The STEM Guitar Project

Sinclair Community College (OH) will collaborate with industry partners and partners from community colleges, universities, K-12 institutions, two NSF ATE national centers, and guitar industry manufacturers to conduct professional development Institutes for secondary and post-secondary faculty. Building on a current highly successful ATE project, the proposed project will increase student interest, engagement, and learning of STEM principles, practices, and careers through guitar design and building.

PROJECT GOALS AND DELIVERABLES

This project has two overarching goals:

Goal 1: To help faculty increase their students' interest, engagement, and learning of STEM principles, practices, and careers through guitar design and building.

The **objectives** are:

1. Increase the number of teachers of diverse secondary and post-secondary faculty trained in an interdisciplinary project-based approach to teaching innovative inquiry-based learning techniques inspired by the STEM skills gap.
2. Increase the number of secondary and post-secondary students that learn about STEM concepts and improve their attitudes and behaviors towards STEM through STEM Guitar curriculum modules developed by participants trained in this project.
3. Increase the number of institutions that formally adopt established standards and strategies for STEM Guitar project curriculum, resulting in wider reach and overall sustainability.

Goal 2: To create a replicable model for establishing and maintaining a STEM Community of Practice (CoP).

The **objectives** are:

1. Increase the interaction and collaboration among faculty and participants training in STEM Guitar-building principles, resulting in a sustained CoP.
2. Demonstrate an improvement of student learning outcomes that relate to STEM principles and career ambitions and elevate the importance of project-based learning for STEM principles.

Successful completion of the project will result in the following **deliverables**:

A. **21 Guitar Building Institu**tes for a total of 310 secondary and post-secondary faculty participants, including one Institute specific to administrative staff and one specific to demonstrated faculty leaders and champions in guitar building and STEM principles;
B. A replicable and sustained STEM Guitar Project **Community of Practice** with online follow-up activities to the Guitar Building Institutes that support the continued development of learning modules to further student learning of STEM principles;
C. Expanded multidisciplinary STEM **guitar-building and design curriculum** aligned to nationally recognized standards, industry and academic, including a new guitar-related advanced manufacturing curriculum;
D. Six national **presentations**;
E. Two submitted scholarly **publication**s.

DESCRIPTION OF PRIOR NSF SUPPORT

DUE 1304405: *Learning, Engaging, Attaining, and Doing with Guitars Used in Teaching Achievable Real Situations in STEM* (LEAD GUITARS in STEM), Amount: $894,707 Period: 9/1/13 – 8/31/17

Broader Impacts: Currently in a no-cost extension year, LEAD GUITARS in STEM is led by Sinclair Community College and involves Butler County Community College, College of the Redwoods,

Edmonds Community College, Purdue University, and Ventura College. As of Year 3, more than 226 faculty have been served through guitar-building professional development institutes. LEAD GUITARS in STEM has experienced significantly increasing interest in these institutes, and it is anticipated that more than twice the targeted number of faculty will be served by the end of the no-cost extension year. Additionally, the project has seen an increase in female participation through conscious outreach and recruitment efforts, with 20 out of the 100 participants in year 3 being female. LEAD GUITARS in STEM is also achieving its objective to target faculty who teach in underrepresented populations. Thirty-three percent (33%) of the institute participants reported that more than 51% of students were receiving free and reduced lunch in the schools where they taught. Twenty-six percent (26%) of Guitar Building Institute participants reported that their schools had more than 51% students from underrepresented populations. Combined with the efforts of the first NSF guitar-building grant, LEAD GUITARS in STEM has been implemented in 44 states. According to Google Analytics, the project website, http://www.guitarbuilding.org, has had close to 22,000 users. About 70% of the web accesses were from new visits; 30% were from returning users. The website continues to serve as a resource to educators across the country who are interested in using guitar-building to teach STEM principles.

Intellectual Merit: According to recent (July 2016) evaluation finding, the faculty participants entered the institutes rating themselves "average" in terms of their confidence in teaching STEM. They later reported "very good" levels of confidence in teaching STEM. Participants were very positive about their adoption and adaptation in their classrooms of the concepts they learned during the institutes. Follow up surveys demonstrate positive changes in their instructional processes as well as influencing their institutions and colleagues in adopting/adapting and integrated STEM model for teaching. Regarding student outcomes, all of the student assessments showed significant improvements in students' related content knowledge. Before students engaged in the guitar-building experience, they were neutral about their interest in STEM and its importance, usefulness, and application. After their academic and hands-on guitar build experiences, they reported greater interest in STEM and recognized its importance, usefulness, and applications to their lives (Castañeda-Emenaker, Morrison, & Dariotis, 2016).

LEAD GUITARS with STEM has been honored in various capacities, including being the only undergraduate project invited to participate in the USA Science and Engineering Festival. Additionally, LEAD GUITARS in STEM is the highest rated plenary session and was the first to be highlighted by NSF as one of its own projects at the ATE-PI annual conference. Publications under this award are forthcoming.

Relation of Prior Support Work to the Proposed Work: The proposed project, STEM Guitar Project, will leverage and expand the current faculty development project in guitar-building. This proposal is in response to the overwhelming interest across the nation to both continue and expand guitar design and building institutes to teach integrated STEM principles. To date, the current project has received 30 applications for eight funded hosting locations for 2017. After several conversations with the current program officer, STEM Guitar project was encouraged to propose a budget for this new proposal that exceeds the typical $900,000 maximum request for NSF ATE projects. The increased budget details the necessary resources to respond to the growing support and need for guitar design and building Institutes, with a focus on engaging school leaders and faculty "champions" as strategic supporters, and demonstrating improved student academic outcomes and perceptions of STEM degrees and careers.

