Materials Technology Education Processes and Outcomes: The MatEdU Program

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Abstract: The National Resource Center for Materials Technology Education (MatEdU) and its continuation program, the MatEdU Online Digital Library, has made major progress in areas related to education, technology training, inter-communication, and networking in materials technology. A significant impact of this National Science Foundation-funded Advanced Technological Education resource center has been implementing materials technology into multiple areas, from technology and electronics education to advanced manufacturing, energy materials, and critical materials utilization. Using its website as its centerpiece, workshops, and educational modules along with opportunities for undergraduate research and faculty mentoring at community colleges are available. Practical examples abound, including guitar building, additive manufacturing, and numerous types of advanced materials and applications. This paper provides the information future programs will need to build follow-up programs to enhance technology education further.

Keywords: materials, education, technology, workshops, curricula, mentoring, networking

Introduction

Materials technology is the basis for developing new and advanced systems in areas from aerospace and automotive to household appliances, all of which are made of materials whose properties are enhanced by their structure, properties, and processing techniques used for their production. The use of micro- and nano-scale materials in combination with enhanced processing yield new and specific enhancements in mechanical, electrical, optical, and magnetic behavior. New processing techniques utilizing natural materials can also improve the environment and create a greener future. New horizons are becoming achievable today with scientific and engineering advances in materials.

These advances create a need for enhanced materials technology education, which may include re-training in new systems and new tools for education from elementary school to technology education institutions. Advanced educational programs can demonstrate the critical relationship between materials structure and properties and the importance of processing in determining the final properties of a manufactured structural or electronic part. Additionally, hands-on materials-related activities have been proven to help

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learners of any age experience the excitement of science applied to technology, leading to potential interest and future pursuit of materials technology study or careers.

The many new materials configurations and combinations that will be employed in structures and electronics in the coming years include: composite, nano, micro, and two-dimensional materials. These are the metamaterials that will enhance the products of the future. Developing technology-related professional and educational activities leads to a greater understanding of materials processing knowledge that is critical for taking full advantage of new technological advances. This paper presents the approach and impact of the MatEdU program on these needs.

Materials Technology Education (MatEdU) Project

In the mid-1990s, The Boeing Company had already begun researching the possibility of replacing traditional metal parts in their airplanes with parts made using composite technology. If integrated correctly, the results would increase fuel efficiency while reducing the plane's overall weight. However, a challenge emerged. The state did not have training programs or a trained workforce in composites that could step into this new era. Washington's Governor Gary Locke (1997-2005) made a promise to Boeing that, if they kept the composites work in Puget Sound, he would work with the community and technical colleges in Washington State to create and offer training programs focused on composites that would, in turn, provide Boeing the trained workforce it needed.

Edmonds College (formerly Edmonds Community College) accepted that challenge and, in the fall of 2003, set up the state's first Associates Degree and Certificate program in Materials Science. Although composites were the initial focus, Edmonds included basic information on other materials such as ceramics, metals, etc. The creation of the initial program provided Edmonds the opportunity to submit a National Science Foundation (NSF) Advanced Technological Education (ATE) proposal in 2004 to expand the program. The proposal was awarded in 2005 and established the National Resource Center for Materials Technology Education (MatEd), which was eventually rebranded as MatEdU.

A team of engineers, technologists, scientists, and educators developed or collected curricula, resources, and ideas whereby instructors could integrate materials and technology into existing or new curricula at all levels and in many STEM subjects. The team benefitted from collaborations with various professional groups, foundations, and numerous community and technical colleges and universities.

The team also developed a set of partnerships that enhanced communication and provided networking opportunities for many other projects and centers—revealing the materials focus needed for these partner programs to function. Workshops and curricula emphasizing technologies dealing with engineering materials were being requested from K -12 teachers and college technology instructors. The project that emerged was called the National Resource Center for Materials Technology Education, and later, Online Instructional Resources for Materials Technology Education, and it continued for 18 years, with completion in 2023. The project is comprehensively called "MatEdU”.

