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A Novel Curriculum for an Engineering Degree in STEM Education and Teacher Preparation

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Abstract

With the rapid development in science and technology and their impact on the global economy, there has been a pressing need for an evolution in Science, Technology, Engineering, and Mathematics (STEM) education for K-12 students. STEM labs and activities have become very popular in schools and favorable activities for students. STEM-based schools have been established in several countries in response to the students' passion for science and engineering. While STEM refers to Science, Technology, Engineering, and Mathematics, the engineering part removes the barriers and encapsulates all the other topics within its applications. Therefore, STEM educators with an engineering technology background would significantly impact students' project-based and hands-on learning.

This paper presents a unique engineering technology degree in STEM Education developed and implemented at Texas A&M University. The STEM Education engineering degree resulted from a collaboration between the College of Engineering and the School of Education and Human Development, and it is offered within the Multidisciplinary Engineering Technology program in the Department of Engineering Technology and Industrial Distribution. The STEM Education teacher certification track represents a novel engineering program that prepares the needed future STEM educators who will inspire K-12 students to be future scientists and engineers. STEM Education students take courses from the College of Engineering and School of Education and Human Development toward a Bachelor of Science in Multidisciplinary Engineering Technology. These students are also prepared to become certified in teaching engineering, mathematics, and physical science, thanks to the program's cutting-edge technical knowledge and teaching methods.

The paper presents the degree curriculum, integrated technology used, skill set taught to students, examples of project-based courses, external student training, and the future outlook and challenges for the program. This paper will provide clear pathways for establishing similar programs at engineering schools worldwide.

Introduction

STEM (Science, Technology, Engineering, and Mathematics) education will play a vital role in shaping the future of technology development [1]. In an increasingly complex and technologically driven world, implementing STEM skills in K-12 education is crucial for fostering innovation, critical thinking, analytical, and problem-solving skills. In addition to early preparation of students for a wide range of careers in STEM fields such as engineering, computer science, medicine, and environmental science. Moreover, STEM education cultivates a mindset of curiosity and inquiry, encouraging students to explore the world around them and seek solutions to real-world challenges [2]. As technology continues to advance rapidly, individuals with STEM expertise are well-positioned to contribute to advancements that benefit society, from addressing environmental issues to developing groundbreaking technologies. By promoting STEM education, future generations are empowered to be active participants in the global knowledge economy, driving progress and ensuring a sustainable and prosperous future. Developing countries that adopt STEM education in their K-12 education have shown rapid development in their economies [3,4].

STEM education faces several challenges that impact its effectiveness and inclusivity. Insufficient resources, both in terms of funding and quality teaching materials, hinder the ability of educators to provide hands-on and engaging experiences for students [5]. Additionally, there is a persistent gender and diversity gap in STEM fields, with underrepresentation of women and minority groups. This lack of diversity not only limits the talent pool but also narrows the perspectives brought to problem-solving [6]. Moreover, the fast-paced evolution of technology requires constant updates to curriculum and formal teacher training, posing a challenge to educational institutions to stay current [7]. Access to STEM education is also unevenly distributed, with disparities in opportunities between urban and rural areas or affluent and economically disadvantaged communities. Addressing these challenges requires collaborative efforts from educators and industry stakeholders to ensure equitable access, promote diversity, and provide the necessary support for effective STEM education that prepares students for the demands of the 21st-century workforce.

The demand for qualified STEM teachers is more critical than ever, as these educators play a pivotal role in shaping the next generation's skills and mindset. A shortage of skilled STEM teachers exists globally, limiting students' access to quality education in these crucial fields. Competent STEM instructors inspire curiosity and foster analytical thinking, instilling a passion for discovery and problem-solving [9]. With technology advancing rapidly, the need for educators who are well-versed in STEM subjects is evident. Effective STEM teachers not only impart knowledge but also nurture creativity, critical thinking, and innovation—essential skills for future success. By preparing STEM educators at the early stages of their education, we can bridge educational gaps, encourage underrepresented groups to pursue STEM careers, and prepare students to navigate an increasingly complex and technologically driven world.