INTELLECTUAL MERIT AND MOTIVATING RATIONALE FOR PROPOSED PROJECT

It is well known that the nation's workforce for the 21st century must have knowledge and competencies in science, technology, engineering, and mathematics (STEM) fields to contribute to a strong economy and to be competitive at the international level. Just as widely discussed, the STEM "skills gap" continues to persist, where positions remain unfilled because of a shortage of STEM skills. However, recent reports begin to describe this gap in a different manner, arguing that the STEM labor market actually "suffers from **a very particular kind of skills gap**. It's not just that there aren't enough

skilled workers to fill the jobs; it's that the **skills workers have aren't specific enough**" (Krigman, 2014, np). Further, as of June 2013, 20% of all jobs require knowledge in one of the STEM fields, and this number only continues to increase (Rothwell, 2013).

The above industry data and shift toward a more intentional skills-based approach is foundational to this project. To help meet employers' specific needs for technicians with advanced technical knowledge and hands-on experience, STEM Guitar Project will invite faculty participants to Institutes to develop and share learning activities and curriculum that focuses on guitar-making skills while creating a **clear linkage to the broader STEM concepts**. The Institutes are aligned with core curriculum national standards—such as the Next Generation Science Standards—furthering the best practices detailed by the National Research Council (2011), noting the following science and engineering practices as essential: asking questions and defining problems; developing and using models; planning and carrying out investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations and designing solutions; engaging in argument from evidence; and obtaining, evaluating, and communicating information.

STEM Guitar Project curriculum design and implementation intentionally targets adolescent (ages 10-19) identity development and decision-making. Shoffner et al. explain how student perceptions developed and choices made during adolescent years "may restrict or enrich a youth's future career aspirations," and these formative experiences are essential for youth to not only acquire knowledge, but **develop career-related interests** (2015, p. 102). Young people make decisions about future coursework that can have a long-term impact on academic pursuits and careers. The project deliberately focuses on adolescent students because it holds the greatest chance of successfully helping students "reexamine their beliefs, thereby broadening their career horizons" (Shoffner et al., 2015, p. 114). This focus emphasizes the significance of a two-year degree pathway, given that half of all STEM jobs—with annual salaries averaging $53,000—are available to workers without a four-year college degree (Rothwell, 2013).

In addition to the timing for adolescent high school students, the STEM Guitar Project relies on a project-based curriculum. Harris et al. synthesized research on project-based curriculum in science as it relates to student outcomes, finding that "curriculum materials that support students' **direct engagement** with phenomena in science can help students learn" (2015, p. 1363). Unfortunately, project-based learning, which enables students to makes sense of scientific phenomena through hands-on, integrated, and sustained learning, is not common in high school classrooms. STEM Guitar Project aims to reverse this trend by providing adolescent students with the necessary opportunities to engage deeply in science and engineering practices. Guitar building provides the "essential [opportunities] to develop and use models, construct explanations, and engage in argument from evidence" Harris et al., 2015, p. 1363).

While project-based, inquiry-based learning is a proven method to increase student learning, **it is highly dependent on the quality of professional development educators receive,** including how to integrate and adapt materials to fit the district's goals for student learning (Harris et al., 2015). In a status report on teacher development in the United States, Wei et al. clearly explain that "efforts to improve student achievement can succeed only by building the capacity of teachers to improve their instructional practice and the capacity of school systems to advance teacher learning" (2009, p. 1). Improving instructional practice to increase student learning, however, involves a considerable investment that not many professional development programs recognize. Wei et al. reveal that student achievement improved most "when teachers were engaged in sustained, collaborative professional development that specifically focused on deepening teachers' content knowledge and instructional practices" (2009, p. 5). Further, "sustained" indicates 30 or more hours of professional development, as the traditional "episodic and fragmented approach of traditional professional development does not afford the time necessary for learning that is 'rigorous' and 'cumulative'" (Wei et al., 2009, p. 8). Based on these findings, STEM Guitar Project will provide 40 hours of professional development to teachers during the Institute and

additional follow-on opportunities for engagement, including ongoing access to a robust Community of Practice where faculty are practicing and maintaining their newly learned instructional practices.

Finally, student learning, when intentionally coupled with educator professional development, was even furthered with administrative support (Geier et al., 2008). Based on these two factors, STEM Guitar Project will further increase its impact on student learning by providing robust, extensive, and continued professional development opportunities for faculty participants as well as hosting an Institute particularly for administrators, both supporting STEM Guitar Project's sustainability as well long-term student impact. A central aspect in all Institutes will be the alignment to national science standards as well as opportunities for participants to consider how STEM Guitar Project aligns with their individual district pacing recommendations, leading to a greater chance of implementation with fidelity, thus promoting student learning (Harris et al., 2015).

BROADER IMPACTS:

Solving the STEM technician shortage hinges on the ability of the educational community to produce well-trained technicians as well as recruiting and maintaining the interest of students throughout the STEM pipeline. The project supports students' academic knowledge while developing their career-related interests. Project activities will increase the enrollment of populations traditionally underrepresented in STEM and target the recruitment of faculty participants who educate underrepresented student populations.

In addition, the proposed project includes a number of strategies to extend the reach and sustainability of a successful current ATE the project, including strengthening of the collaborative manufacturing sustainability process of project. It also makes explicit the connection between national standards, job readiness or related skills, and guitar building activities to support the institutionalization of the project at the participants' schools. Professional development Institutes focused on school administrators will also help support the sustainability and expansion of the project at participants' schools. Broad dissemination of lessons and laboratory experiences created as part of the Institutes will be available on the project's online platform, ensuring that materials and project reports are available for educators across the nation interested in STEM Guitar Project and teaching STEM principles through evidence-based strategies.