The well-known work of Dr. Rustum Roy [1] and colleagues, which focused on convincing scientists in general and funding agencies in particular that an everyday technology and science focus could enhance interest and enthusiasm for technology and science study, motivated the many undertakings in this project. Pursuits were planned and orchestrated to convince instructors that the science and technology of everyday materials could be a useful tool.

Early work in this area included focused classes for instructors at several universities; one such class formed the groundwork for a current K-12 teacher program sponsored annually in many locations by the ASM Materials Education Foundation [2]. Individual contributions to the literature [3-6] and later follow-up focus work for technology instructors in manufacturing [7] added to the need for a program such as MatEdU.

MatEdU continued to evolve and has infused the need for materials knowledge into programs from manufacturing technology to health-related fields, utilizing unique experiences such as guitar building, hands-on curricula, and student-based projects and providing mentoring and a model for both networking and communication in the advanced technological education area.

This paper presents first the website, where all information relevant to the project is stored, including a wide variety of resources for educators and students. This is followed by a discussion of the programs and projects that have grown out of needs identified for educational materials and from collaborations with outside groups. This includes curriculum development, conferences, workshops, research opportunities, and help in the development of future projects.

The Website: www.materialseducation.org

The MatEdU website provides a guide to the programs and resources available in the broad area of materials technology education. It is not comprehensive, but focuses on resources and curricula in areas of practical application as related to engineering and science. Activities need to engage the student, especially at the younger ages. The lessons, referred to as "modules" in this program, proceed from introductory levels to more difficult concepts and applications, where instructors can adapt the materials to their class and situation.

As can be seen on the accompanying web page image, site visitors are provided with information for both educators and students, along with a variety of other educational material in areas including:

- Educator's areas of interest, such as core competencies in technology; curriculum collections; and related programs,
- Resources, including curricula in materials, engineering, and technology; useful websites and videos; NSF programs; textbooks; and related papers and publications,
- Career resources and career pathways, and
- News in materials technology and related areas.

The contents of these website sections are discussed below as relevant to the development and use of materials technology curricula, available resources and references, and specific programs of interest to instructors and students.

