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The STEM Guitar Project

2019-2020 Evaluation Report

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The STEM Guitar Project

2019-2020 Evaluation Report

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Executive Summary

Introduction

This is the Executive Summary of the 2019-2020 evaluation report for The STEM (Science, Technology, Engineering, and Math) Guitar Project funded by the National Science Foundation Advanced Technological Education (NSF ATE Award #1700531). This evaluation report is prepared for Sinclair Community College in Dayton, Ohio, the primary institution involved with the Project. The report covers the period from August 2019 through April 2020 and focuses on the formative and some summative aspects of the Project evaluated within the context of the 2019-2020 program implementation. Limitations, conclusions, and recommendations are included in this Executive Summary.

Results

The context for the 2019-2020 program evaluation includes the Project background and the program evaluation approaches, design, and methods. The Project background deals with the Project's overall description, goals, objectives, and program theory. The Project's goal is focused on increasing student interest, engagement, and learning of STEM principles, practices, and careers through guitar design and building. The program theory is based on the STEM Guitar Project's intent to mitigate the skills gap and need for technicians with advanced technical knowledge and hands-on experience made possible through its faculty professional development Guitar Building Institutes (GBI's) in 2019-2020. The STEM Guitar Project trained 147 participants through the implementation of eight Summer Guitar Building Institutes (GBI's) [within three program tracks: (1) two Acoustic Guitar Building Institute (AGBI), (2) three Electronic Guitar Building Institute (EGBI), and (3) three Hybrid – Computer Numerical Control machining with Electric Guitar Building Institute (HGBI); another GBI at Golden Colorado in late October-early November 2020; two veterans' workshops [one in Temecula, CA in July 2019 and another in Edmonds, WA in November 2019]; and one outreach guitar build with Women Walking West at Greater Cincinnati in February 2020.

Like the previous year, the program evaluation uses the mixed methods and developmental evaluation approaches. Evaluation capacity building was used to help the Project Team develop its evaluative thinking to optimize use of evaluation results for continuous program improvement. Appropriate qualitative (e.g. applied thematic analysis) and quantitative (e.g. non-parametric and descriptive statistics) analysis tools are used accordingly. The evaluation goals and questions are based on the Project goals and focus guided by Guskey's five levels of evaluating professional development and the Project's program theory and

philosophy. The five evaluation questions are based on: (1) diversity of participants, (2) program effects on Project participants, (3) support for STEM Guitar program implementation (4) effects on students, and (5) the Project spread and overall sustainability. Data collection methods included pre-post Institute/workshop evaluation surveys for faculty as well as the outreach and veteran participants, in-person interviews of sampled Faculty Champions from a GBI and the 2019 Summit, a focused group interview from the 2019 Summit participant, in-person and telephone interviews of sampled veteran participants, informal discussions and access to Project Team GBI reflections and implementation perspectives, observation of an AGBI and one veterans' workshop, participant observation of the summit meeting, classroom observation of STEM Guitar case study classroom, interview of the case study faculty and student leaders, and review of archival data regarding the Team process and curricular development. In early May 2020, additional information was gathered from previous GBI participants through a short survey to determine how they are making use of the STEM Guitar Project online materials during this time of schools/colleges closures. Additionally, it was meant to gather the GBI alumni's perspectives about any online instructional support that the STEM Guitar Project may be able to do for them.

The single case study design started in 2018 [where the design intended the use of a quasi-experimental research approach with the pre-test post-test control group design involving prospective and retrospective cohort's longitudinal data] was revised. Challenges in institutional situations limited data collection for the case study class. The revised plan follows through on the performance of three different academically-performing student groups: high-performing, mid- and low-academic performing students. While the class survey use continues, the revised plan is to follow through on the performance of three different academically-performing student groups: high-performing, mid- and low academic performing students. The case study is partly influenced by an anthropological research method approach where participant observation was made part of the data collection and field work viewing the case in terms of its census, map, and calendar.

The main evaluation results are organized by formative and summative results. Formative results include the Project Team working structure and process, Project implementation, and Project output. Summative results include data showing increased involvement of STEM Guitar participants, program effects on participants, support for faculty in their STEM Guitar program implementation, program effects on students and emerging outcomes, as well as Project spread and overall Project sustainability.

The STEM Guitar Project working structure and process remains seamless through several years of Project existence. On the Project Leadership is the Executive Committee (EXECOM), composed of the Lead Project Principal Investigator (PI) and four co-PIs. They meet virtually once a month and continue to take pro-active roles in Project leadership and promotion of collaborative participation among Project Team members. The Project Team structure remains viable as it continues onboarding of STEM Guitar Champions and Advocates to the Project Team. The Project overall working and decision-making process involves the dedication and full commitment of the Project EXECOM and Team members to the STEM

Guitar Project, as evident in the quality of support and Project team processes developed in improving the Project. Everyone in the Project Team, having been introduced to evaluative thinking, is on “continuous improvement mode”, as the Project Team continues to use various tools available throughout the Project period. With team members spread across the United States, use of telephone, email communication, and online platforms and tools such as Zoom conference calls have been critical in sharing information and making Project decisions. Overall, with a stable Project Leadership and Project Team structure, the Team is open to a wide variety of tools to help improve the Project implementation process.

Project implementation starts with host/site selection and recruitment of participants; GBI agenda, process for GBI implementation and evaluation ensuring fidelity of implementation; and curricular preparation/adaptation. There was a total of 147 participants trained in 2019-2020: 123 faculty GBI (from both the summer GBIs and the GBI at Golden Colorado), 15 veterans (from the Temecula, CA and Edmonds, WA workshops), and 9 outreach participants connected with Women Walking West. One hundred forty-four GBI alumni responded to the survey conducted in May 2020.

Hosts for the 2020 GBI’s were selected establishing three new institutional contacts and enriching connections with four existing institutional contacts in the process; two for AGBI’s, three for EGBI’s, two for HGBIs, and four for veterans’ workshops. Established and improved recruitment and selection of faculty participants help the Project in reaching out to its targeted participants – underrepresented populations. Institute and workshop agendas are being reviewed and updated. To date, there are about 100 applicants to the 2020 faculty GBI Selection and decisions regarding confirmation or revision of schedules [because of recent closures of schools and colleges due to corona virus] will be done sometime in June 2020.

Sinclair Community College guitar manufacturing/production team continues to serve the Project, adjusting to the changing needs of clients due to client exposure to CNC CAD design where they are able to produce their own guitar body parts. Guitar kit sales in the 2019-2020 school year increased by 25% over the 2018-2019 sales. There were more orders of guitar kit supplies and tools in 2019-2020, indicating the effects of faculty HGBI training in the summers of 2018 and 2019. More faculty embarked in CNC-manufactured guitar parts during 2019-2020.

Curricular material development and vetting of these materials with district standards, Next Generation Science Standards (NGSS), and employability skills are in place. Improvement and revisions of existing materials continues. Development of many videos, especially with the on-going demand for online courses continues. Curricular learning and teaching materials are organized and posted on the Project website (https://guitarbuilding.org) even as the website undergoes review and improvement.