PROJECT ACTIVITIES

The project team planned the core activities below to accomplish each objective for **Goal 1: To help faculty increase their students' interest and engagement in, study of, and learning of STEM principles, practices, and careers through guitar design and building.**

Objective 1: Increase the number of diverse secondary and post-secondary faculty trained in an interdisciplinary STEM project-based approach to teaching innovative inquiry-based learning techniques inspired by the STEM skills gap.

Activity 1: Host a minimum of seven Guitar-Building Professional Development Institutes across the country each year of the three year project with a particular focus on the recruitment of under-represented populations in order to increase their participation in STEM fields.

Guitar-Building Institutes will include an average of 15 faculty or administration members and utilize a STEM curriculum with the unique aspect of electric guitars and electronic amplification to teach STEM content. This curriculum especially considers how to engage traditionally under-represented populations in STEM education. Faculty members from community colleges and/or high schools will participate in a five-day intensive, hands-on professional development Institute focused on grade-level appropriate curriculum development, ***exposing more than 10,800 students*** during the grant period to STEM-building principles**.**

Faculty Recruitment: The Institute participants will be comprised of a core team of STEM faculty from high schools (9^{th}-12^{th} grade) and community colleges. The Institutes will be publicized to STEM faculty through a range of media and opportunities including:

- Publications and websites of all participating education partners and supporters
- National listservs and websites of organizations such as the Society for Manufacturing Engineers; Industrial Technology Education Association; American Society of Engineering Education; Project Lead the Way; the American Society of Mechanical Engineers; National Science Teachers Association; and American Association of Physics Teachers
- Personal contacts at conference presentations, as past experience indicates that over 50% of the STEM Guitar workshop participants heard of the program through conferences
- Existing listserv comprised of faculty participants of current and previous grants (LEAD GUITARS in STEM)

The STEM Guitar Project will utilize a standardized selection and participation criteria for participants developed by the Leadership Team with evaluator input.

Application process: Faculty applying to the STEM Guitar Project Institute will submit a completed application by March 1^{st} for Institutes occurring in that same year (see Attachment C: Sample Application). The application collects information about teaching experience (grade level, subjects, number of years of experience, etc.) and school/students demographics. Faculty will indicate their availability or access to equipment/resources (such as advanced manufacturing) as well as provide demographic information about their student populations and/or institutional settings. This additional information will further nurture this project's intentionality behind the recruitment and retention of underrepresented student populations, elucidating best practices and strategies across the nation regarding culturally relevant teaching.

Selection of the core team of participants—The Leadership Team will select the participants for the Institutes based on: 1) geographic distribution, 2) size and type of institution (minority-serving, urban, rural, suburban), and 3) numbers of faculty from and working with underserved populations. A geographic and ethnic mix of faculty participants is desired. Alternate participants will be chosen to serve as replacements in the event selected applicants are unable to participate. Selected participants and alternates will be notified of their status and provided a selected reading list prior to the Institutes.

Commitment of faculty participants: Participants must commit to develop one multi-day Modular Learning Activity relating to STEM guitars as part of their signed agreements to participate in an Institute. An Administration Support Form must be signed by the participant's administration demonstrating their commitment to support implementation when he/she returns from the Institute. Once faculty have successfully completed the STEM guitar Institute, they can apply for a startup grant through the project. This competitive grant will provide tools and guitar kits which will serve as "seeds" to help develop a sustainable application of STEM guitar fabrication at their institutions. Guitar kits and supplies will be used as incentives for the faculty participants to provide evaluative research data as described in evaluation plan. Additional yearly support funding will be available for faculty to attend and present at the combined M-STEM & STEM Guitar National Conference. These reviewed and vetted presentations are made by secondary and post-secondary faculty that are implementing the program.

Outreach to Underrepresented Populations

Participants will be sought from underrepresented populations including women, ethnic minorities, and persons with disabilities. Faculty who teach underrepresented populations will receive additional guidance and support through STEM Guitar Project. Targeted outreach activities include:

- Email blasts to non-governmental organizations (Women Walking West, Music for Life) and existing network of STEM Coordinators providing support to STEM programs around the nation

- Direct mail and e-marketing to organizations whose outreach mission includes high minority and at-risk populations, such as the Math Engineering Science and Achievement (MESA) colleges in California and Local Development Districts of the Appalachian Regional Commission.
- Contact with groups focused on female participation in STEM, including the Society of Women Engineers, MESA Directors, National Girls Collaborative Project, local chapters of the Society for Manufacturing Engineers, and the Pennsylvania STEM Girls Collaborative Project.

Objective 2: Increase the number of secondary and post-secondary students that learn about STEM concepts and improve their attitudes and behaviors towards STEM through STEM Guitar curriculum modules developed by participants trained in this project.

Activity 2.1: Broaden the current core STEM Guitar curriculum by adding new STEM-related topics through the creation of new core curriculum modules, particularly the intersection between guitar-building and advanced manufacturing technologies.

A new direction for the STEM guitar project will be focused on faculty who have advanced manufacturing equipment at their school or campus. These schools will not rely on pre-fabricated guitar kits but will actually make the guitar components using additive manufacturing equipment such as CNC machines. The STEM Guitar Project Leadership Team will provide these faculty members with modules and written processes to implement the new manufacturing curriculum. The modules will be continually refined through faculty participation and lessons learned through implementation. This new manufacturing process allows schools additional learning activities and an opportunity to become part of the supply chain of the project.