The pressing requirement for an increased number of proficient and impactful STEM educators is evident in our quest to build a capable workforce [10,11]. This leads to the need for an undergraduate STEM Education degree, which emphasizes integrated inquiry and innovation and equips the teacher to prepare students for success in the 21st-century economy. In this paper, a unique engineering degree in STEM Education is presented. The current curriculum and the key courses are explained, as well as how they impact the preparation for the future cohorts of STEM Educators. The examples and program progress presented in this paper reflect the first cohort of 12 students. To date, graduates of the program have achieved a 100% pass rate on the Texas certification exams in mathematics, physical science, and engineering. Furthermore, the challenges and future improvements are discussed in this paper.

University Degrees in STEM Education

Undergraduate and graduate STEM education degrees offer a focused pathway for students entering STEM fields. However, most of these degrees are missing the engineering aspect of the STEM concept. Several programs offer STEM Education degrees, but the focus is mainly on Education, Math, Science, Information and Communication Technology (ICT), and, in some limited schools, Computer Science and Entrepreneurship are offered. Table 1 lists examples of STEM education degrees. The common gap in these programs is the lack of covering a broad range of engineering courses to enable the educator to develop and teach project-based real-life projects for the students.

Table 1: Examples of university Degrees in STEM Education

Level/Degree	Emphasis	Delivery	Institution	Country
Undergraduate (B.S.)	STEM Entrepreneurship	Traditional	Florida State University	USA
Undergraduate (B.S.)	Science, Math & Computer Science	Traditional	Merrimack College	USA
Undergraduate (B.Ed.)	Science, Math, ICT, Technology	Traditional	University of Johannesburg	South Africa
Undergraduate (B.S.)	Education, Science & Math	Traditional	University of Maryland Baltimore County	USA
Undergraduate (B.S.)	Education, Science & Math	Traditional	Hamline University	USA
Undergraduate (B.S.)	Science & Math	Traditional	Southern Arkansas University	USA
Graduate (M.S.)	Strategies & Techniques	Online	University of Iowa	USA
Graduate (M.Ed.)	Research	Online	University of Texas at Austin	USA
Graduate (M.Ed.)	Curriculum And Instruction	Online	Texas Tech University	USA

The Multidisciplinary Engineering Technology Program

The STEM Education engineering program presented is one of three engineering technology tracks in the Multidisciplinary Engineering Technology (MXET) Program in the Department of Engineering Technology and Industrial Distribution (ETID) at Texas A&M University. The MXET program was established to equip the students with multidisciplinary engineering knowledge and skills combining Mechanical, Electronics, and Computer Engineering fields. The advantage of an engineering technology degree is the extensive hands-on skills in labs backed by theoretical and scientific engineering education in lectures taught by a diverse range of university-level educators, including academic professors and professors of practice with wide industrial experience.

The MXET program offers three tracks, Mechatronics Track (established in 2016) [12], STEM Education Track (established in 2017) [13], and Electro Marine Track (future program) [14] in three locations in Texas as shown in Figure 1.

Figure 1: MXET program tracks and locations

The current active tracks incorporate courses from multiple disciplines, including Mechanical and Manufacturing Engineering Technology (MMET), Electronic Systems Engineering Technology (ESET), Multidisciplinary Engineering Technology (MXET), and School of Education and Human Development (SEHD) teacher certification courses. Figure 2 shows the brief course distribution.