There is greater involvement, diversity, and geographical spread of STEM Guitar Project participants. Project participants in 2019-2020 (N=147) were spread across the four regions of the United States. Most of the participants (46%) came from Region 4, followed by Region 3, with 24% of the participants. There were 33% female participants in 2019-2020; a 10% increase

compared with 23% from the previous year. White/Caucasian participants were the largest group of participants in 2019-2020; however, there was 100% increased participation of Asian-Americans (n=7) and Black/African Americans (n=6) since there were no reported participants from these groups the previous year. During 2019-2020, the Project included a more diverse group of participants beyond faculty (additional 10% participants completing either an Associate's degree or "some college credit") reaching more educationally-diverse groups of people across participants who got the chance to improve their STEM Guitar-related technical and soft skills. Five percent more of the total 2019 GBI faculty reported that over half of their school population is underrepresented compared with the previous year's report. There was a 2% increase in institutions served from rural areas in 2019-2020 compared to 2018-2019. The demographic characteristics of the surveyed GBI alumni approximated this demographic spread.

Participants in the 2019-2020 implementation of The STEM Guitar Project learned STEM-related hard and soft skills meant to provide them with employability skills. There were common STEM-related hard skills learned by the three sets of participants (faculty, veterans, and outreach) especially related to guitar set-up, finish, quality control, and intonation. Learning the use of appropriate tools (power and hand) and machines, measurement skills and iterative application of a process are employability skills and important experiences experienced by the participants. Per survey self-reports of the 2019-2020 GBI and workshop participants, productivity with accountability, flexibility/adaptability, as well as critical thinking with problem solving are the three-most valued soft skills learned. More than 30% of the GBI alumni surveyed in May 2020 indicated they continued building guitars with their students through their online teaching during school/college closures. In addition to improved confidence; distracting them from their Post-traumatic Stress Disorder (PTSD) concerns; and improvement of their interactions with family, friends, and the community; veterans affirmed the importance of learning embedded soft skills inherent in the STEM Guitar program implementation despite differences in their ages, educational background, and field of service.

The STEM Guitar Project continues improving its support for faculty in their STEM program implementation. This is done through improvement of the Institutes and workshops, making available and improving access to teaching and learning materials, especially videos and other online materials in these times of school closures. More than sixty percent of the GBI alumni surveyed in May 2020 indicated that they were using instructional videos during the school/college closures as they conducted their online teaching; additionally, they would like the Project to provide more materials (curriculum and videos) in individual modules that they can continue to use in their online teaching. The Project promotes and facilitates improvement of administrative and educational institutional support for faculty by reaching out to administrators and helping them understand the program better. A good example of this is the administrative video that will soon be released to academic institutions. The annual Faculty Champion summit has been a major venue for faculty to share best practices and other exemplars that faculty can use in their teaching the Project-based guitar building program. The Project encourages and facilitates interactions among participants and students through its website and Facebook account.

Program effects on students were noted through results from the case study classroom and other faculty self-reports about improvement of student academic performance and learning of hard and soft skills that are marketable to business and industry in the community. Faculty in the case study school implement the STEM Guitar program promoting the learning of attributes that support the district goals (equity of opportunity, strong community, high expectations, global readiness, and culture of kindness). Survey results indicated that the 2019-2020 STEM Guitar students have learned through STEM through guitar building different STEM-related skills, the importance of STEM in real-world applications, and honed their grit and confidence in achieving their goals.

Faculty Champions confirmed what was indicated by the case study students in learning about STEM concepts and how they are applied in real-life situations. They shared their own success stories about their students. They affirmed that the STEM Guitar program has a productive and consistent impact on their students' academic performance. A faculty shared that 89% of all students (N=178) he taught in guitar building class since 2016 achieved grades of B+ and above. Two faculty reported that they had former students who were awarded scholarships because of STEM knowledge gained from the STEM Guitar build. Another Faculty champion, who is currently a member of the Project Team, shared successful stories about his former STEM Guitar students from some years back. This Faculty Champion reported his students' success in their college path pursuing STEM-related fields [in architecture, agricultural engineering, civil engineering, computer engineering, and mechanical engineering technology; one even pursued his Master's degree] and employment in technical fields like auto-body repair. He noted that these students attributed their success to their guitar building experiences. One other faculty reported that the three most important skills students learned in his class are: soldering, hand tool use (experiencing and practicing the use of a tool, such as a band saw, etc.), and machine use (lately, students started using Fusion 360). Other knowledge and skills illustrating impact of the STEM Guitar program on students include: measurements and the integration of wood shop with the guitar build; math and hands-on skills (especially doing fret spacing); science and lab; multiple ways of solving a problem; and coming up with multiple solutions. As another faculty indicated, the technical skills students learned in his class are employability skills marketable to different companies and industries around their community.

The STEM Guitar Project widens its reach and continues to be recognized in academic institutions and academic professional organizations with active Project dissemination through publications, professional conferences, interactions with business partners and supporters, and media exposure. The Project website and STEM Guitar Project Facebook account also help in the Project's wider reach.

The STEM Guitar Project is able to explore and develop continuing business and industry partnerships with business/industry connections. It continues to strengthen these partnerships. The Team would like to enhance employability skills through the Project's Institutes/ training by creating an industry-recognized badging or skill identification system,

digital badging, and standard-based certification. The skill sets will be cross-walked with the Project's educational competencies, developing a process of skills recognition learned from the STEM Guitar programs that would equate to industry service technician levels. Among specific industry partners being tapped for the skills certification venture are: Fender Musical Instruments, Taylor Guitars, Martin Guitar and Heritage Guitars, and Credly. Taylor Guitars continues to take a key role in supporting the current grant's acoustic guitar building track by way of technical support and potentially supplying educational guitar kit materials for the Project. Boeing Company remains a major partner, especially for the Washington State participants. Boeing provided input regarding employability hard and soft skills that are important considerations in developing the guitar building curriculum. Continued Project efforts in exploring Project connections with employability technical and soft skills were spearheaded by this initial partnership with Boeing and the support of the NSF funded MatEdU Center in Edmonds Community College located in Washington State. Other existing corporate partners (All Parts, Black Diamond Strings, D'Addario, Forest Scientific Corporation, FML (Frank Miller Lumber), Indasa, ShopBot, Stewart MacDonald) continue to support the STEM Guitar Project, by providing participants with personnel expertise and in-kind support.

Overall Project sustainability is a continuous Project concern, as overall sustainability efforts have been part of Project activities since the beginning of the grant. These activities involve the development of the supply chain; the development and maintenance of Project partnerships with academic institutions, business/industry, and the larger community; and exploring other funding support, including submitting supplemental grants.

Limitations

Limitations noted in the previous years' reports continue to be experienced within this reporting period. This Project has an affinity with informal STEM education (National Research Council, 2010, 2015) in the sense that faculty involvement in the professional development is voluntary and curricular implementation varies from participant to participant. Although classroom implementation and curricular integration are highly encouraged, some curricular implementation was conducted out-of-school or as limited program offerings like school extension classes. Thus, systemic collection of direct student academic data and other outcome constructs (as behaviors and attitudes toward STEM) across the implementing groups, remains a big challenge. This Project's challenge was experienced in the previous grant as well. Given the Project reach and budget constraints, general follow-up evaluation for participants is dependent on self-reports. Although not part of the original evaluation plan, short informal interviews with Faculty Champion participants and some veterans (either from prior years' Institutes/workshops or during some on-going events) were conducted by the external evaluator. Constraints were experienced especially with veterans' hesitance in responding to questions about personal effects of guitar building on them. A single case study design (as described above) started in 2918-2019 was used to mitigate this issue. However, evolving limitations in the school and district data pose continued challenges in presenting more robust student outcomes data. Limited faculty-reported student data and faculty Institute participants' self-report about student outcomes are included in this report. The current challenges of the corona virus affected some data collection in case study schools, as well as plans for the spring

veterans' workshops, and decisions about the 2020 summer workshops.