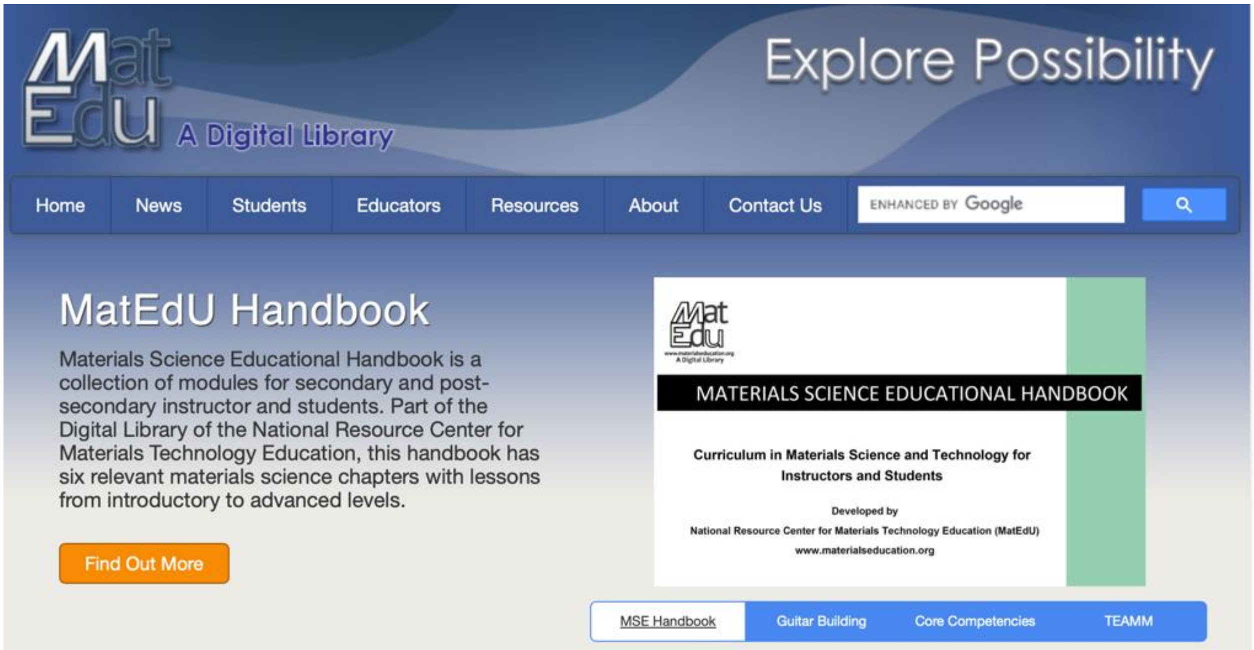

Fig. 1 The MatEdU Website. Available at https://materialseducation.org/.

In 2013, a system for assessing the impact and effectiveness of the website was devised. The intention was to gather information on three key metrics used in website analysis: time on the site, pages most viewed, and downloads. The data collected helped identify the content and information that benefited the audience most. Downloads provided an indicator of the site's "sales and revenue." Even though no sales took place, this was a good way to put a value on the most downloaded modules. Later, it was also possible to view where and how site visitors entered the site. Data showed that visitors entered most often using search engines and often using the keyword search term "types of materials." These data were used to upgrade the site so that the most used search terms were present in the site's metadata. It was also possible to see the external locations from which visitors entered the site. This was valuable information both in knowing where the links originated and in approaching valued partners to form backlink campaigns to elevate the site's overall ranking on the web, driving more traffic to the site.

The website has expanded in scope since its inception and will continue to be an important go-to site for materials information into the future. To accomplish this, while MatEdU is closing, the website is being migrated to become a part of the NSF ATE-funded Micro Nano Technology Education Center (MNT-EC) at www.micronanoeducation.org. MNT-EC includes programs for educators, students, and industry partners in all aspects of micro and nanotechnology, utilizing today's technological advances in materials and microsystems as it uses the information on www.materialseducation.org.

Educators tab

The website's Educators tab includes everything an educator might need to understand and develop programs related to materials technology. This includes a highly successful workshop program, a clear definition of core competencies for technicians, and curriculum modules for use in the classroom.

Materials in STEM (M-STEM)

M-STEM is the newer name for a long-running series of programs of practical materials lessons, labs, and case studies that have been presented in workshops for and by educators. These workshops relate to all aspects of STEM (Science, Technology, Engineering, and Mathematics) and involve educators talking with educators—basically saying, "If I can do it, you can too!" A key ingredient of these workshops is that they were staged in various parts of the U.S., engaging different school and college districts, so that nearly anyone interested could attend on a rotating basis.

M-STEM is built on the basis of the long-standing "National Educator's Workshop" program developed by Dr. Jim Jacobs at Norfolk State University. Teachers at K-12 schools, and instructors at community and 4-year colleges interested in materials technology gathered annually beginning in 1986 to exchange lessons, labs and case studies that would excite student interest. Here, each participant shared their latest labs, demonstrations, and ideas with others, which led to further innovations in curricula, to be presented at future workshops. MatEdU managed the NEW Call for Papers and peer review process; however, upon Dr. Jacobs' retirement in 2010, MatEdU took over the overall management and production of NEW. The annual workshop was broadened and renamed "Materials in STEM" (M-STEM) in 2015, sponsored by MatEdU, which ran successfully until 2019 when cancelled by the pandemic. The complete archives for these programs, including the curriculum presentations, are provided under the Educators tab on the MatEdU website [8].