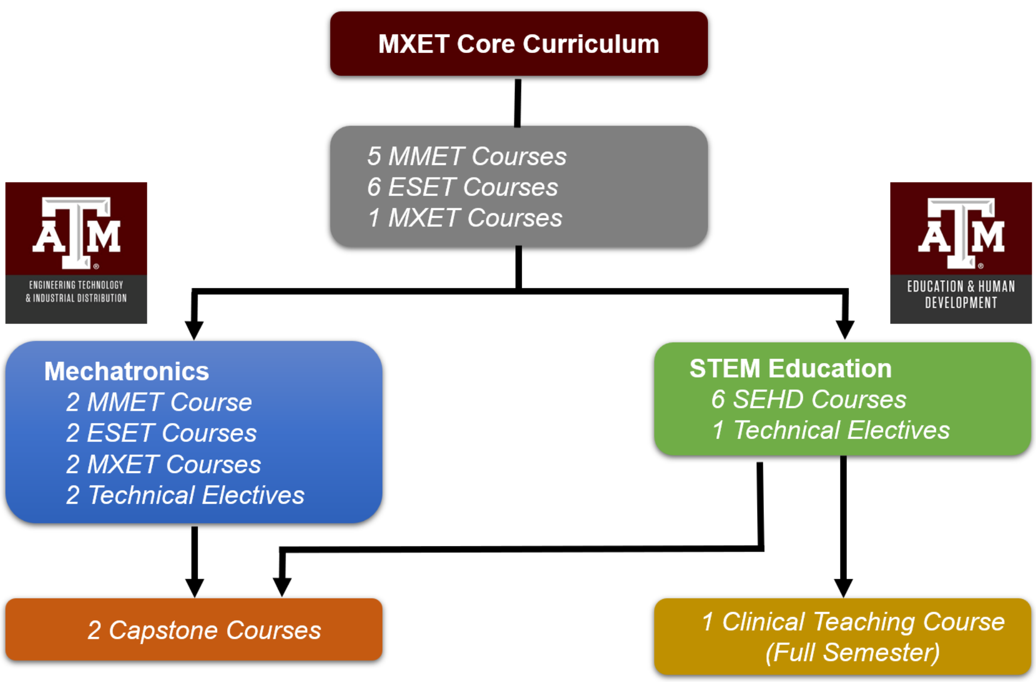

Figure 2: MXET core curriculum

A unique quality of this program is that it is both ABET-accredited and accredited by the Texas Education Agency. The MXET program vision and mission are based on Program Educational Objectives (PEOs) to produce graduates who will [15]:

- Possess and demonstrate technical knowledge of the design, manufacture, sales, and service of complex systems that span multiple engineering technology disciplines.
- Demonstrate an increasing level of leadership and responsibility.
- Exhibit productivity in a dynamic work environment through a commitment to lifelong learning.
- Exhibit a commitment to professional ethics in their professional careers.

The STEM Education Degree Curriculum

The STEM Education track at MXET program offers a Bachelor's Degree in Engineering Technology. The track is offered by the Department of Engineering Technology and Industrial Distribution (ETID) in collaboration with the School of Education and Human Development (SEHD). This fruitful collaboration between engineering and education fields bridges the critical gap in STEM educator preparation. This preparation can be described in three phases with some overlap between them.

In Phase I, the students are initially admitted to the general engineering year at Texas A&M University. The students learn the foundation of engineering supported by Math and Chemistry courses (see Table 2).

Table 2: General engineering curriculum at Texas A&M University

	First Year	HRs
Fall	**Total**	**16**
CHEM 107	General Chemistry for Engineering Students	3
CHEM 117	General Chemistry for Engineering Students Laboratory	1
ENGL 103	Introduction to Rhetoric & Composition	3
ENGR 102	Engineering Lab I - Computation	2
MATH 151	Engineering Mathematics I	4
UCC	University Core Curriculum	3
Spring	**Total**	**15**
ENGR 216	Engineering Lab II - Mechanics	2
MATH 152	Engineering Mathematics II	4
PHYS 206	Newtonian Mechanics for Engineering & Science	3
UCC	University Core Curriculum	3
UCC	University Core Curriculum	3
CHEM 120	Fundamentals of Chemistry II [4 cr]	Or

In Phase II, before the second year, through the Entry to Major process (ETAM), the students apply for the MXET program (all tracks). Starting in the second year, the students learn specific courses in MMET, ESET, and MXET, which are supported by Physics and Math courses.

In Phase III, the STEM Education track students start taking SEHD courses (twenty-nine credit hours), which include field training (Observation Hours) in some courses and a semester-long internship or clinical teaching capstone experience in one of the Secondary schools.

Table 3 lists all degree plans for STEM Education track students, highlighting the SEHD courses. This extensive training in diverse engineering topics, hands-on laboratories, pedagogy and teaching skills, and field training led to the graduation of the students with qualifications to take the State of Texas Certification Exam and hence receive the following:

- Bachelor's degree in engineering technology.
- Teacher certification in mathematics (State of Texas).
- Teacher certification in physical science (State of Texas).
- Teacher certification in engineering (State of Texas).