Conclusions

The 2019-2020 STEM Guitar program evaluation showed encouraging formative and summative results. The External Evaluator continued to help the Project Team in developing their evaluation capacity and evaluative thinking for better evaluation use and continuous program improvement. The STEM Guitar Project further improved its process and outcomes during the 2019-2020 fiscal year as its Project working structure and process remains seamless through several years of Project existence. Overall, with a stable Project Leadership and Project Team structure, the Team was open to a wide variety of things that lend to improving the Project implementation process and results.

Established and improved recruitment and selection of faculty participants helped the Project in reaching out to its targeted participants – underrepresented populations. Selecting three new institutional 2020 GBI hosts established new Project contacts. Maintaining the four other existing institutional contacts as part of the 2020 GBI hosts enhanced this network. Institutional connections through new guitar sales client contracts further widened the Project reach. Guitar kit sales in the school year 2019-2020 increased by 25% over 2018-2019 sales, indicating continuous guitar building implementation in academic institutions.

Increasing involvement of underrepresented groups in the Project shows a continued quest for community relevance. The plan to enhance employability skills (with both hard and soft skills) through the Project's Institutes/ training by creating an industry-recognized badging or skill identification system, digital badging, and standard-based certification is laudable. Making this possible with faculty and veteran participants would in turn transfer to guitar-building students leading the STEM Guitar Project closer to its Project goal of increasing student interest, engagement, and learning of STEM principles, practices, and careers through guitar design and building - better outcomes for productive and skilled members of the community. Indeed, these are great efforts to mitigate industry skills gap.

"Beyond relevance" is the Project's existence reality. Adjustments to challenging situations like the school/college closures posed greater challenges to Project-based and hands-on teaching and learning. The Project Team's active involvement in developing more videos and online materials and continuous search for best practices to support the faculty teaching STEM guitar in academic institutions is commendable. Continuous efforts in Project dissemination through conference presentations and media exposure would be greatly helpful in sharing the Project's best practices. The reality of the Project existence is challenged by the need for future funding. Continued Project Team efforts in exploring potential for funding support is vital to the Project's existence. Continuous program improvement is the hallmark of the STEM Guitar Project.

Recommendations

The recommendations here are geared toward maintaining and enhancing the Project's

best practices and areas of growth. The Project Team's continuous improvement/development efforts have been vital to the growth of the Project. Thus, some of the Project's best practices are worth maintaining and enhancing, such as:

- Project Team's involvement in developmental evaluation and capacity building to further hone its evaluative thinking skills needed in critical program implementation;
- Project's collaborative and participatory decision-making process for greater Project Team buy-in and optimal decisions;
- Enhancement of the Project's processes, structures, and documentation of different aspects of the Project for replicability and scalability;
- Regular team meetings and offering of specialty development meetings as the Project need arises; streamlining of efforts for efficiency;
- Continued improvement of the Project website;
- Development and strengthening of Project outputs;
- Continued exploration of practical ideas to support faculty STEM guitar implementation;
- Development of new and maintenance of existing Project partnerships;
- Efforts to disseminate Project information via conference presentations/publications, and media exposure; and
- Continued effort to solicit Project funding.

The following are areas of growth where the Project is "emerging" and are worth the Project Team's attention and action:

- Robust STEM Guitar Institute/workshop agenda revisions to directly reflect fidelity of implementation, entrepreneurship, and employability skills.
- Modelling of any data collection strategy expected of faculty participants during their program implementation within the GBIs.
- Exploring more new ways and materials addressing different approaches to teaching a Project-based/hands-on Project to prepare for uncertainties such as the coronavirus pandemic.
- Coordinating the Project Team's prolific efforts in developing teaching/learning materials for optimal output.
- Launching the distribution of the administrative video and following through on the effects of this mode of information and support.
- Monitoring guitar kits and supplies sales closely to have additional indicators of program implementation, as well as program reach and spread.
- Exploring more ways to ensure/motivate faculty sharing of results and impact of their teaching STEM Guitar; develop more incentive for faculty to continue sharing student data.
- Developing consistent ways to track effects of employability learning and intended use of these skills.
- Exploring different ways to ensure Project viability and sustainability.

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The STEM Guitar Project
2019-2020 Evaluation Report

Introduction

This is the 2019-2020 evaluation report for The STEM (Science, Technology, Engineering, and Math) Guitar Project funded by the National Science Foundation Advanced Technological Education (NSF ATE Award #1700531). This evaluation report is prepared for Sinclair Community College in Dayton, Ohio, the primary institution involved with the Project. It covers the period from May 2019 through April 2020. This report focuses on the formative and some summative aspects of the Project. With the formal addition of the veterans' build in the Project portfolio in Year 3, four program tracks (Acoustic Guitar Building Institute, Electric Guitar Building Institute, the Hybrid Computer Numerical Control (CNC) machining and Electric Guitar Building Institute, and the veterans' workshops) are included in this report. Project Team members validated the different areas covered in this report through their data sharing and their Project implementation perspectives. The report includes the executive summary, context for the 2019-2020 program evaluation, formative and summative results, conclusions, and recommendations.

Context for 2019-2020 Program Evaluation

Context for this 2019-2020 program evaluation includes the Project background with the program evaluation design/approaches/methods and questions used in 2019-2020, including the reports for the 2019 Summer Institutes and the veterans' build in 2019.

The Project Background

The Project background deals with the Project overall description of its third year of implementation that showcases the Project - its goals, objectives, program theory, as well as the Project working structure and process.

Overall Description, Goals, Objectives, and Program Theory

Sinclair Community College continues to espouse collaborative work with various partners from community colleges, universities, K-12 institutions, two NSF ATE national centers, as well as industry partners and other guitar manufacturers to conduct professional development Institutes for secondary and post-secondary faculty. The STEM Guitar Project, in its third year, enjoys the advantage of building on its successful NSF ATE STEM-Guitar building-related Projects for the past eight years (NSF ATE DUE #1304405 & NSF ATE DUE #0903336). The main goal remains focused on continued increase of student interest, engagement, and learning of STEM principles, practices, and careers through guitar design

and building. Doing so will help solve the critical STEM technician shortage.

The third year of The STEM Guitar Project program implementation included training 109 faculty in solid body electric guitar building, acoustic guitar building, and CNC (Computer Numerical Control) machining in manufacturing guitar parts. Faculty guitar building implementation involved a range of eight to 20 students per faculty for each period that they implemented the program. The culmination of the STEM Guitar Project leads to students who are excited about making guitars and deeply engaged in science, mathematics, and engineering practices critically needed by employers. Additionally, through the students' involvement in the guitar build, the Project supports and helps develop student academic gains and career interests in STEM; thus, promoting development of well-trained technicians, as well as recruiting and retaining students throughout the STEM pipeline, narrowing skills gap (Queen, 2018).

Inspired by the pilot Project efforts of working with some veterans during the second year, the STEM Guitar Project extended its program to two guitar building workshops training 15 veterans during this period. This was made possible through supplemental grant support from NSF. As the Guitar Building Institutes (GBI's) and workshops focus on guitar design and building skills creating a clear linkage to broader STEM concepts, the Project continues to mitigate the skills gap and need for technicians with advanced technical knowledge and hands-on experiences. Additionally, the Project PI conducted one full day of guitar building extension activities, reaching out primarily to nine immigrant women who are part of Women Walking West.