Core Competencies

Core Competencies for technicians working in technology fields are a critical piece in knowing what is important for inclusion in the development of curriculum and technician education. MatEdU undertook a broad survey of practitioners in the fields of materials [9], plus competencies needed for work in marine technology, nanotechnology [10], corrosion, additive manufacturing and medical devices technology, all of which are available collectively in one reference [11]. These core competency needs are presented under the Educators tab on the MatEdU website for use in developing curricula. The core competencies have also been made available to industry for their use in training and in some cases, technician hiring.

MatEdU Modules

These maintain a focus on materials, technology, and science appropriate for students from middle school to technical/community college levels. These curricula have been collected using specific criteria, and each module is peer-reviewed to ensure that it works in the classroom at its designed level and is copyrighted to protect the author's intellectual property. A uniform format is used to ensure that instructors can navigate the module. Modules often include a lab experiment, a PowerPoint presentation, references, and instructor notes. Modules are designed to align with core competencies and with **Standards for Technological Literacy** [12]. K-12 modules are designed to align with the concepts found in the **Next Generation Science Standards** [13] and applicable connections to **A Framework for K-12 Science Education** [14]**.** Alignment helps college, school, or district personnel identify the concepts in each module that satisfy their own system's curricular requirements.

A search engine on the MatEdU website is available to help find curricula by level, subject, and author. Subjects range from Additive Manufacturing to Wood, with many other topics in-between.

Modules developed early in the program included simple introductory demonstrations and labs, such as:

- Materials Science of Household Appliances
- Micro-to-Macro: Linking Microstructure to Material Properties
- Composite Materials—Sticks and Glue
- Classification of Materials
- Odd Behavior of Rubber Bands

These modules may be found by title on the MatEdU website using the search engine.

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Subject matter for more recent modules has evolved from conventional subjects, including materials design and processing methods, to subjects more relevant to today's needs. For example, subjects of recently developed modules include the following, which may also be searched by title on the website:

- Introduction to Magnetic Composites
- Additive Manufacturing of Magnetic Materials
- Lithium The Third Element (basics of Li-ion batteries)
- 3D Printing Filament Recycling
- Sustainable Composite Materials from Renewable Resources
- Global Impact with Activity (Impact of Design and Innovation)
- Evaluating the Next Generation of Solar Cells

Over 150 separate modules are available. Copyright ensures that other publishers can copy none of these modules, but copyright permissions in all modules state that the material may be reproduced and used for educational purposes. Peer review ensures that the module will work in a classroom and that the technology and science are presented correctly and, in a manner, where both the instructor and students can understand and carry out the module's objectives.

Materials Science Educational Handbook

It was clear from some instructors that choosing a specific module for their class was difficult without guidance. To provide this guidance, a set of modules, taken from the overall list of MatEdU modules, was collected specifically for instructors who wanted a materials technology and science "curriculum" that was classroom-ready. This handbook consists of six chapters, beginning at an introductory level, then continuing through metals and alloys, composite materials, polymers and plastics, ceramic materials, and engineering materials and design [15]. These are independent chapters and have been shown to assist instructors in developing their own materials technology programs.

Resources tab

This section of the website provides a wide variety of carefully chosen educational resources related to materials. Other specific instructional resources are also listed in this section. This includes a series of references, including:

- Engineering teaching libraries
- Materials professional organizations with educational programs
- Relevant websites and textbooks
- Career resources
- Papers and publications of interest

Using numerous collaborations, including important published works from a wide variety of sources, assures that this listing will be useful to educators in general and specific technological programs in particular.

News and Student tabs

Materials and related science/technology advances have been coming fast and furiously in recent years. The Innovative News tab provides an overview of some advances in materials and technology and related advances in micro- and nanotechnology, materials availability, sustainability, associated micro-electronics, environmental issues, manufacturing innovations, and digital informatics and biotechnology. These innovative news articles, taken from many sources, combine material concepts with many applications in fields as diverse as maritime, aerospace, and automotive. Students are continually learning more about the all-encompassing issues that material interactions can have on the lifetime of products and seem to be developing new means for problem-solving that can "save the planet."