The ETID department oversees and conducts advising for the engineering courses, while SEHD oversees and conducts advising for SEHD teacher certification courses. The Department of Teaching, Learning and Culture (TLAC) at Texas A&M University, through aggieTEACH program, prepares the candidates for initial certification so that they can enter the secondary classroom (grades 7-12) after graduating with a bachelor's degree. The admission requirements and required courses are reviewed annually to be aligned with the State of Texas certification requirements [16] as shown in Figure 3. Table 3 shows the classification of the engineering (ENG) courses, the SEHD course, and the required courses for the certification (CERT) process.

aggieTEACH Admission Requirements

- Currently enrolled as an undergraduate student at Texas A&M University
- Minimum of 3 semesters remaining in undergraduate coursework
- 15 credit hours in certification content
- 2.75 overall GPA in undergraduate coursework
- 2.5 minimum GPA in major-area content hours
- aggieTEACH application & program acceptance

Required SEED/Teacher Certification Coursework

COURSE	HRS
INST 210: Understanding Special Populations	3
RDNG 465: Reading in the Middle and Secondary Grades **OR** RDNG 372: Reading & Writing across Middle Grade (Summer Distance Ed)	3
You must be formally admitted into the aggieTEACH SEED Minor program before registering for EDCI 358 & Clinical courses	
CLINICAL 1	
TEFB 322: Teaching and Schooling in Modern Society (field: ½ day/week)	3
EDCI 358 Cohort: Instructional Methods in Engineering & Technology Education (Taken concurrently with Clinical 2 **OR** Clinical 3)	3
CLINICAL 2	
TEFB 324: Teaching Skills II (field: ½ day/week)	3
CLINICAL 3	
TEFB 406: Science in the Middle & Secondary School **OR** TEFB 407: Math in Middle & Secondary School (field: ½ day/week)	3
CLINICAL 4 ADDITIONAL SEMESTER	
MEFB 497, TEFB 429, or TEED 425: Clinical Teaching	6, 9 or 12

GRADUATION UPON COMPLETION OF CLINICAL TEACHING

Figure 3: aggieTEACH SEED minor coursework for MXET program [16]

Table 3: MXET STEM Track Curriculum at Texas A&M University

	Second Year	HRs	ENG	SEHD	CERT
Fall	**Total**	**16**			
PHYS 217	Engineering Lab III - Electricity & Magnetism	2			
ESET 210	Circuit Analysis	4	√		
ESET 219	Digital Electronics	4	√		
MMET 207	Metallic Materials	3	√		
PHYS 207	Electricity & Magnetism for Engineering & Science	3	√		
Spring	**Total**	**17**			
ESET 269	Embedded Systems Development in C	3	√		
ESET 350	Analog Electronics	4	√		
MMET 275	Mechanics for Technologists	3	√		
INST 210	Understanding Special Populations 1	3		√	√
MMET 370	Thermodynamics for Technologists	4	√		
Summer	**Total**	**3**			
MATH 304	Linear Algebra (forced of math elective)	3			√
	Third Year				
Fall	**Total**	**18**			
ESET 349	Microcontroller Architecture	4	√		
MXET 375	Applied Dynamic Systems	3	√		
MMET 376	Strength of Materials	4	√		
TEFB	Introduction to Culture, Comm, Society & Schools	3		√	√
STAT 211	Principles of Statistics I (forced technical elective)	3			√
	Technical Elective	1			
Spring	**Total**	**16**			
ENTC 399	High Impact Experience	0			
ESET 359	Electronic Instrumentation	4	√		
MMET 363	Mechanical Design Applications I	3	√		
ESET 419 or MMET 429	Engineering Technology Capstone I Managing People & Projects in a Techn Society	3	√		
RDNG 465	Reading in the Middle and Secondary Grades	3		√	√
TEFB 324	Teaching Skills II	3		√	√
Summer	**Total**	**6**			
UCC	University Core Curriculum	6			
	Fourth Year				
Fall	**Total**	**14**			
ESET 420 or MMET 422	Engineering Technology Capstone II Manufacturing Technology Projects	2	√		
EDCI 358	Instructional Methods in Eng & Tech Education	3		√	√
TEFB 406	Science in the Middle and Secondary School	3		√	√
TEFB 407	Mathematics in the Middle and Senior School [3 cr]	Or		√	√
UCC	University Core Curriculum	3			
COMM 203	Public Speaking	3			
COMM 205	Communication for Technical Professions [3 cr]	Or			
ENGL 210	Technical and Professional Writing [3 cr]	Or			
Spring	**Total**	**6**			
MEFB 497	Supervised Clinical Teaching	6		√	√