The STEM Guitar Project support, especially for faculty, includes the Applied Learning Community (the STEM Guitar Project's brand of Community of Practice). This is made possible through the yearly Program Summit that allows faculty to maintain and cultivate newly-learned instructional practices. Continued Project support is also made possible through the Project website's (guitarbuilding.org) publication of Modular Learning Activities (MLA's), videos, and other materials that can be used by faculty in their guitar building implementation, as well as the promotion of sharing through the Project's STEM Guitar Facebook account. The Project Team also remains available via email and telephone access to about 900 GBI and workshop alumni.

As in previous years, the STEM Guitar Project continues to promote strategies to uphold and extend its sustainability and continue its efforts to increase enrollment of populations traditionally underrepresented in STEM. Strategies include strengthening the collaborative manufacturing process and connections with national standards, job readiness/related skills, and guitar design and building activities; advocating strong involvement of school administrators in systemic and broad dissemination of Institute lessons and laboratory experiences in schools and colleges; and involving veterans regional and national associations to reach out to veterans around the country. Dissemination of lessons learned is made possible via the Project's online platform, which also supports sustainability and expansion of the Project at participants' institutions and beyond.

Program Evaluation

This section includes the program evaluation approaches, design, methods, evaluation questions, and limitations.

Evaluation Approaches, Design, and Methods

Overall, the program evaluation of the STEM Guitar Project employed a mixed research methods analysis. Additionally, the external evaluator utilized developmental evaluation (Patton, 2011) approaches especially in dealing with the formative component of the program evaluation.

As part of mixed methods analysis, the applied thematic analysis technique (Clarke & Braun, 2017; Guest, Mac Queen, and Namey, 2012), was used because of its flexibility and responsiveness to situations - in this case, handling of the specific evaluation questions, which were based on the Project objectives. Per Guest, etc. (2012), the applied technique refers to the "*common purpose of solving practical problems*" (p. 11), especially as the external evaluator employed "*bounding of the analysis"* (p. 35) according to the evaluation questions related to projected outcomes about program effects. Clarke & Braun's (2017) view of thematic analysis plan as a flexible and non-research design analysis plan is well suited to this situation, as it is a non-research program evaluation.

While qualitative data were gathered along with the administered quantitative surveys on the 2019-2020 participants, some qualitative data were also gathered from external evaluator participant observations and archival data. Additionally, qualitative data were collected informally from Faculty Champion participants from prior years to better understand the effects of faculty program implementation on their classroom practice and their students. Given this key objective, a priori codes and categories based on the skills concepts and innate processes involved with guitar building, as pre-identified by the Project Team, were primarily used emerging into larger applied themes. Ninety percent inter-rater reliability is achieved by completing an inter-rater reliability coding with at least 10% of the qualitative data handled. Given such qualitative data, exploratory sequential, descriptive, and comparative analytic approaches were used with the thematically categorized data in integrating qualitative and quantitative data. Qualitative data display incorporated some mixed methods approaches in the tradition of Creswell & Plano-Clark (2011), where the integration of the quantitative and qualitative are presented in a matrix. A mixed method approach and analysis involves an optimum mix of qualitative and appropriate quantitative data collection and analysis techniques. They reflect, not only results in terms of numbers, but perspectives that can be assembled from qualitative data to enhance quantitative results when triangulated. Appropriate quantitative (e.g. non-parametric and descriptive statistics) analysis tools were used accordingly.

Data collection methods included: pre-post Institute/workshop evaluation surveys for faculty as well as outreach and veteran participants; informal in-person interviews of seven sampled Faculty Champions from a GBI and two Faculty Champions from the 2019 Summit; in-

person and telephone interviews of sampled veteran participants; informal focused interview of a group from the 2019 Summit participants; informal discussions and access to Project Team GBI reflections and implementation perspectives; observation of an AGBI and one veterans' workshop; participant observation of the 2019 Summit meeting; observation of a STEM Guitar case study classroom; interview with case study administrator, faculty, and student leaders; and review of archival data regarding the Team process and curricular development. In early May 2020, additional information was gathered from previous (2017, 2018, 2019) GBI participants through a short survey to determine how they are making use of the STEM Guitar Project online materials during this time of school/college closures. Additionally, it was meant to gather the GBI alumni's perspectives about any online instructional support that the STEM Guitar Project may be able to do for them.

A follow through of the single case design (Ledford, 2018) with a pre-test post-test control group design (Shadish et al., 2002) study of a "champion's" high school started in 2018-2019 was conducted. The prospective and retrospective cohort (Lamorte, 2017) longitudinal study, as well as the collection of academic data and other STEM-related data for both the prospective and retrospective cohorts were reviewed and reconsidered because of data constraints in the school and district. Continued efforts to collect program evidence of student effects are being explored with use of high-tech, high touch assessment via available online apps (as applicable), taking advantage of students' partiality to social media. A strategy to follow-up on a sampling of the high-performing, medium, and low academic-performing students that were part of the guitar implementation class is now in place. Data about these samples are expected to be included in the cumulative end-of-Project report.

The developmental evaluation (DE) approach informed the Project's process and formative evaluation in 2019-2020. As in the previous two years, Team members were encouraged and involved in evaluative thinking enabling intentional process use (Patton, 2015, 2011, 2008) of evaluation feedback and findings for Project continuous improvement, increasing Team members' sense of program accountability (Archibald, 2018; Carden & Earl, 2007; Schwandt, 2018). Each of the five evaluation questions used as bases for program evaluation has formative and summative components. The formative components, which include team and program implementation processes, have implications and direct effects on expected outcomes being measured per the evaluation question. DE is useful in the ongoing development and exploration of new pathways in the Project's team processes and professional development implementation endeavors. DE activities and process-use are enhanced further as the Project Team becomes involved with capacity building (King, 2007; Preskill & Russ-Eft, 2016) activities led by the External Evaluator. DE activities are instrumental in achieving the summative components. For this Project focused on professional development, the summative components draw from Guskey's (2000, 2002) five levels of evidence for evaluating the Project's professional development. The outcomes are geared toward (1) the increased involvement of diverse secondary and post-secondary faculty; (2) effects on faculty regarding their practice effecting student outcomes; (3) student learning about STEM concepts, behaviors and attitudes toward STEM; (4) Project facilitating a replicable and sustained Community of Practice; and (5) wider reach of the STEM Guitar Project and its overall Project sustainability.

Aware that Deterding's and Solmeyer's (2018) ideas about involving practitioners in cumulative study add to relevance and applicability of results, the External Evaluator also continues to act as an evaluation coach (Grob, 2018) and helps in examining how the Project refines and streamlines its data collection process by adapting previous years' learning to a more focused data collection effort targeting a small group of experienced ("Champion") faculty and newly-trained faculty.