Activity 2.2: Improve the integration of Next Generation Science Standards (NGSS) and Common Core Standards (CCSS) into the STEM guitar Modular Learning Activities (MLAs), making more explicit the connections between the standards and the STEM guitar-building activities.

Next Generation Science Standards and Common Core Standards drive the critical elements that are part of the public educational system—often dictating the curricula, textbooks, and even specific student assessments. These standards establish the levels of performance that students and teachers are expected to meet. Based on past project feedback and challenges, the STEM Guitar Project will explicitly connect the standards with the guitar-building activities and explain the connection at the Institute. This deliberate cross-walk of standards and activities elevates the instructional capacities of the participants and allows participants to articulate the importance of project-based learning through guitar building in a manner that makes sense to schools and districts and aligns with what they perceive as “most important.” This will ensure sustainability after the grant period.

Activity 2.3: Streamline the development of participant Modular Learning Activities (MLAs) as part of Guitar Building Institutes by providing time to modify, create, or adapt new and existing MLAs.

Modular Learning Activities are the individual yet interrelated units that explain in detail distinct aspects of the guitar-building process. MLA illustrates the complex undertaking of the full guitar-building process linked to STEM. During the Institutes, **participants will utilize MLAs to teach related guitar-building skills and STEM principles based on their personal expertise**. Based on feedback from past Institutes and the follow-on activities, participants have difficulty finding time in addition to their existing instructional responsibilities to complete personalized MLAs. It is the intent of this activity to provide additional time and guidance during the Institutes so that participants exit the professional development opportunity fully equipped with the necessary resources to implement STEM Guitar Project MLA’s in their respective classrooms. The participants will benefit from the instructional expertise of the STEM

Guitar Project Leadership Team as they discuss MLAs in the context of secondary or post-secondary classrooms and move through some of the philosophical barriers to implementation. As participants engage in the Community of Practice after the Institute, Leadership Team members will be available to support faculty through the realities of STEM Guitar Project implementation. Allowing this time contributes to the project's likelihood for long-term sustainability outside of the project period.

Activity 2.4: Create a clearinghouse of faculty-created MLAs to promote wider implementation and dissemination of project materials.

Guitar-Building Institute participants will share their completed MLAs in an online clearinghouse, created as part of this project. After review by the Leadership Team to ensure relevant content and teaching strategies, the MLAs will be available to educators interested in teaching STEM principles through the activity of guitar-building. MLAs will use a standardized format that indicates level of instruction (high school grade level or post-secondary level), specific instructional topic area, links to national standards, safety protocols, and materials needed for completion.

Activity 2.5: Ensure STEM Guitars exposes an estimated 10,800 students through classroom implementation from the project-trained faculty members, as indicated in the chart below.

Assuming that participants will each engage ***at least*** 20 students each year during the three year project, the table below shows the calculations for involving 10,800 students.

<table>
<tr><th colspan="4">NO. OF STUDENTS ENGAGED IN STEM GUITAR-BUILDING PRINCIPLES THROUGH FACULTY PARTICIPANTS</th></tr>
<tr><th>2017-18</th><th>2018-19</th><th>2019-20</th><th>TOTAL</th></tr>
<tr><td rowspan="3">90 faculty participants x 20 students = 1,800 students</td><td>1,800 plus</td><td>1,800 plus</td><td>5,400 (3 years)</td></tr>
<tr><td rowspan="2">90 faculty participants x 20 students = 1,800 students</td><td>1,800 plus</td><td>3,600 (2 years)</td></tr>
<tr><td>90 faculty participants x 20 students = 1,800</td><td>1,800 (1 year)</td></tr>
<tr><td></td><td></td><td>Total students</td><td>10,800 students</td></tr>
</table>

Activity 2.6: Develop high-tech and high-touch engagement tools and opportunities that recruit and draw students to Guitar Building Institutes.

The STEM Guitar Project will continue to build on lessons learned from previous work that demonstrates the need for high-tech and high-touch engagement tools to gain and keep student interest in STEM-related fields. This project will create high-tech virtual and simulated guitar building activities that introduces basic STEM guitar-building concepts. This simulation will be on display at all major project-related conferences and meetings, as the STEM Guitar Project also underscores the importance of face-to-face interactions and ample opportunities for connection.

Additionally, this project builds on a robust website (guitarbuilding.org) to offer curriculum modules, instructional videos, Institute resources, and all design documentation. The website is already a "one stop shop," serving as a resource for faculty to use in their classrooms. The proposed project will focus on development of an online Community of Practice, with the ability to post instructional content and access other faculty posts through the online forum and STEM Guitar mobile application. The development of the online forum and mobile application will facilitate the transformation of the existing base of STEM Guitar instructors and students into an interconnected Community of Practice. Materials developed by the faculty participants will be approved by the Leadership Team and then shared via the project's online platform and through other media and in-person meetings to broaden the participation of teachers and their students to teach and learn about STEM in innovative ways.

***Objective 3*:** Increase the number of institutions that formally adopt established standards and strategies for STEM Guitar project curriculum, resulting in wider reach and overall sustainability.

Activity 3.1: Establish standards and strategies for STEM Guitar project curriculum and implementation, resulting in wider reach and overall sustainability.

The project Leadership Team will continue to strengthen the collaborative manufacturing sustainability process from the current grant, which includes two established regional distributive manufacturing sites. The collaborative guitar manufacturing sites exemplify the application of a distributive supply chain. High schools and colleges that develop and manufacture the parts used in the guitar kits also provide financial support to the supply chain partners. The proposed advanced STEM guitar training in CNC manufacturing will expand this network of educational institutions that make their own guitar kits.