The program structure presented requires that students start with a traditional engineering technology program, including math, physics, and chemistry, along with engineering technology technical courses. This sequence prepares a teacher like none other in the teaching profession. This next generation of engineering-trained teachers brings to the K-12 classroom a strong preparation for the authentic application of mathematics, science, and engineering technology. This approach is a formal method of placing engineering-trained teachers' front-and-center in the K-12 classroom. Teacher candidates from this program are uniquely equipped to integrate mathematical, scientific, technological, and engineering principles in design problems that engage students in challenging and meaningful STEM learning experiences. As the student progresses through the third and fourth years, education courses related to educator licensure and practice in school settings are also taken.

Program Enhancement

To further support the STEM track students in their STEM educator preparation journey, professional development workshops in partnership with industrial stakeholders are provided to the students at no cost. For example, LEGO Education Facilitated Professional Learning [17] was provided by a certified LEGO Education Academy trainer to enable educators to actively engage in experiential professional learning programs designed to produce a robust set of transferable instructional skills and strategies that foster student success as shown in Figure 4 [18]. Having trained, the students are led by MXET faculty to deliver robotics workshops for local schools shown in Figure 5 [19]. MXET program partnered with Pitsco Education to provide teacher professional development workshops in advanced robotics, and drone programming [20].

Figure 4: Professional development workshops for STEM track students [18]

Figure 5: STEM track students deliver robotics workshops to local schools [19]

Challenges and Future Courses

1. Current Challenges

1.1 Limited Pathways

The first challenge for the MXET faculty is how to create different pathways for students to join the STEM Education track at MXET. Recruitment and advertisement for the program mainly start by the end of the general engineering year. By this time, the students who joined the College of Engineering usually have decided earlier on their desired major in engineering. A pathway to allow the student to join the STEM Education track with suitable admission requirements will bring the attention of many students who are passionate about STEM education.

1.2 Curriculum Update Timeline

Based on the same vision of developing this novel engineering degree, continuous curriculum update is required to keep the future STEM Educator up to date with the rapid development in engineering and technology. Changing an engineering curriculum can be a complex and challenging process due to various factors, including [21,22]:

- Accreditation and Certification Requirements: Engineering programs often need to adhere to accreditation standards set by professional bodies. Any changes to the curriculum must align with these standards to ensure that graduates meet the requirements for professional licensure [23].
- Resource Constraints: Implementing changes in a curriculum may require additional resources such as faculty training, updated materials, and new facilities. Limited budgets and resource constraints can hinder the implementation of desired changes.
- Faculty Resistance: Faculty members may resist change, especially if it requires them to learn new technologies or methodologies. Convincing experienced educators to adopt new teaching methods or revise their courses can be challenging.
- Time Constraints: Engineering programs are often structured with a specific timeline, and any changes may impact the graduation timeline for current students. Balancing the need for improvement with the desire to avoid disruption to ongoing programs can be challenging.
- Industry Relevance: Engineering curricula need to stay relevant to industry demands and technological advancements. It can be challenging to keep the curriculum updated in real-time, given the rapidly changing landscape of technology and industry needs.
- Stakeholder Involvement: Involving various stakeholders, including industry professionals, alumni, and students, in the decision-making process is crucial. Balancing the diverse interests and expectations of these groups can be a challenge.
- Interdisciplinary Integration: With the increasing importance of interdisciplinary skills in engineering, incorporating diverse subjects into the curriculum can be challenging. Coordinating efforts across different departments or schools within an institution can be complex. A positive engineering and education faculty collaboration is essential to bringing about real change in the development of a next generation STEM teacher with a powerful engineering background.

