided to develop a scientifically rigorous framework, Small-To-Big-Physics, that can be used to develop curricula to teach STEM fundamentals that do not need to rely on reading or mathematics. By starting at the sub-atomic particle scale, including only those theories determined to be necessary to sufficiently explain relevant phenomena, a reduced set of knowledge is necessary to understand NSE concepts. The reduced set of theories can be expanded to include additional theoretical frameworks necessary to explain increasing larger natural phenomena. The continuation of this process results in a smaller set of scientific theories necessary to explain observable phenomena from the atomic to the astronomical scale when compared to Big-To-Small Physics.

By combining the Human Learning Model and Small-To-Big-Physics frameworks, Engineering Education Researchers are able to develop curricula that is customized to align with a target student population and align seamlessly with existing regulated STEM curricula. In order to minimize external factors that may reduce STEM education effectiveness, the preferred curriculum development process is a collaborative effort between the Engineering Education Researchers and individuals interested in improving outcomes in STEM education.

Methods: Collaborative STEM Demonstration Development

The STEM Learning Model was originally developed as an internal process to meet organizational goals. The ability to successfully use the STEM Learning Model framework has been limited to the Engineering Education Researchers responsible for development. In order to expedite expanded availability of the framework for other interested persons, a Train-the-Trainer Curriculum Development Process was established. The Train-the-Trainer Curriculum Development Process enables an individual without a background in education methodologies to teach STEM fundamentals to students, independent of math or reading proficiency. A general overview of a recently executed Train-the-Trainer Curriculum Development Process is described below. The developed curriculum was used in a STEM event titled "Opportunities in Nuclear: Demystifying the Science" that was a part of the 2022 Black Family Technology Awareness Day (BFTAD) at RPI.

Train-The-Trainer Step 1: Familiarize. To start, the trainee, referred to as the Session Leader, identified the learning objectives, and the Engineering Education Researcher determined the relevant Small-To-Big-Physics fundamentals that were to be used. The Session Leader was led through a series of tactile Small-To-Big-Physics modules to learn core fundamentals. The Session Leader was then asked to take the materials used and repeat the Small-To-Big-Physics modules with others while serving as the trainer instead of the Session Leader. During this time, the Engineering Education Researcher drafted a curriculum to achieve the learning objectives identified by the Session Leader. In this instance, the general objective was for student participants to understand Nuclear Fusion Fundamentals.

After sufficient practice as the Small-To-Big-Physics module trainer, as determined by the Engineering Education Researcher and Session Leader, a debrief session was held to prepare the Session Leader for an expanded trainer role. During the debrief, relevant portions of the Human Learning Model were used to explain why outcomes observed by the Session Leader occurred during the Small-To-Big-Physics trainer exercises. These lessons learned were highlighted as areas of interest for subsequent curriculum development. Various techniques were identified that would allow utilization of areas of strength and accommodate areas that needed improvement.

Train-The-Trainer Step 2: Learn. Since BFTAD transitioned to a virtual event in response to the COVID pandemic, the media for the STEM session was determined to be a WebEx online meeting room with a PowerPoint presentation that was supplemented with hands-on activities. The Engineering Education Researcher provided a series of Small-To-Big-Physics modules, in the form of PowerPoint slides, for the Session Leader to review. Each module was practiced independently, with the Engineering Education Researcher simulating a virtual audience, to ensure the Session Leader was able to achieve desired outcomes of each module while leading a virtual session. After each module was sufficiently matured, as determined by the Engineering Education Researcher and Session Leader, a consolidated PowerPoint presentation was compiled and practiced with the Engineering Education Researcher and other volunteers simulating a virtual audience in multiple sessions. Volunteers were selected that had no prior knowledge of Small-To-Big-Physics or Big-To-Small Physics nuclear fusion fundamentals.

After each practice session, feedback from the volunteers was used to modify the lesson plan and PowerPoint presentation as necessary. Several more rounds of practice with the Engineering Education Researcher serving as the virtual audience was completed to confirm suggested edits were accurately incorporated and that the overall pacing and time of the presentation were consistent with the BFTAD agenda.

In order to ensure effective communication with the students in a virtual environment, Survey Questions throughout the presentation were created to enable the Session Leader to assess student participation and performance. For example, when students were asked to complete an online activity within a period of time, a survey question was provided to allow students to indicate when the activity was completed.

Train-The-Trainer Step 3: Execute. The Session Leader presented the experimental curriculum to attendees of the BFTAD session on February 12, 2022. Since the role of the Engineering Education Researcher was limited to preparing the Session Leader to lead the session, the Engineering Education Researcher did not observe or participate in the session. Details relating to the execution of the session (in the context of the Train-the-Trainer Curriculum Development Process) are included in the Data Collection and Results sections below.