Faculty Development and Curriculum: The five-day Institute agenda includes instruction, demonstration, applied learning assignments, tours, and information about state and national standards for STEM, entrepreneurship, supply chain management, and advanced manufacturing (see Attachment D: Sample Agenda). The agenda will be finalized in the fall of 2017 by the Leadership Team based on the final evaluation of the current project and input from the Advisory Committee. The Institute curriculum will be tied to workforce skill gap needs and STEM concepts including basic physical principles and fabrication processes, and will provide the opportunity to excite and engage participants. Entrepreneurship, supply chain management, and advanced manufacturing concepts will be introduced.

Example of Some Basic Physical Principles Covered During STEM Guitar Institute: Electric guitars are a valuable teaching tool since the mechanism that produces sound depends on the interaction of electromagnetic pickups and the dynamics of vibrating strings. The electronic signal generated by the guitar then needs to be amplified and sent to a speaker. This familiar and immediately interesting object makes use of a variety of different physical principles, best described using mathematics rather than prose. This combination synthesizes topics from several STEM disciplines and encourages students to move between them as they seek to understand how the guitar works.

As an example of the path of discovery, consider how a single vibrating string can be used to make music. Each string has a fundamental frequency based on its mass and the applied tension. A player can change that string frequency by changing tension or by changing length. Tuning the instrument is a process of changing the tension using geared machines so that the strings vibrate at very particular frequencies. Playing the instrument entails effectively shortening the strings by pressing them against the frets on the neck. It follows that the frets must be placed at specific locations on the neck; but where? The locations are calculated once the student understands that the frequencies of the notes in the chromatic scale are based on a power series. By following this path, a trained instructor can show students how to calculate the frequencies of all the notes in the human hearing range and how to use those frequencies to calculate fret positions for any instrument. In addition to being able to make the calculations, students will be shown the underlying connection between all fretted instruments, providing an example of how specific information can lead to more general principles and be cross walked to multiple programs/technical areas.

During the Institute, faculty participants will be presented with prepared teaching modules and will conduct experiments that demonstrate specific principles from the STEM disciplines. At the end of the Institute, participants will have a clear understanding of how to make electric guitars and how to integrate varied STEM subjects and learning activities in STEM disciplines using guitars. As they assemble their instruments, participants will learn how dimensions and tolerances are critical in accurate assembly. When the instruments have been assembled, the teachers will learn how, using simple STEM-based principles, to accomplish a complete instrument set up (including adjustment of the bridges, truss rods, and string positions) so that their instruments will play in tune across the musical range.

Summary of STEM Guitar Advanced Manufacturing Institute Activities: Guitar manufacturing processes used by major manufacturers will be presented as part of the professional development

Institutes series. This Institute will focus on the design and manufacturing of guitar bodies and necks. A new curriculum tying manufacturing and CNC to guitar fabrication will be created. Institute participants will receive CNC training and experience cutting their own body design. This activity will focus on how to develop opportunities in entrepreneurship, linkages to skill sets needed for technicians in manufacturing, how to be sustainable, and experience how guitars are mass produced using computer-controlled equipment. Participants will see how manufacturers produce parts, finish them, and assemble them in discrete steps. When possible, Institute participants will tour local guitar manufacturing facilities and guitar industry representatives will be invited to discuss their design/manufacturing processes and STEM labor needs. The NSF ATE Center participating in this project, MatEdU, is committed to providing up-to-date information on manufacturing processes and how teachers can share this information as it relates to STEM. MatEdU's focus is to share information on the various materials needed to make a guitar (i.e., metal, wood, polymer, etc.) and the properties of each of those materials.

Activity 3.2*:* Train school leaders at Guitar Building Institutes focused on administrative staff to gain institutional support and broader, stronger implementation.

The STEM Guitar Project will offer three specialized Institutes designed for educational administrators. The Institutes will emphasize the various opportunities or methods to institutionalize STEM Guitar Project into existing curriculum while also supporting administrators in how they can encourage their faculty members to infuse project-based learning and STEM principles through sustainable guitar building practices. This will result in greater administrative understanding and school ownership, contributing to the long term sustainability of the STEM Guitar Project.

The project team planned the core activities below to accomplish each objective for **Goal 2: STEM Guitars will create a replicable model for establishing and maintaining a STEM Community of Practice (CoP).**

Objective 1: Increase the interaction and collaboration among faculty and participants training in STEM Guitar-building principles, resulting in a replicable and sustained Community of Practice.

Activity 1.1: Create or refine a platform that centralizes project-wide activities by project end.

The STEM Guitar Project platform will employ both in-person and virtual opportunities for educational interaction, which could include a project-specific mobile app, online forum, webinars, in-person summits, virtual symposiums, etc. As part of the current project, the website, guitarbuilding.org, offers some of the features that will be migrated to the more robust platform developed as part of the STEM Guitar Project. To develop the platform, technology experts from the Leadership Team will convene regularly to discuss the requirements/needs for the platform as well as explore and decide upon the various technologies that will support the needs.

Objective 2*:* Demonstrate an improvement of student learning outcomes that relate to STEM principles and career ambitions and elevate the importance of project-based learning for STEM principles.

Activity 2.1: Utilize the project-created platform as a mechanism to showcase faculty and student outcomes as they relate to STEM Guitar-building principles.