- Globalization and Cultural Considerations: In a globalized world, engineering programs may need to consider international standards and cultural diversity. Adapting the curriculum to address global perspectives and cultural differences can be challenging.
- Technology Integration: Integrating new technologies into the curriculum, such as online learning platforms or simulation tools, may face resistance or challenges related to infrastructure, access, and faculty expertise.
- Assessment and Evaluation: Developing effective methods for assessing student learning and program outcomes following curriculum changes is crucial. Designing fair and reliable assessment tools that measure the desired skills and competencies can be challenging.

Addressing these challenges requires careful planning, collaboration, and a phased approach to curriculum changes. Involving all stakeholders, staying informed about industry trends, and maintaining flexibility in response to evolving needs are essential elements for successfully navigating these challenges.

2. Future Courses

In the last few years, faculty from MXET and SEHD have identified the pressing need for new courses to be integrated into the current curriculum either as technical electives or replace out-of-date courses not aligned with the program objectives. For example, the recent courses under development and approval are briefly reviewed below:

2.1 Engineering Design & Project-Based Learning (By Dr. Garth V. Crosby (MXET) & Dr. Bugrahan Yalvac (SEHD))

This course is an applied research training and unique engineering education design experience which meets the 29-hour STEM Education focus area requirements. The course will be delivered in two modules — Module 1, Applied Research Training, and Module 2, Engineering Education Experience. The course will: equip engineering preservice teachers with the skill sets to lead engineering project design experiences for both secondary school students and in-service teachers; provide formal and on-the-job training by Spark! PK-12 Engineering Education Outreach through existing STEM outreaches to underrepresented secondary school students; provide teaching practice to participate as co-instructors in training for certified in-service teachers; and connect applied research practices to develop a proposal for an Engineering Capstone Project.

2.2 STEM Education Foundations (By Dr. Mohamed Gharib (MXET))

This course is a hands-on, project-based course in STEM Education practice. The students will learn how to develop hands-on workshops on several topics in science and engineering for K-12 education, including prototyping, engineering design, mobile app development, 3D CAD design, LEGO Education Academy approach, FIRST robotics, VEX robotics, and SeaPerch ROVs. The lectures will focus on the approach, planning, analyzing recent advances, and aligning with national standards. The lab sessions will be project-based STEM workshops. A final project will be a full workshop implementation demo with the development of teaching material and a report. Several topics in the course are based on the case studies presented in [24-30]

3. Discussion

3.1 Comparison with other approaches

Texas A&M University's joint engineering-education curriculum develops teachers with a very different background than most current secondary STEM or technology and engineering education teachers. Our graduates will possess an accredited engineering degree that gives them the knowledge and skills of an engineer that can be used to further enhance the quality, focus, rigor, and relevance of secondary school STEM or technology and engineering education programs. Most current efforts at integrating engineering education into the secondary experience are either attempts to provide some skill to traditional science or math education teachers or the development of engineering-based curricular materials and experiences that may be presented by technology education teachers or by visiting engineers. Engineering technology program graduates will have a deeper understanding of the integration of STEM content, engineering science, and the engineering design process than can be developed in other engineering technology degree programs.

Therefore, engineering technology as the pre-service academic preparation for the next generation STEM teacher will add a dynamic element to our K-12 schools. The product is a highly qualified teacher versed in the sciences, technology, engineering, and mathematics who would close the subject and learning relevance gap through authentic application, exploration, design, and inquiry in classrooms.

Summary

We ask you to imagine a world in which workers are technically competent but technologically illiterate. A world in which a person can "fix" a hardware problem with a personal computer but may not be able to evaluate the risks, benefits or tradeoffs associated with understanding if a gas-electric hybrid engine is a good investment, or if it would be better for the environment than a traditional internal combustion engine. Our citizens, our economy, our environment, and our democracy are all dependent upon a certain level of "technological understanding" and ways of coming to know the important interdependence of STEM subjects. How can a person reasonably vote in an election on issues such as "Star Wars Defense System", "Human Cloning", "Fuel Cells", "Flexible Transistors", "Robots", "Nanotechnology", etc… without having general background knowledge in engineering and technology? Unless action is taken, we are at a crossroads where citizens can be trained to do a skilled job but not understand the benefits or consequences of using a present or future technology rationally and responsibly. In reality, few students are leaving our K-12 schools today with adequate literacy in engineering and technology to become the informed citizens of tomorrow and making informed educational choices for their future.