The Student tab provides information for students interested in technology careers, from internships to college programs. Some of these areas offer incentives for students to learn more. The popularity of the MatEdU website has encouraged numerous outside programs and projects to request to be listed on the website, either as resources or as student opportunities. Generally, only non-profit organizations are considered and listed only if they would substantially enhance our audience. Recent requests not yet listed include opportunities in energy and climate resources in addition to more traditional areas. Internships and apprenticeships are included as they interest students but are not necessarily considered in college-related resources.

Programs and Projects

Integrating all of the resources above, eighteen years of MatEdU has resulted in a wide variety of programs and projects undertaken by faculty members from K-12 to college, by students at all levels, by administrators, and by engineers and scientists, all in concert with a number of external organizations. Many of the ideas in these programs and projects can be used by new organizations utilizing the experience of MatEdU and its partners. MatEdU has introduced materials selection and processing into existing programs such as guitar building (materials selection, electronics), aerospace technology (composites, materials properties), additive manufacturing (materials interactions, materials selection) and others. There are so many connections between materials concepts and these related fields that collaborative programs are inevitable with the right leadership.

MatEdU has also developed a case study outlining the development of the materials program at Edmonds College [16]. This stands as a “blueprint” for developing a materials educational learning environment and includes an outline with details and an inventory of what is needed. The blueprint has been presented to many colleges across the U.S. and has drawn considerable interest.

Specific follow-on ideas based on MatEdU’s experience are different for different programs. First, of course, is the website and the information thereon. As noted, the website in its 2023 configuration is being migrated to become a part of the Micro Nano Technology Education Center (MNT-EC) at www.micronanoeducation.org. While it is expected that MNT-EC will utilize this partnership for their programs, there is much from MatEdU that can be utilized to develop other programs related to materials and technology education. MNT-EC also sponsors the Journal of Advanced Technological Education, where this article appears.

Technology Education Workshops for Instructors

One clear opportunity for wide application is related to the M-STEM programs that were noted above [8]. These hands-on workshops have generated considerable interest and connections among technology instructors in STEM-related areas. The conference's focus has always been communication: **Educators talking with Educators**. Participants want to talk about their best labs, demonstrations, or case studies and easily share their ideas with others. Unfortunately, due to the time constraints of their jobs, these educators have not been as good at writing up a lesson dealing with their ideas. As seen in the appendix to the M-STEM section [8], many simply provide their PowerPoint presentations. Development of modules from these instructors' ideas would bring recognition to them and could be a focus of further programs in curriculum development.

One advantage of this sort of workshop is that it is often possible to apply for separate funding to put on the workshop. Depending on the funding agency or institution, this can be for workshop operations or sometimes for participant stipends or travel. Finding the participants for whom the subject content is directly related to their background can lead to outstanding presentations and the enthusiasm needed for self-perpetuation.

Technician Education in Additive Manufacturing.

The advance of additive manufacturing (AM) technologies has added to the curriculum in a variety of areas. As new materials are developed, and 3D printers are increasingly capable of utilizing multiple materials, it is imperative that technicians understand these material's properties and how they interact with other components of the system involved. MatEdU has addressed this potential gap in the convergence of additive manufacturing and materials through the Technician Education in Additive Manufacturing & Materials (TEAMM) project [17], which has included the identification and adaption (or adaptation?) of ASTM skills standards to keep pace with advances in research and development. TEAMM is supported through the utilization of social networking technologies, proactive identification and communication with key stakeholders, and improved access to professional development.

The National Science Foundation's Guitar Building Workshops

The NSF ATE Guitar Building Workshop program has provided an excellent example of hands-on learning and methods to infuse materials into a curriculum. Instructors at all levels benefit from this program to help their students build an electric guitar by applying scientific, engineering, and technological principles. Participants are presented with methods to teach applied learning techniques that help engage students and spark enthusiasm to learn STEM subjects. This had been a national program funded by NSF ATE and hosted by various institutions across the U.S.