Evaluation Goals, and Questions

As in the first two years of this current grant, the third year program evaluation for The STEM Guitar Project considered two overall evaluation goals based on the Project overall goals: (1) to determine how well the Project helped faculty increase their students' interest, engagement, and learning of STEM principles, practices, and careers through guitar design and building; and (2) to assess the Project's success in creating a replicable model for establishing and maintaining the STEM Guitar Projects' Applied Learning Community, the Project's brand of community of practice. Basically the same five evaluation questions addressing both the formative and summative components from the previous two years were the bases for this Project evaluation: (1) To what degree has the Project increased the number of diverse secondary and post-secondary faculty trained in an interdisciplinary Project-based approach to teach innovative inquiry-based learning techniques that are inspired by the STEM skills gap? (2) How successful were faculty participants in increasing the number of secondary and post-secondary students that learn STEM concepts, as well as improving their attitudes and behaviors towards STEM, as a result of faculty training in this Project? (3) How successful has the Project been in demonstrating improvement of student learning outcomes that relate to STEM principles, career skills, and aspirations? (4) To what extent has Project facilitation of more interaction and collaboration among faculty participants resulted in a replicable and sustained Applied Learning Community? (5) How successful were the Project's efforts to increase the number of institutions that formally adopt and establish standards and strategies for STEM Guitar Project curricula resulting in wider reach and overall Project sustainability?

Limitations

Limitations noted in the previous years' reports continue to be experienced within this reporting period. This Project has an affinity with informal STEM education (National Research Council, 2010, 2015) in the sense that faculty involvement in the professional development is voluntary and curricular implementation varies from participant to participant. Although classroom implementation and curricular integration are highly encouraged, some curricular implementation was conducted out-of-school or as limited program offerings like school extension classes. Thus, systemic collection of direct student academic data and other outcome constructs (as behaviors and attitudes toward STEM) across the implementing groups, remains a big challenge. This Project's challenge was experienced in the previous grant as well. Given the Project reach and budget constraints, general follow-up evaluation for participants is dependent on self-reports. Although not part of the original

evaluation plan, short informal interviews were conducted by the external evaluator with Faculty Champion participants and some veterans either from prior years' Institutes/workshops or during some of the on-going events. Constraints were experienced especially with veterans' hesitance in responding to questions about personal effects of guitar building on them. A single case study design (as described above) started in 2918-2019 was used to mitigate this issue. However, evolving limitations in the school and district data pose continued challenges in presenting more robust student outcomes data. Limited faculty-reported student data and faculty Institute participants' self-report about student outcomes are included in this report. The current challenges of the corona virus affected some data collection in case study schools, as well as plans for the spring veterans' workshops, and decisions about the 2020 summer workshops.

2019-2020 Formative and Summative Results

Formative Results

The report about program formative results deal with the Project Team working structure and process, as well as Project implementation, and product output established during the 2019-2020 Project year.

Project Team Working Structure and Process

The STEM Guitar Project working structure and process remains seamless through several years of Project existence. On Project Leadership is the Executive Committee (EXECOM), composed of the Lead Project Principal Investigator (PI) and four co-PIs that meet virtually once a month and continue to take pro-active roles in Project leadership and promotion of collaborative participation among Project Team members.

The Project Team structure remains viable as it continues onboarding of STEM Guitar Champions and Advocates to the Project Team. One member retired from the Project Team and has been replaced by a new team member from the pool of STEM Guitar Champions. Two Veteran Advocates who are part of a national veterans' association also joined the Project Team. The specialty sub-teams and working committees (acoustic build sub-team, CNC sub-team, electric guitar sub-team, administrative webinar team, the veterans build team, evaluation and marketing sub-teams) continue to perform their critical roles in contributing to Project needs.

The Project overall working and decision-making process involves the dedication and full commitment of the Project EXECOM and Team members to the STEM Guitar Project, as evident in the quality of support and Project Team processes developed in improving the Project. The Project Team members continue to work collaboratively, communicating through remote connections at least twice a month, and maintaining documentation of

cumulative agenda and meeting conference minutes. This collaborative Project decision-making process allows for greater opportunities to respond to Project issues accordingly. Regular formal virtual meetings were held as a group and sub-groups (The Project EXECOM and specialty sub-teams); informal virtual meetings were held as needed (for example, specialty sub-teams meet virtually as often as necessary; the External Evaluator has immediate access to the PI via email and telephone communications). The Project Team takes advantage of strategic times when majority of Project Team members are available for some functions and/or conferences (for example, the National Association of Music Merchants - NAMM event in Florida and the STEM Guitar Summit held in Golden, Colorado) to discuss Project concerns about implementation and sustainability.

Everyone in the Project Team, having been introduced to evaluative thinking, is in "continuous improvement mode", as the Project Team continues to use various tools available to them throughout the Project period. With team members spread across the United States, use of telephone, email communications, and online platforms and tools such as Zoom conference calls have been critical in sharing information and making Project decisions. Other software and online platforms used, especially for gathering written perspectives of Project Team members, are Google Docs and Survey Monkey. Spreadsheets for Project activities are developed as the need arises, to facilitate better data sharing and collection. Many times, pivotal questions from the External Evaluator steer this development (for example, Project spreadsheets for sharing Project media exposure and Project's dissemination through publications and conference presentations continue to be useful for the Project Team, including responses to critical questions about Project best practices and fidelity of implementation).

Overall, with a stable Project Leadership and Project Team structure, the Team is open to a wide variety of tools to help improve the Project implementation process and initiatives. This includes Project documentation, on-boarding of team members, site selection, recruitment and selection of participants, materials and curricular development process (kit preparation; Modular Learning Activities MLAs; video preparation, revision, vetting and launch; manuals for GBI implementation and guide for faculty implementation), and process preparation for Institute implementation (including development of the STEM Guitar app, preparation of Institute/workshop agendas and evaluation components).

Project Implementation

This Project implementation section starts with host/site selection and recruitment of participants, as well as focus on GBI agenda, process for GBI implementation and evaluation; and curricular preparation/adaptation.

Host/Site Selection and Recruitment of Participants

The STEM Guitar Project is heavily based on its professional development starting with the faculty Institutes and the veterans' workshops; thus, the first step taken by the

Project every year is the host/site selection for faculty Institutes and veterans' workshops.

Host/Site selection begins with a solicitation, published on the home page of the Project website (www.guitarbuilding.org) linked to the url address for site location intended for any institution who may be interested in hosting the NSF funded summer guitar build http://guitarbuilding.org/stem-guitar-summer-institute-host-application/. Additionally, an invitation for a private sponsorship of guitar build workshops is also posted on the Project website (http://guitarbuilding.org/stem-guitar-workshop-sponsorship-application/) for any institution who can support their own personnel or can facilitate the training of personnel beyond the STEM Guitar Project NSF funding.

There were eight 2019 faculty GBI institutional hosts where the eight summer GBI's were held: two Acoustic Guitar Building Institutes (AGBI's) [one on July 29, 2019 through August 2, 2019 at Hanford High School in Richland, Washington State and one at Pennridge High School in Pennsylvania on August 12-16, 2019]; three Electric Guitar Building Institutes (EGBI's) [one held on May 4-10, 2019 at the Santa Fe Community College in Gainesville, Florida, one at Ivy Tech in Fort Wayne, Indiana on June 24-28, 2019, and another at Stuyvesant High School in New York on July 15-19, 2019]; and three Hybrid-CNC Electric Guitar Institutes (HGBI's) [one for the TXRX Maker Space at Houston, Texas on June 24-28, 2019, one at Bozeman High School at Bozeman, Montana on July 22-26, 2019, and one at Forest Scientific Training Center in Phoenix, Arizona on June 10-14, 2019]. An outreach guitar building workshop was conducted by the Project PI with Women Walking West at Deerfield Township, Warren County, Greater Cincinnati, OH in February 2020. Two veterans' workshops (Dofo Winery Veterans Build in Temecula, CA in June 2019 and the Twang II Veterans Build at Edmonds Community College in Edmonds, WA in November 2019) held during this period have been partly sponsored by some local private industries and community organizations.