The study of engineering in education helps create a citizenry that is highly literate, disciplined, capable of thinking critically and creatively, knowledgeable about a range of cultures, and able to participate actively in discussions about new discoveries and choices. Students are leaving our K-12 educational systems with an adequate understanding of educational technology (computers), but dangerously lacking in the skills and abilities to make informed decisions on present and future engineering and technological issues.

Texas A&M University and indeed the entire engineering technology and education community can take a proactive leadership role in initiating systemic change in STEM teacher preparation that will positively influence the future of all k-12 education. This new joint degree program is built on new partnerships across traditional academic and disciplinary lines to innovate, cooperate, and prepare highly qualified teachers.

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References

[1] R. Tytler, "STEM education for the twenty-first century." Integrated approaches to STEM education: An international perspective, pp. 21-43, 2020

[2] S. Ardianti, Y.P. Dwi Sulisworo, and R. Widodo, "The impact of the use of STEM education approach on the blended learning to improve student’s critical thinking skills." Universal Journal of Educational Research, vol. 8, no. 3, pp. 24-32, 2020.

[3] T.W. Teo, "STEM education landscape: The case of Singapore." In Journal of Physics: Conference Series, vol. 1340, no. 1, p. 012002. 2019.

[4] F. Kayan-Fadlelmula, S. Abdellatif Sellami, A. Nada, and U Salman, "A systematic review of STEM education research in the GCC countries: Trends, gaps and barriers." International Journal of STEM Education, vol. 9, no. 1, pp. 1-24, 2022.

[5] H. El-Deghaidy and M. Nasser, "Science teachers’ perceptions of STEM education: Possibilities and challenges." International Journal of Learning and Teaching, vol. 1, no. 1, pp. 51-54, 2015

[6] O. Lee, "Effective STEM education strategies for diverse and underserved learners." In Workshop of the Committee on Highly Successful Schools or Programs for K-12 STEM Education, National Research Council, Washington, DC, 2011.

[7] M.E. Madden, B. Marsha, B. Heather, B. Kimberley, H. Derek, H. Mark, L. Brian, P. Jill, and P. Gordon, "Rethinking STEM education: An interdisciplinary STEAM curriculum." Procedia Computer Science, vol. 20, pp. 541-546, 2013

[9] P.R. Hernandez, B. Ralph, W.E. Jonathan, I. Badaruddin, E.R. Karen, W.C. Thomas, and M.A. de Miranda. "Connecting the STEM dots: Measuring the effect of an integrated engineering design intervention." International journal of Technology and design Education, vol. 24, pp. 107-120, 2014.

[10] M.A. de Miranda, "Interdisciplinary Learning New Perspectives on Interdisciplinary Teaching and Learning: Shifting Pedagogies of the Profession and the Muddy Puddle of STEM Teacher Associational Fluency." The Bloomsbury Handbook of Technology Education (2023).

[11] T.J. Siller, M.A. de Miranda, and D. Elizabeth "Board 137: Engineering Pathways for P-12 Teacher Preparation." In 2018 ASEE Annual Conference & Exposition, 2018.

[12] J. R. Porter, J.A. Morgan, W. Zhan, and M. Johnson, "Multidisciplinary Engineering Technology: Addressing the Change in Industry Workforce Needs." In 2016 ASEE Annual Conference & Exposition, 2016.

[13] J. Porter, and J. Morgan, "Multidisciplinary engineering technology: Rapidly responding to educational opportunities." In 2018 ASEE Conferences-Conference for Industry and Education Collaboration/San Antonio proceedings, 2018.

[14] J.R. Porter, A.K. Verma, M. Gharib, A.L. Moore, "Multi-campus Collaborative Degrees: A Proposed Degree in Marine Mechatronics", In 2024 Conference for Industry and Education Collaboration, 2024.