The Community of Practice will offer a mechanism to showcase student work related to the STEM Guitar Project. This showcase will provide access to the vast resources and research behind STEM Guitar Project, such as MLAs, best practices, design files, and discussion board. It will be utilized as a demonstration for the importance of project-based learning and STEM principles. Students will also have the opportunity to share, via video or written reflections, their experiences with the STEM Guitar Project and its influence on their perceptions of STEM degrees and programs.

Activity 2.2: Expand, refine, and streamline student outcome data collection processes.

Based on current Guitar Building Institute challenges, capturing student outcomes and improving data collection processes of participating faculty and students is central to STEM Guitar Project. The project has tested several tactics of data gathering and will rely on faculty participants to assess their students (in their respective settings) with ample project guidance from the Leadership Team. Student outcomes will then be captured in the faculty follow-up surveys after six months, one year, one year and six months, two years, and two years and six months. (See evaluation section for additional details.) Additionally, STEM Guitar Project will identify ten faculty "champions" who will assist with data collection processes. With support from the Leadership Team and the project's external evaluator, the project will help faculty use a quasi-experimental design using control groups, identified through propensity score matching, and provide more focused support for the types of assessments to conduct. Assessments could be completed as formal written assessments for cognitive/content knowledge, performance assessments, or videos of student presentations and products.

TIMETABLES

The timetable is based upon experience from the current project and addresses challenges associated with the year-around schedules of the faculty participating in the Professional Development Institutes (see table below). Future Institute locations will consider geographic location, community need, impact on underrepresented populations, and support that will be provided after the event.

DATES AND DETERMINED LOCATIONS FOR THE PROFESSIONAL DEVELOPMENT INSTITUTES			
2017	**2018**	**2019**	**2020**
November: STEM Guitar Project Conference in conjunction with M-STEM	**March Administrators Institute** Locations TBD	**March Institute,** Mesa Community College—Mesa, AZ administrative GBI	To be determined
	June Institutes Sinclair Community College and an East Coast location	**June Institutes** San Diego State University and Midwest location	
	July Institutes Southern states location	**July Institutes** College of the Redwoods or other West coast location	
	August Institute Northwest US and Mid Atlantic location	**August**—ATE Center MatEdU Edmonds Community College (WA) and southern states location	
	November: STEM Guitar Project Summit in conjunction with M-STEM	**November:** STEM Guitar Project Summit in conjunction with M-STEM	

The timetable below states the major milestones of the project requested to *begin September 1, 2017.*

	Year 1: 2017-18				**Year 2: 2018-19**				**Year 3: 2019-20**			
Major Project Activities	Sep-Nov	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov	Dec-Feb	Mar-May	Jun-Aug	Sep-Nov	Dec-Feb	Mar-May	Jun-Aug
Initial Leadership Team meeting	X											
Advisory board meetings		X				X				X		
Recruitment of Institute host locations		X	X			X	X			X	X	
Recruitment of Institute participants			X				X				X	
Selection of participants and provide pre-Institute materials (STEM Institute and CNC Institute)			X				X				X	
Community of Practice, includes platform development and ongoing project support		X		X		X		X		X		X
Institutes Held across the US (including Administrative Institutes)				X				X				X
Debrief of Institutes, review of evaluation data					X				X			X
Conference presentation at M-STEM	X				X					X		
Formative evaluation activities			X		X		X		X		X	
Summative evaluation activities				X				X				X

MANAGEMENT PLAN

The project PI and Co-PIs will all play roles in managing the project. The PI will oversee project administration and management, personnel, activities, purchases, and NSF reporting requirements. PI Tom Singer, Sinclair Professor of Mechanical Technology, has many years of project management and related teaching experience to contribute. He is the recipient of the National Institute for Staff and Organizational Development Teaching Excellence Award.

The experienced leadership for this project includes faculty and technicians from community colleges, universities, and K-12 schools that make up the Leadership Team. The project also benefits from the resources provided by an Advisory Board and supported through its partnerships with two National Science Foundation ATE Centers.

EXECUTIVE COMMITTEE	
NAME AND ORGANIZATION	**RESPONSIBILITIES**
• Thomas Singer, PI, Sinclair Community College (OH)	Overall management of project, assist in Institute instruction and sustainability
• Sean Hauze, Co-PI, San Diego State University, San Diego (CA)	Coordination of online Community of Practice forum, and interactive mobile app development.
• Richard French, Co-PI, Purdue University, West Lafayette (IN)	Assist in Institute instruction and curriculum development Coordinate new product development / improvement for sustainability
• Doug Hunt, Co-PI, Southern Wells Jr./Sr. High School (IN)	
• Debbie French, Co-PI, Wilkes University, Wilkes-Barre (PA)	Assist in Institute instruction and curriculum development Provide national curriculum standards management

The Executive Committee will oversee the project and ensure deliverables and Institutes are developed and executed and that information about the project is broadly disseminated and publicized. The Executive Committee will meet through teleconference calls twice each month, and more frequently as needed through email and other means, such as Skype. An ongoing topic will be ways to pursue support to ensure the sustainability of STEM Guitar Project.

The Leadership Team is comprised of the Executive Committee (above) and Senior Personnel (below).