Institutional hosts/sites for the 2020 GBI's were confirmed. There will be two AGBI's at Sinclair Community College, Dayton, OH on June 8-12, 2020 and San Diego City College, San Diego, CA on July 20-24, 2020. Three EGBI's will be held at the following institutions: Travis Early College High School, Austin, TX, on June 15-19, 2020; Anuntuck Community College, Enfield, CT on July 20-24, 2020; and Pennridge High School, Perkasie, PA on July 27-31, 2020. Two HGBI's will be held at the Kankakee Community College, Kankakee, IL on June 22-26, 2020 and Grants Pass High School Grants Pass, OR on August 3-7, 2020. Faculty application for the 2020 GBI's is still underway. Four veterans' workshops were scheduled for 2020. The current challenge of the corona virus pandemic left some of the schedules and hosting possibilities uncertain at this period. The April 2020 workshops in Dayton, OH and Boulder City, NV had to be rescheduled. Applications for two veterans' workshops intended for July-August 2020 in Temecula, CA and Lake Stevens, WA are being processed. Hosts and sites for veterans' training are yet to be confirmed. Because applications tend to exceed the number that can be supported through the NSF funding, sponsor solicitations, as shown on the Project website, are on-going.

Faculty Institute participants are recruited through various modes but the three most prevalent sources: word-of-mouth advertisement by previous participants, direct email to individual potential participants, and solicitations posted on the home page of the Project website (www.guitarbuilding.org) and on the site location meant for teachers (http://www.guitarbuilding.org/workshop-details-for-teachers/). Recruited Institute participants are invited to complete an online application (via Survey Monkey), The application survey was developed by the External Evaluator in consultation with the Project Team. The application survey includes demographic information that will help determine the Project's target population - underrepresented populations. The survey also included questions to tease out applicants' intent about use and implementation of the program as well as facilitating program-related experiences and support for hands-on learning in the applicants' classroom and academic institutions. Selection criteria are recommended by the specialty sub-teams for the program tracks. Completion of the Electric Guitar Building Institute or an extensive experience in building electric guitars is part of the requirements for Acoustic Guitar Building Institute applicants. Members of the Project Team volunteered and/or were assigned to be either lead or support trainers for the Institutes, with everyone on the team having at least one Institute. Usually the more experienced and senior team member ends up leading Institutes.

Established and improved recruitment and selection of faculty participants help the Project in reaching out to its targeted participants – underrepresented populations. The Project's primary definition of underrepresented population is based on the National Science Foundation (NSF) identified concern about underrepresentation of women, persons with disabilities, and race/ethnic groups (such as blacks, Hispanics, and American Native Americans) in science and engineering education and employment. The STEM Guitar Project extends its definition to include "persons with disabilities" beyond physical disability and includes "economic disability", thus, prioritizing involvement of institutions serving a greater proportion of students with "free and reduced" lunch as important to the Project. The Project Team will make final decisions by the first week of May 2020. A final list of faculty participants will be generated after the Project Team's final decision. A clean list of participants will be on hand after the Summer Institutes; a number of times, there are "no shows" during the Institute. The final list of participants will confirm if the STEM Guitar Project has indeed increased the training of diverse unrepresented population of secondary and post-secondary faculty.

GBI Agenda, Preparation for Actual Institute Implementation, and Evaluation

Preparation for program implementation is the Project's process that facilitates and models guitar-building program implementation for Institute participants. This is meant to help Institute participants in increasing their students' learning and acquisition of guitar-building STEM-related learning. Agenda for the Summer GBIs and the veterans' guitar workshops are reviewed regularly, especially before the first wave of these events. Some aspects focused on in 2020 are: review of the Institute agenda to enable use of the newly developed MLAs and videos intended for classroom use preparing for possibility of more

online classes in the future; also included are more focused efforts on fidelity of implementation and clarifying the use of the STEM Guitar app to document faculty learning and provide data for faculty reflection on their own learning. For the veterans' workshop, the agenda review focuses on trainers' handling and overt demonstration of employable hard and soft skills, as well as basic entrepreneurial knowledge such as time management, concepts of feasibility, efficiency and team work, among others.

The Project's training practices, especially for the faculty GBIs, provide the structure and backbone for participants' guitar-building program implementation. These are reflected in the Institute agendas, that include not only the week-long Institute activities, but also preparations for the webinar and participants homework, about a month prior to actual activities in Institute sites. Extra time for the preparatory webinar is necessary to ensure saving optimum time for modelling program implementation in the week-long Institute. Obviously, guitar building implementation in the participants' institutions will take more than one week. During the webinar, the Project background, previous program results, and Project expectations, pre-readings, homework and incentives for participants are shared. The webinar also provides opportunities for participants to ask questions and clarification about program expectations. The Summer Institute agendas serve as the guide for Institutes' preparations and week-long activities, not only for the participants, but for Trainers.

Part of the preparation for Institute implementation is development of the Institute evaluation to ensure overall quality of training and fidelity of Institute implementation. The two Institute evaluations (one for participants and one for Trainers) prepared by the External Evaluator The instrument for Institute participants is meant to collect data about their reactions to the Institute, what they learned, as well as get their perspectives about any areas of growth. The instrument for Institute Trainers is meant to get their perspectives about the overall Institute program and quality of Institute program implementations. These instruments are highly influenced by Guskey's (2002) evaluation of professional development. Actual evaluation of participants' institute experiences (reported through their responses about "areas of growth" and "other comments") is summarized in Appendix 1. Participants reported "great experiences" with the Institute and being grateful about the implementation and support for all program tracks. While they were happy with the overall program content and Institute experiences, they noted some areas of growth related to specific program track [e.g. for HGB – more Fusion 360/CNC related improvements], pacing of the Institute activities, and the need for adequacy of quality materials, tools, and fixtures, among others.

The 2020 Institute evaluation instruments will likely take on most of the 2019 survey items. These are being prepared and will be reviewed by the Project Team to ensure they are consistent with the 2020 agenda foci as these agendas are still being developed. For these instruments, the External Evaluator requested the Project Team members to focus on issues and questions related to fidelity of implementation; these questions were asked previously, since any program impacts or outcomes will be greatly influenced by fidelity of

implementation. The list of questions was developed around elements of implementation (Dusenbury, et.al., 2003; Mihalic, 2004). These include clarity of different elements of STEM Guitar Project implementation in terms of adherence to the program, dosage, program differentiation, quality of delivery, as well as key knowledge and employability skills (including participants' reactions and engagement). Feedback about these will likely be considered in the revision of Institute and workshop evaluation instruments. As a matter of process, any changes in these evaluation instruments are reviewed and vetted by the Project Team before final implementation.

Materials and Curricular Development Process

The STEM Guitar Project encourages a collaborative process in developing teaching and learning materials. Initiative and leadership in developing specific guitar build concepts start with the Project Team member who has concept-specific expertise; materials are then shared with the rest of the team for feedback, further development, organization (for ease of access by each program track: acoustic guitar, electric guitar, Hybrid/CNC, and veterans' group), and final vetting. These materials could be new MLAs, more focused shortened videos, apps, and other guides, manuals, or materials that may be useful for implementation. Existing materials are being reviewed, reorganized, and further vetted for relevance, especially in the current pandemic situation forcing schools and colleges to be closed in the last three months for the rest of the 2019-2020 school year, probably extending through summer 2020.