[15] Multidisciplinary Engineering Technology - BS, STEM Education Track. Available at: *https://catalog.tamu.edu/undergraduate/engineering/technology-industrial-distribution/multidisciplinary-engineering-technology-bs-stem-education-track/*

[16] Texas A&M aggieTEACH SEED MINOR. Available at: *https://tlac.tamu.edu/academics/aggieteach-secondary-education/*

[17] LEGO Education Professional Support. Available at:

https://education.lego.com/en-us/professional-development/

[18] Educators develop teaching skills through robotics workshop, ETID News (November 4, 2022). Available at: *https://engineering.tamu.edu/news/2022/11/educators-develop-teaching-skills-through-robotics-workshop.html*

[19] Aggies lead hands-on robotics learning in Brazos County, ETID News (May 17, 2023). Available at: *https://engineering.tamu.edu/news/2023/05/aggies-lead-hands-on-robotics-learning-in-brazos-county.html*

[20] Partnering with Industry for Robotics Education and Outreach. ETID News (November 17, 2023). Available at: *https://engineering.tamu.edu/news/2023/11/partnering-with-industry-for-robotics-education-and-outreach.html*

[21] O.V. Galustyan, G.P. Zhirkova, W. Can, S.S. Gamisonia, I.I. Boldyrev, and O.V. Khripunkova, "Updating of higher education curriculum for future engineers during the COVID-19 pandemic." Journal of Education and Learning (EduLearn), vol. 18, no. 1, pp. 194-200, 2024.

[22] T. Rüütmann, I. Annus, J. Kübarsepp, U. Läänemets, and J. Umborg, "Updated curriculum for engineering pedagogical continuing in-service education." In International Conference on Interactive Collaborative Learning, pp. 556-567. Cham: Springer International Publishing, 2021.

[23] B. Ozfidan, and M.A. de Miranda, "K12 teacher credentialing containing engineering content in the USA." Eurasia Journal of Mathematics, Science and Technology Education, vol. 14, no. 1, pp. 3-13, 2017

[24] M. Gharib, T. Katbeh, B. Cieslinski, and B. Creel B. " A Novel Trilogy of E-STEM Programs". In ASME International Mechanical Engineering Congress & Exposition (IMECE2021), November 15-18, Virtual, Paper No. IMECE2021-69012, 2021.

[25] N. Alyafei, A. Shaikh, M. Gharib, and A. Retnanto " The Role of Pre-College STEM Education in Student Enrollment in Petroleum Engineering". In SPE Annual Technical Conference and Exhibition, September 21-23, Dubai, UAE, paper No. SPE-206071-MS, 2021.

[26] M. Gharib, T. Katbeh, B. Cieslinski, and B. Creel B. "An Integrated Engineering Agriculture STEM Program". In ASME International Mechanical Engineering Congress & Exposition (IMECE2020), November 15-18, Portland, Oregon, USA, Paper No. IMECE2020-23584, 2020.

[27] G. Salama, T. Katbeh, B. Creel, G.B. Cieslinski, and M. Gharib, F. Ramadan, and W. Mazen "Illustrating Engineering Education: A Children's Book to Support STEM Outreach in Qatar". In IEEE International Conference on Engineering, Technology and Education (IEEETALE 2019), December 10-13, Yogyakarta - Indonesia, Paper No. 1570576315, 2019.

[28] M. Gharib, B. Cieslinski, B. Creel, and T. Katbeh (2019) "A Model Engineering-Based Learning STEM Program". In ASME International Mechanical Engineering Congress & Exposition (IMECE2019), November 8-14, Salt Lake City, UT, USA, Paper No. IMECE2019-10360, 2019

[29] B. Cieslinski, M. Gharib, B. Creel, and T. Katbeh, "A Model Science-Based Learning STEM Program". In ASME International Mechanical Engineering Congress & Exposition (IMECE2019), November 8-14, Salt Lake City, UT, USA, Paper No. IMECE2019-10352, 2019

[30] M. Gharib, B. Cieslinski, J. Al-Marri J., and B. Creel, "A Project-Based Learning STEM Program for Middle and High School Students". In ASME International Mechanical Engineering Congress & Exposition (IMECE2018), November 9-15, Pittsburg, PA, USA, Paper No. IMECE2018-88647, 2018