Guitar building is a perfect means of demonstrating the need to apply materials concepts [18]. The specific type of wood identified to provide the guitar's tone is critical and has been the subject of a recent detailed investigation [19]. To design and build a guitar, materials properties of wood and the process of working the wood must be considered, along with properties and types of metals, properties of polymers, and the behavior and application of polymers in the system. Building a guitar also requires other STEM-related concepts, including;

- Mathematics: geometry of the body design, fret spacing, musical scales;
- Physics: frequency, string tension, waves, tones;
- Electronics: solenoids tolerances, intonation;
- Acoustics: body design, wood selection, intonation.

The STEM Guitar Project is still significantly impacting the ATE community. ATE Central is working with the former P.I. to create an ATE Impacts video. The NSF ATE Impacts coordinator will highlight the project through a video of ATE successes that have continued beyond the grant. The project team continues to collaborate with three of the most well-recognized guitar companies: Fender, Taylor, and Gibson. The video intends to highlight the project's long-standing industry linkages, their partnerships with educational institutions nationally, and the overall long-running project impacts. The goal of the video is to show the country the interaction and support of the guitar manufacturing community and the impact of STEM guitars on students. The video is expected to be released in early 2024.

Technology Curriculum Development

Developing educational lessons, labs, and related activities has been a principal focus of MatEdU [20]. To make it easier for new authors, MatEdU developed an outline that could be followed in lesson development. The lessons were called "modules" to emphasize that all types of lessons, labs, and other related curricula were to be included. All modules, after receipt and an initial review by the MatEdU Editor, were peer-reviewed by an expert in the field who could determine if the science or technology was correct and whether the presentation was such that it could be used in a classroom by an instructor who was not intimately knowledgeable with the content.
Many educators have taken the opportunity to develop curricula, usually related to presentations they had made at meetings, lessons they have used in their teaching, or related opportunities. Hands-on lessons, labs, and case studies were encouraged. When a specific need became clear, MatEdU put out a call for authors. This yielded authors from high schools, colleges, and universities and from engineering and technology companies where there were interested individuals. College instructors, in particular, were interested because it allowed them to add a peer-reviewed publication to their resume.

Various organizations, such as the nanotechnology center “NACK” [housed at Penn State University], provide curriculum development opportunities for college instructors. However, at pre-college and community college technology levels, not many instructors take the time to develop hands-on technology modules that others can use. This is a significant gap since technology instruction in high schools, in particular, needs top-quality, up-to-date curricula. Opportunities exist to build technology instruction into some high school science classes by introducing hands-on technological concepts needed to demonstrate science principles. High school science is an excellent venue for introducing technology in applying the science presented in the curriculum.

One collaborator of note is the ASM Materials Education Foundation, which has developed a curricular program that introduces K-12 teachers to materials science [2]. Workshops are provided annually in a hands-on format that allows participating instructors and teachers to experience activities that they can use in their classrooms. This enhances teachers' understanding and makes science, technology, and engineering classes more exciting for students. A wide variety of lessons are available but without the formality of MatEdU modules.

MatEdU partner Colorado School of Mines has tackled the question of how best to provide STEM resources to students in multi-lingual classrooms. The CSM Critical Materials Institute focused on developing lessons based on current and relevant STEM research topics for students in K-12 classrooms who are just learning English [21]. Lessons are structured in a supportive manner for students using visuals, fill-in-the-blanks, and word banks. Teachers are also provided with step-by-step guides, quick visuals, graphs, and engaging activities to help them teach the concepts and terminology to multi-lingual learners. Collaborating with Rocky Mountain Mathematic Engineering Science Achievement (RM MESA), they are pleased to say that they have just "delivered a lesson to teachers who are going to be reaching 600 underserved students this year!”