Project Output

This section on Program output includes sales of STEM Guitar kits, vetted developed/revised modular learning activities (MLAs), created learning videos, the STEM Guitar app and other learning materials, the video for Administration webinar, and the actual number of trained participants during the period.

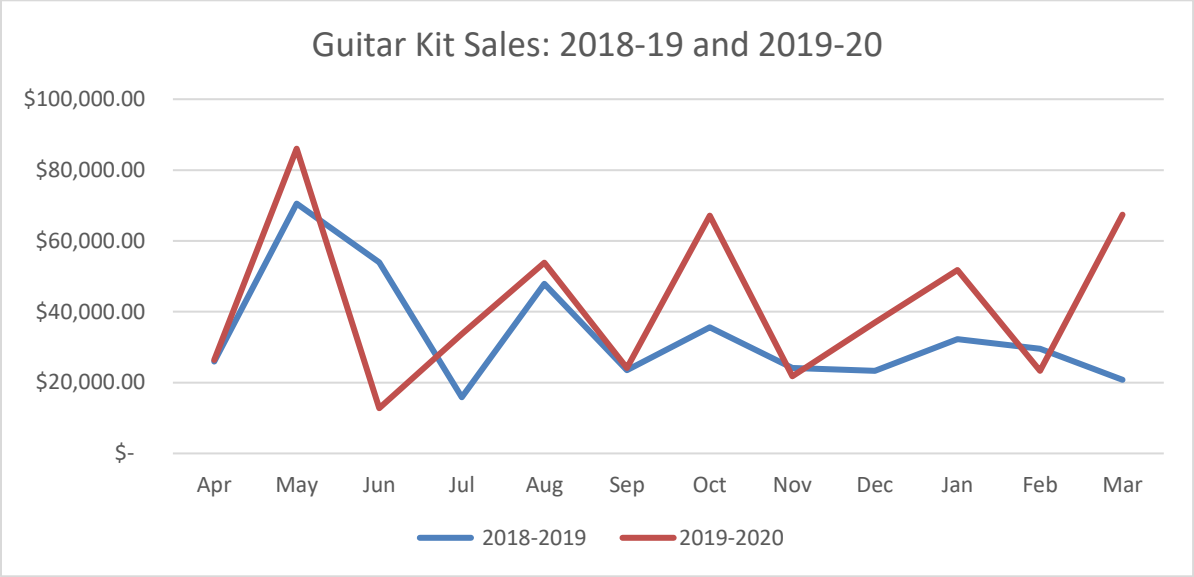
The STEM Guitar Kits

As in past STEM Guitar grant years, the Sinclair Community College Manufacturing Team has worked, and continues to work even in the current grant, as an independent/self-sufficient group not funded by the STEM Guitar grant. This group is an integral part of the STEM Guitar program as the Lead PI continues to provide oversight of this team as part of his administrative and academic role at Sinclair Community College. One of the Production Team members is being partly funded through the Project in his capacity as a technical support staff for the HGBI, particularly in implementation and use of Fusion 360. STEM Guitar kits are available through the Sinclair College Manufacturing Team's effort. Finished products are advertised on the STEM Guitar website "Storefront" (http://www.guitarbuilding.org/store/#!//c/0/offset=0&sort=normal).

The sales volume indicates classroom implementation through the 2019-2020 school year. Guitar kit sales in the school year 2019-2020 increased by 25% (see Figure 1) over

the 2018-2019 (Castaneda-Emenaker, 2019 April) sales. Per the Project PI, there were more orders of guitar kit supplies and tools in 2019-2020 indicating the effects of the faculty Hybrid CNC-Electric guitar training in the summers of 2018 and 2019. More faculty embarked in the CNC-manufactured guitar parts during the period. For example, sales of signature guitar kit (pre-machine bodies) are decreasing and sales of wood blanks and the partially machined blanks are increasing.

Figure 1. Comparative Guitar Kit Sales



MLAs and Videos and Other Learning Materials/References

The repository of the STEM Guitar teaching and learning materials is the Project website http://guitarbuilding.org. The site is organized with particular website breadcrumbs that lead to different materials needed in the programs. There are four key breadcrumbs for faculty teaching learning resources: “Teach”, “Downloads”, “Models” “Videos”, and “Community”. The “Community” breadcrumb is where the faculty is encouraged to share their own developed teaching materials and videos. To date, the STEM Guitar Project has more than 100 teaching learning material resources and still counting.

“Teach” (http://guitarbuilding.org/teach/) allows for faculty orientation to the Institutes, examples of modular learning activities with corresponding curricular standards, examples of teaching syllabi, and guitar grading rubrics. A template for MLA development is provided, as well as MLA examples with topics along the 12 areas of guitar build (CAD/CAM, electronics, fret spacing, guitar anatomy, guitar geometry, guitar necks, intonation, scale length, set-up, threaded fasteners, tolerances, wood for guitars) with MLAs with curricular standards http://guitarbuilding.org/institute/modular-learning-activities/. Other references are found in http://www.guitarbuilding.org/teaching-syllabus/.

As of this date, “All Downloads” (http://guitarbuilding.org/downloads/) stores downloadable materials organized according to two of the program tracks: acoustic guitar and electric guitar. Other materials included are downloadable materials related to at least 22 topic areas useful in the build.

The model design files useful for CNC have at least six model design files (http://guitarbuilding.org/current-guitar-models-design-files/). Wiring schematics are found in http://guitarbuilding.org/electronics-wiring-schematics/

At least 27 new videos are on http://guitarbuilding.org/videos/ and more videos are found on the STEM Guitar YouTube account (https://www.youtube.com/user/STEMGuitar). Eight new videos were shared the last week of March 2020 that may not have been included in the website portfolio of learning videos:

- Introduction to materials used in electrical and electronic circuits:
  https://www.youtube.com/watch?v=4NHh7KYSNck
- What is electricity? What are the characteristics of electricity in a functional circuit? Ohm’s Law:
  https://www.youtube.com/watch?v=jCOoPITygBE
- Simple electrical circuits. Wire and components:
  https://www.youtube.com/watch?v=bxTLUwKU9y8
- Conceptual intro -- how do motors (amplifier loudspeakers) and generators (guitar pickups) work:
  https://www.youtube.com/watch?v=NSqu_u7nYU0&t=86s
- Electronic components in electric guitars; and, their schematic symbols:
  https://www.youtube.com/watch?v=EZPl8q__tHU&t=10s
- Schematic diagrams and wiring diagrams, in general; and, for electric guitars:
  https://www.youtube.com/watch?v=FQc0kIAOom4
- What are Solder and Soldering? The purposes of soldering. Soldering tools and supplies:
  https://www.youtube.com/watch?v=FwEcyBY0f3M&t=28s
- Overview – how to solder electronic circuits:
  https://www.youtube.com/watch?v=zt5KczKHJ8Q

Efforts in developing more online teaching/learning materials continues as evidenced by more sharing from Project Team members. Example, new video links were shared in early April 2020:
https://www.youtube.com/watch?v=zuTxVeKnylc;
https://www.youtube.com/watch?v=J5oaZvEATeE&t=58s;
https://www.youtube.com/watch?v=wmuTjUVWV44&t=273s

Prolific as the Project Team members are, they continue to develop online materials and videos to help their students and extend the use of resources with other faculty. As of May 2020, additional video materials were developed. A Project Team member created three 6-12 minute videos (01 String Ferrules; 02 Strap Buttons; 03 Bridge and Ground)

using one of the Project's signature kits as a demo subject. Another Project Team member developed three videos for his students to follow along with using the signature guitar kit demo (01 String Ferrules; 02 Strap Buttons; 03 Bridge and Ground). In early May, another Project Team member developed videos posted on YouTube showcasing his student guitar tool caddy (https://www.youtube.com/watch?v=mcESHUHjXNc) and the making of cardboard guitar (https://www.youtube.com/watch?v=SekyHeFHHyM. Another Project Team member added a new video in mid May 2020 about how to recover from breaking a screw posted on YouTube (https://www.youtube.com/channel/UCBPekin_8Meff8vXz_pY5eg?view_as=subscriber).