Data Collection

The purpose of this effort was to determine if an individual that has no formal training or experience in teaching, with limited knowledge of nuclear fusion fundamentals, can effectively facilitate a STEM session for pre-college students. The pre-college students were not within the scope of the effort; informed consent of their participation in research was neither requested nor provided. As a part of the session, data related to student participation was collected using WebEx Polls as a method to assess audience participation and understanding of the material. This data was reviewed with the Engineering Education Researcher in the context of the effectiveness of the Session Leader leading the session. Additionally, the Session Leader completed a Post-Session Execution survey related to the experience presenting the experimental curriculum as detailed in the Results section.

Results

The purpose of this effort was to explore the feasibility of using the STEM Learning Model framework to develop an experimental curriculum that could be taught 1) by an individual that does not have a background in teaching, and 2) is not a domain expert in NSE, to high school students. The session was determined to be a success by the Session Leader and the Engineering Education Researcher based on feedback from the Session Leader in the form of a post-Session Execution survey. The survey and responses are included in Table 2 below.

Prior to this effort, utilization of the STEM Learning Method Framework was limited to the Engineering Education Researchers that contributed to is development. Primarily used as an internal process to meet departmental goals, rigorous data collection aligned with mainstream education research methodologies had not been performed. The results of the survey indicate the Train-the-Trainer Curriculum Development Process is an effective and practical method to broaden participation in STEM by preparing a Session Leader to effectively execute a STEM session. This demonstration of effectiveness suggests additional curricula can be constructed for other individuals interested in broadening participation in NSE or other STEM fields.

The exclusion of student participant performance limits the conclusions that can be drawn regarding the overall effectiveness of the proposed theoretical framework. However, now that the feasibility of individual volunteers facilitating STEM sessions has been demonstrated, future efforts can be expanded to include student participants and their feedback in research results.

Session Preparation	
Q1	Considering the preparation steps leading up to the Virtual Session, which parts of the training do you feel you learned from the most?
A1	*I feel I learned the most from slide preparation and the practice runs. In preparing the slides I had to think about what information the participant was going to receive and how best to package that information. However, I learned there is a distinct difference between theory and practice. I may have thought I prepared the slides well and I had an idea of what I wanted to say but actually practicing the presentation multiple times with a simulation audience brought to light several deficiencies I had in either my presentation style or the information the audience was actually able to absorb.*
Q2	What skills have you gained from the Train-the-Trainer activities?
A2	*I gained the ability to guide/direct activities in a virtual environment (i.e. WebEx) by controlling the pacing of delivering information to an audience and being able to adjust on the fly when given audience feedback.*
Q3	Which Train-the-Trainer activities were most effective in teaching you how to successfully execute the Virtual STEM session?
A3	*Learning to use polls was the most effective activity. Depending on the number of participants in a session it may or may not be feasible to look at everyone (through a video camera) to see how they are progressing with a particular activity. By constructing the polling questions appropriately, it was possible to gauge participant involvement and understanding of the material without the need for direct visual or auditory feedback, which would be available in an in-person STEM session.*
Q4	How do you think the learning experience of the Train-the-Trainer session could improve?
A4	*Having a more accurate picture of the size and capabilities of the audience (will there be visually/audio communication, do they have stable internet, etc.) I believe would allow for the Train-the-Trainer session to be more finely tuned to prepare the trainer for the actual session (i.e. reducing the amount of unknowns)*
Session Execution	
Q1	At the beginning of the Virtual Session, did you feel prepared to teach the lesson plan?
A1	*Yes, I definitely felt prepared.*
Q2	At the end, did you feel that you were adequately prepared to teach the lesson plan?
A2	*Yes, I still felt prepared to teach the lesson plan*
Q3	Was the execution of the session consistent with your expectations? Why or why not?
A3	*Redacted – Response was related to event coordinator logistics.*
Q4	How do you think the learning experience for the Virtual Session Participants could improve?
A4	*Redacted – Response was related to event coordinator logistics.*
Q5	How do you think the session would have been different in-person instead of virtual?
A5	*Redacted – Response was related to event coordinator logistics.*
Post-Session Reflection	
Q1	What did you like most about the Train-the-Trainer process?
A1	*The amount of simulated practice runs greatly boosted my confidence and ability to lead a virtual STEM session.*
Q2	Would you recommend the Train-the-Trainer process to others?
A2	*I would definitely recommend this process to others.*
Q3	Do you have any suggestions for how the Train-the-Trainer process could be improved?
A3	*A better understanding of the capabilities for the participants could help inform the design of the presentation*
Q4	Do you have a deeper understanding of what it takes to recruit underrepresented demographics into STEM education and careers?
A4	*I think so.*
Q5	Do you have any suggestions for how persistent underrepresentation in STEM can be disrupted?
A5	*Redacted – Response was related to event coordinator logistics.*

Table 2: Post-Session Execution Survey

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