One of the limitations of developing and publishing hands-on curricula related to technology is a lack of incentive. At the community college level, in particular, there are no incentives for faculty to publish that there are at the university level. The MatEdU program has benefitted from the use of small financial incentives provided by an outside contractor, which allowed community college instructors to develop useful modules in areas such as critical materials and composites. Also, through collaboration with ~~the~~ Nano-Link, an NSF ATE-funded regional center, the MatEdU module collection included listings of 18 nanotech modules in English plus their translation into Spanish.

Information on student internships and the innovative use of competency-based apprenticeship programs developed using MatEdU curricula have been successful and are expanding. Students are recruited from high schools and community colleges in areas of interest to a company and work and learn in specific areas focused on core competencies for that area. This type of opportunity is often appropriate for students who are not 4-year college-bound and often can be used to enhance the diversity of the company's technician workforce. Core competencies in numerous areas are available for faculty and student use [11]. College-bound students are provided basic information on the many available options under the Student Resources tab.

Enhancing Undergraduate Research in Community Colleges

Research opportunities are widespread at universities and 4-year colleges, but community college students often lack this opportunity. As noted above, faculty have little incentive to develop and publish papers or curricula on their new ideas in curriculum. One way to help faculty provide research opportunities for students is to introduce short, course-based undergraduate research projects. This can help broaden students' ideas and be a good introduction to solving problems in industry. Such projects can be based on the subject at hand and can provide faculty with subject content for a published paper.

One way of introducing such research into courses is through "hackathons" [22], in which a small group of students with mentors from academia or industry undertakes creative problem-solving. Hackathons are a way to offer short-duration projects that often fit easily into course curricula and allow the students to be creative and learn something new that is perhaps tangential to the course curriculum. Short-term projects created by engineers and scientists in local industries can provide a source for such projects.

MatEdU collaborators have been involved in generating undergraduate research in community colleges using the hackathon approach. One example is an investigation as to means of reducing the weight of paint used on an aircraft. The weight of paint on a large aircraft can be substantial and will increase if a second coat is required [23]. A student project focused on using technology to enhance coverage of the first coat to reduce the need for a second, thus reducing aircraft weight. Another looked at tools used in antibody engineering, involving both computational work and laboratory measurements [24]. Getting students into short-term research opens up a wide variety of potential options for students and creates ways for instructors to broaden their curricula. Reporting on hackathons and other projects at the community college level is critical for the advancement of technological education.

Faculty Mentoring for Grant Writing

MatEdU collaborates in developing peer mentors for faculty wanting to develop programs within the National Science Foundation's Advanced Technological Education (ATE) program. Mentoring of faculty by experienced project investigators "broadens participation in ATE and develops the next generation of leadership to ensure the advancement of technician education in support of our nation's economy" [25]. Personal mentoring will be critical in developing new programs in areas such as energy, environmental, and transportation technologies, which can involve critical and rare earth materials and their practical ramifications in transportation systems, high-power batteries, and clean energy.

One example here is the maritime technology program at Skagit Community College. Mentoring from MatEdU included the development of programs that benefit both entities, with curriculum development relevant to both and collaborative programs. Developing connections between program developers has been critical. Continual communication on all aspects of MatEdU has enhanced programs and developed faculty members who can design and handle programs as they expand.

The mission of these mentoring programs is to help community colleges find and develop grant funding using real-time leadership development and technical assistance. Over the past several years, this program has generated a variety of ATE proposals from many community and technical colleges across the U.S. Some programs have had success by adding a coaching component to the grant-writing process [26]. Mentoring and coaching techniques apply well to collaborative projects and are enhanced by a mentor's experience in networking among peers and colleagues at other institutions.