ADDITIONAL SENIOR PERSONNEL	
NAME AND ORGANIZATION	**RESPONSIBILITIES**
• PI and Co-PIs	See Executive Committee table above
• Mike Aikens, Consultant, Retired Professor • Tim Wilhelm, Consultant, Kankakee Community College (IL) • Dave Parker, Consultant, Teacher, Noble High School, North Berwick, (MA) • Ed Ufford, Teacher, Richland School District (WA) • David Lake, Teacher, Kiona-Benton High School, Benton City, (WA) • Nancy Chang, Teacher, Edmonds Heights K-12, Edmonds, (WA) • Scot Rabe, Professor, Ventura College (CA) • Steve Brown, Professor, College of the Redwoods, Eureka (CA)	Assist in Institute instruction and curriculum development Assist with evaluation data coordination Provide national curriculum standards management
• Kevin Murphy, Consultant, Marketing and Development	Assist in the logistics and operation of Institute sites Serve as marketing manager, conference call manager. Assist in project sustainability

NAME AND ORGANIZATION	RESPONSIBILITIES
• Imelda Castañeda-Emenaker, EdD, Sr. Research Associate, University of Cincinnati (OH)	Coordinate external evaluation Provide ongoing feedback to the Leadership Team

Immediately upon notice of NSF support, the Leadership Team will plan a strategic meeting to refine the roles of the national network of people supporting the grant. The Team will review the Institute schedule, customize the curriculum and technology areas for three years of Institutes, and discuss new tools, resources, and products. The Leadership Team will also select faculty members to serve as Champions. These Champions will be those successfully involved in STEM Guitar who will be tapped to assist with training and data collection efforts to extend project capacity. The Leadership Team will meet via teleconference eight times per year to continuously improve activities for STEM Guitar Project.

An Advisory Committee comprised of industry and educational representatives will provide advice, guidance, and feedback throughout the grant period. Some Advisory Committee members have agreed to host project meetings and/or Institutes and others have agreed to serve as guest speakers at Institutes. Selected Advisory Board members will work with the Leadership Team to approve faculty-developed modules prior to distribution to ensure quality and accuracy. Other members will work to enhance the visibility and resources of STEM Guitar Project.

ADVISORY COMMITTEE	
NAME	ORGANIZATION
Dick Boak	Martin Guitars, Director, Museum and Archives, Special Projects
JoAnn Crabtree	Taylor Guitars, Director of Training and Development
Tim Shaw	Fender Guitars, R & D
John Martincic	Owner of Forest Scientific, CNC manufacturer
Josh Hurst	Senior Design Engineer, Fender Guitars
Ralph Ibarra	Managing partner 2TEK LLC. And founder of Guitars for a Cause™ organization
Steve Wendel	State Director, Project Lead the Way
Mel Cossette	Executive Director National Resource Center for Materials Technology Education (MatEdU)
Marilyn Barger	Executive Director Florida Advanced Technological Education Center (FLATE)

Conversations with Martin, Fender, and Taylor guitar companies, in addition to their current project involvement, indicate significant industry support and interest in STEM education, and will provide faculty participants with a real-world understanding of entrepreneurial opportunities, business models, supply and demand challenges, marketing, and scheduling and delivery. They are also prepared to provide advice and technical assistance, host Institutes and tours, and/or supply parts for guitar building. *National Resource Center for Materials Technology Education (MatEdU)* will provide specific strategies to help STEM Guitar Project maximize the number of institutions and individuals that benefit from its curriculum and programs. *Florida Advanced Technological Education Center (FLATE)* will assist with participant recruitment by promoting the project in Florida and will connect the project to supplies. These Centers are committed to helping the project take STEM Guitar Project to underserved areas of the country and assisting with curriculum development.

SUSTAINABILITY PLAN

Objective 4 is critical in that it addresses the need for standards, strategies, and sustainability for the project. In addition to the formal adoption of established standards and strategies for STEM Guitar Project within school and district-wide curriculum pacing, the sustainability plan includes continuing to build upon and expand the distributive manufacturing networks and supply chain management plans that provides guitar kits for teachers nationwide.

The current sustainability of the distributive manufacturing network of the guitar kits used in the STEM instruction has proven the efficiency and effectiveness of the entrepreneurial supply chain

network, and includes materials and parts acquisition, processing, and dispersal. More than 1,400 guitar kits have been produced in 2016, generating over $350,000 in revenue this year.

Industry support remains high for this project. For example, Forrest Scientific donated a $65,000 CNC router to help increase the throughput of guitar kit manufacturing. Additionally, in-kind contributions will continue to foster sustainability, and the STEM Guitar Project will continue to benefit from donations by Martin Guitars, Taylor Guitars, Stewart Macdonald, Fender Guitars, and D'Addario. There are currently two high schools and one university (Central Washington) participating in the entrepreneurial supply chain that helps the network receive kits for their classrooms, and this number will be expanded with the new grant.

Sustainability will be addressed throughout the grant period during Leadership Team meetings. Sponsors from industry and other organizations beyond those described above will be pursued to supply funding, materials and supplies, and other support for the improvement and continuation of the project.

EVALUATION OVERVIEW, DESIGN, AND APPROACH

The evaluation of the STEM Guitar Project will use mixed methods (Creswell & Plano-Clark, 2011) and developmental evaluation (Patton, 2011) approaches. A mixed methods approach uses an appropriate mix of qualitative and quantitative data collection and analysis techniques and reflects not only results in terms of numbers but the perspectives that can be assembled from qualitative data to enhance the quantitative results when triangulated. From the beginning of the project and moving toward the summative evaluation component in Year 3, the developmental evaluation (DE) approach will inform the project's process and formative evaluation, especially regarding key project components. DE will be useful in the ongoing development and exploration of new pathways for the curriculum of the Guitar Building Institute (GBI). Similarly, DE will aid in examining how the project refines and streamlines its data collection process by adapting what has been learned from previous years to a more focused data collection effort targeting a small group of experienced ("Champion") faculty and newly trained faculty. DE will inform the creation of a model for establishing and maintaining a STEM CoP, which is meant to be replicable and scalable. DE will contribute to lessons learned about processes and systems within the project, enabling successful completion of innovative activities.