Discussion and Conclusions

Tremendous advances in technology have been made over the past few years in many areas. These advances are widely reported in the science and technology literature and often in the popular press. At the level of technician education, one could expect an accompanying set of literature discussing how programs have been developed to affect the needed training. Unfortunately, such advances in education and training are not always available. This is most acute at the community and technical college level, where programs such as the NSF Advanced Technological Education (ATE) Program accomplish much of this critical work.

MatEdU has operated successfully for over eighteen years and has pointedly attempted to provide information on its programs using the internet, op-ed articles in technical journals, and scholarly publications [4,27-29]. MatEdU personnel have also been involved with undergraduate research and mentoring for grant writing, where incentives from colleges and industry could be used to enhance the reporting of successful projects.

While MatEdU has seen considerable progress in the programs discussed earlier, a significant impact of the program has been the implementation of the infusion of materials technology into multiple areas, from technology and electronics education to advanced manufacturing, clean energy, and critical materials utilization. This includes enhanced faculty knowledge and an overall faculty understanding of the role of science in technology and engineering. It has also provided ideas for increased student interest and for updated workforce training programs. Numerous partnerships and collaborations have enhanced MatEdU programs and many other institutions.

The National Educators Workshop and the M-STEM workshops were highly impactful to those instructors who attended. The attitude was that "if you (a presenter) can do this in your classroom, I should be able to do the same" - that is, these programs developed trust and confidence among participants and helped all to expand their ideas. In a survey, M-STEM participants estimated that their work would impact over 3000 students per year. However, a focus needs to be made on female instructors, as only 39% of the participants were female during the most recent three years.

Other means of developing faculty involvement included Showcases, NSF events, Elementary School STEM nights, and the Latino Leadership Initiative. Over 2000 instructors and up to 7800 individuals were reached using these programs in the most recent 3-year period.

Data on website use, provided by Google Analytics, show that multiple visitor sessions of 500 or more were recorded during the past several years, realizing a new visitor gain of about 1000 each year. Website discovery and traffic were enhanced by including the most-used keyword search terms, resources, and types of materials. In the site's metadata, these terms account for 47% of all visits, with an average time on related pages of 3 minutes, well over the average duration reported by Nielsen Norman Group.

Among the top website targets by visitors are the curriculum modules. During 2022, there were 154 downloads, with the Materials Science Educational Handbook chapters dominating; 65% of visits turned into downloads. Organic sources (searches from a search engine) yield the most visits, 71% of all traffic, while direct sources (where MatEdU is bookmarked from an external source) yield 24%, and referrals (where MatEdU is linked from an external source) yields 4% of the total website traffic. These observations indicate that users have grown to trust and are interested in the content on the website, and signifies an increasing use in the future. The website is easily discoverable and has content that the users want, leading to its success. Search engine results consistently put www.materialseducation.org in the top tier of websites used in searches. Over 6000 users annually accessed 100 social media postings, enhancing audience impact.

A wide variety of instructors have indicated that using the MatEdU instructional modules in the classroom has led to increased student learning. Recent enhancements to include rare earth elements, critical materials, and composite, natural, micro, and nano-materials make the module collection valuable. Expanding the scope of available instructional materials would continue to make the website even more valuable to instructors and students.

Materials Science is a rapidly expanding area, and numerous colleges are interested in starting an academic program in the area. MatEdU's recent case study provides a blueprint for a learning environment in Materials Science. This blueprint has been presented at a wide range of conferences and secondary and post-secondary institutions [16], resulting in considerable interest being developed in several institutions and organizations. While Materials Science is the focus of this case study, the principles involved could easily be adapted to other subjects and the expanding world of materials.

The MatEdU program has provided means whereby instructors can publish their curriculum modules under rigorous rules (with peer review) and has provided means for instructors to present and publish the results of their educational activities. The new Journal of Advanced Technological Education, J ATE, in which this article appears, is specifically designed to provide a means for such reports to appear in print. Using the models provided in this paper, subsequent programs can further develop the ideas presented here, present the results in future publications, and provide future generations of faculty and students with enhanced educational programs in technology.

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