A comprehensive collaborative approach to qualitative data collection will be adopted to reflect the project processes and support some quantitative results. To this end, the project team will share project documentation and implemented practices throughout the project period. A quasi-experimental design (Shadish et al., 2002) will be used for quantitative data using control groups (e.g., propensity score matching (Guo & Fraser, 2010)) and pre- and post-tests for quantitative data components. The project's Logic Model (with resources, activities, participation, outputs, and results for Years 1 to 3 and beyond) shows the extent of the project's activities in supporting its two major goals (see p. 15). The evaluation will also draw from Guskey's (2000) five levels of evidence for evaluating the project's professional development Institutes: (1) participants' reactions; (2) participants' learning; (3) organizational support and change; (4) participants' use of knowledge and skills; and (5) student learning outcomes. The Guitar Building Institute is a major professional development project component. Ongoing feedback from the evaluation team will be integrated at key stages of the project and during the project team's bi-monthly conference call meetings. Ongoing feedback improves the utility of evaluation for project learning and accountability (Patton, 2008). As Kundin (2005) noted, it is important to talk about project challenges as events unfold and interact in situations where people develop and change. The evaluation plan and deliverables include verbal feedback for continuous program improvement during conference calls, end-of-year reports for Years 1 & 2, a close-out report at the end of Year 3, and at least three (one per year) conference presentations or other formal dissemination of results. In producing the evaluation deliverables, the evaluation team will ensure the application of the program evaluation standards of utility, feasibility, propriety, accuracy, and accountability standards (Yarbaugh et al., 2010).

Evaluation Methods

Evaluation Goals and Questions: The two evaluation goals parallel the two major project goals: (1) to determine the extent to which participating faculty increased student interest in and engagement with learning of STEM principles, practices, and careers through guitar design and building; and (2) to assess how well the project has created a replicable model for establishing and maintaining a STEM Community of Practice. Six sets of evaluation questions, aligned with these project goals, will address both formative and summative evaluation components. Indicators and measures for each of these questions are included in the Evaluation Data Collection Matrix (See Attachment E).

1. How well has the project recruited and retained diverse community college and high school faculty after training in interdisciplinary STEM project-based approach teaching and innovative inquiry-based learning inspired by the Society of Manufacturing Engineers (SME) identified skills gap needs?
2. How well has the project facilitated the faculty development in and access to Modular Learning Activities (MLAs)? To what extent have MLAs developed by faculty been vetted for accuracy, appropriate assessment, content, consistency, alignment with standards, and significance to real-world situations?
3. To what extent have the trained faculty members reached their students and helped them become aware of STEM Guitar building concepts? What "high-tech" and "high-touch" engagement tools and opportunities has the project developed to recruit and draw students to STEM guitar building? To what extent has the project affected participating community college and high school students' learning about STEM concepts as applied to the concept of guitar building? To what extent has the project affected participating community college and high school students' attitudes towards STEM and STEM careers?
4. How well has the project facilitated the formal adoption by institutions of established standards (e.g. NGSS, Technical Standards) and strategies for STEM Guitar project curriculum? What strategies has the project introduced to these institutions and established as part of the project processes to contribute to the project's overall sustainability? To what extent has this formal adoption by institutions resulted in a wider reach?
5. What activities and platforms has the project explored and established to organize a Community of Practice? To what extent have these strategies and platforms contributed to a sustainable CoP?
6. To what extent has the CoP facilitated the showcase of project-based learning for STEM principles, student learning outcomes relating to STEM principles, and student knowledge regarding STEM careers? To what extent has the project expanded, refined, and streamlined student outcome data collection processes?

Anticipated Participants/Respondents: The proposed project anticipates training at least 310 faculty and at least 40 administrators. The project is meant to reach more than 10,800 students of the trained faculty through project exposure and introduction to the STEM Guitar curriculum. Fifteen faculty and approximately 400 students will participate in more in-depth data collection. Approximately ten industry and community partners are also expected to participate.

Measures and Data Collection: The project team will provide the evaluation team with project-generated or existing data sources (e.g., project process/implementation documents, GBI curriculum, copies of MLAs, supply chain development documentation, and CoP data). The faculty will provide student assessment data regarding content knowledge, students' technical and soft skills (per rubrics designed for student performance assessments), and samples of student products. The evaluation team will collect data via (a) interviews and/or focus groups with the project team, key partners, and faculty Champions (during the Summit) regarding the project implementation process and overall perceptions about the project

outcomes; (b) *an online* survey to guide faculty selection; (c) follow-up surveys to assess faculty implementation of the program, outcomes including teachers' attitudes towards and skills at teaching STEM (from the Faculty Follow-up Instructional Survey); and (d) surveys to measure students' attitude towards STEM, their knowledge regrading STEM careers, and their interest in pursuing STEM careers.

Data Analysis Strategies: Document review will be guided by rubrics developed to measure project objectives. Thematic analysis (Guest et al., 2012) will be conducted on all qualitative data. Interview and/or focus group discussion data will be audio recorded, summarized, and thematically coded by two coders (reliability will be checked to achieve 90% agreement or more). Coding will occur iteratively: review followed by initial category generation and then refinement (Creswell, 2014). Appropriate descriptive and inferential statistics will be used to analyze quantitative data. A triangulated analysis of quantitative and qualitative data (Creswell & Plano Clark, 2011) will be conducted to answer evaluation questions and to examine how well the project's objectives are being met. Ongoing feedback and recommendations will be given to the project team to incorporate into training, curriculum development, and other program activities.