A STEM Guitar app was developed in time for use at the 2019 Summer GBIs. During this period, this app helped in faculty documentation and reflection about their own learning. The app is being reviewed for its potential for more extensive use in the next GBIs and in faculty program implementation.

As noted above, the Project Team continues to develop, revise, improve, and vet STEM Guitar MLAs, videos, and learning materials. In the past three months, especially with the outbreak of corona virus and closures of academic institutions, the Project Team members continue to develop and share more resources (e.g. Onshape, Inc. 3-D CAD cloud-based resource), materials and strategies to teach STEM Guitar and related material online. Offering an online GBIs is under consideration as an option. Actual preparations for this are on-going. In mid-May 2020, a Project Team member started revising Project requirements for the e-Portfolio and the Implementation Plan to better suit projected Online workshops starting June 2020.

The initial production of the Administrative Video was released. It includes testimonials from high school administrators about their perspectives and experiences in implementing the STEM Guitar program at their institutions. This video is being enhanced with the addition of perspectives from at least one college administrator. The Administrative Video is meant to be shared with other administrative personnel as an orientation to the program to help support faculty participants' STEM Guitar implementation.

Number of 2019-2020 Trained Participants

The STEM Guitar Project trained a total of 147 participants in Year 3 (2019-2020): 109 participants chosen from the 157 faculty 2019 Summer Institute applicants, 15 veterans from two veterans guitar workshops held in June and November 2019, 14 participants in an outreach guitar build at Golden Colorado in late October-early November 2019, and the nine female participants from Women Walking West trained in an outreach workshop in February 2020.

Summative Results: The Project Moving Toward Outcomes

The 2019-2020 outcomes are geared toward (1) increased involvement of diverse participants (faculty, also including veterans and outreach participants], (2) effects on program

participants (especially on faculty regarding their practice effecting student outcomes) (3) support for faculty and the Project facilitating its brand of a replicable and sustained Community of Practice in terms of its Applied Learning Community, (4) student learning about STEM concepts, behaviors and attitudes toward STEM, and (5) wider reach of the STEM Guitar Project [including the veterans, and participants in the outreach Project] and its overall Project sustainability.

Increased Involvement of STEM Guitar Project Participants

The main events implemented by The STEM Guitar Project in 2019-2020 are portrayed in Figures 2, 3 and 4.

Figure 2. 2019 GBI Faculty Participants

Figure 3. 2019-2020 STEM Guitar Outreach and Veteran Participants

Figure 4. The Golden Colorado GBI Participants with Project Team Members

The more conscious efforts to increase participation of women faculty and faculty of diverse ethnic backgrounds in the STEM Guitar GBIs, the formal inclusion of the veterans' guitar building workshops, and the outreach guitar build at Golden Colorado and the Women Walking West, increased the STEM Guitar Project participants' diversity compared to the previous year**.** Figures 5, 6, and 7 show the overall demographics of the total 2019-2020 STEM Guitar Participants.

Figure 5 shows 33% female participants. This indicates a 10% increase among female participants compared with 23% from female participants in the April 2018-2019 report (Castañeda-Emenaker. 2019). Note that 2019-20 has a broader participant base (N=138 out of 147 participants reporting gender information) compared to 2018-2019 (N=86 out of 87 participants reporting gender information). However, in terms of actual number, the total number of female participants in 2019-2020 (n=49) compared to 2018-2029 (n=21) increased by 133%.

Figure 6 shows only 22% of the total participants are non-white compared to 25% in 2018-2019. White/Caucasian participants were the largest group of participants in 2019-2020; however, in terms of actual numbers, there was 100% increased participation of Asian/Americans (n=7) and Black/African Americans (n=6) since there were no reported participants from these groups in the previous year.

Figure 7 shows 84% of the 2019-2020 STEM Guitar Project participants have college degrees or higher, while 6% chose not to report this information. With the inclusion of a more diverse group of participants beyond faculty, the Project reached additional 10% (n=15) completing either an Associate's degree or "some college credit" who got the chance to improve their STEM Guitar-related technical and soft skills. Therefore, 2019-20 participants represented greater educational diversity.

Figure 5. 2019-2020 Participants' Gender

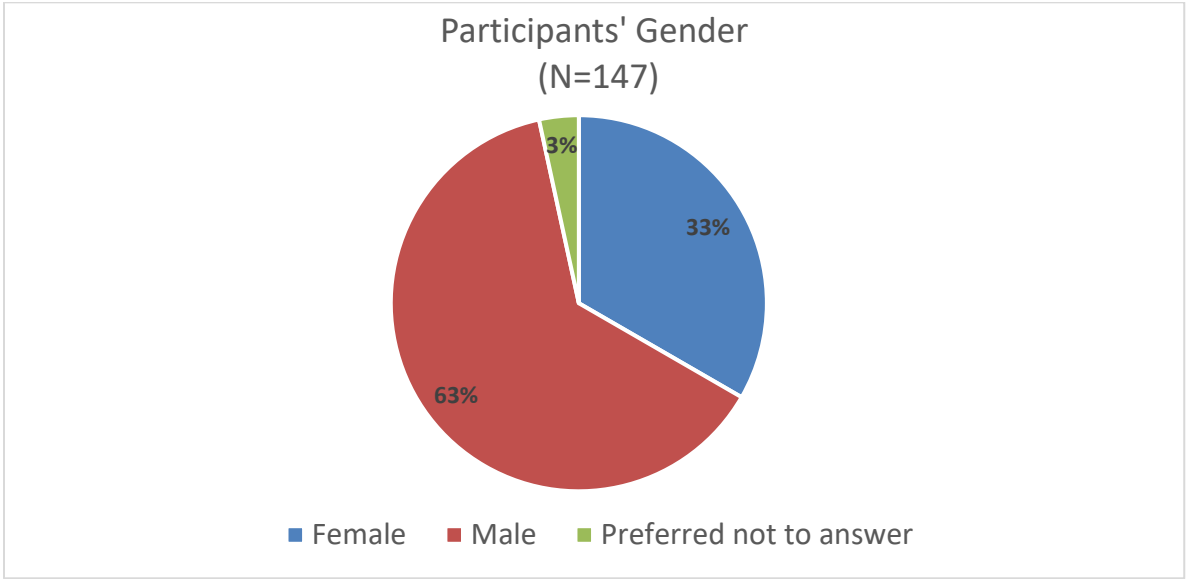


Figure 6. 2019-2020 Participants' Ethnicity

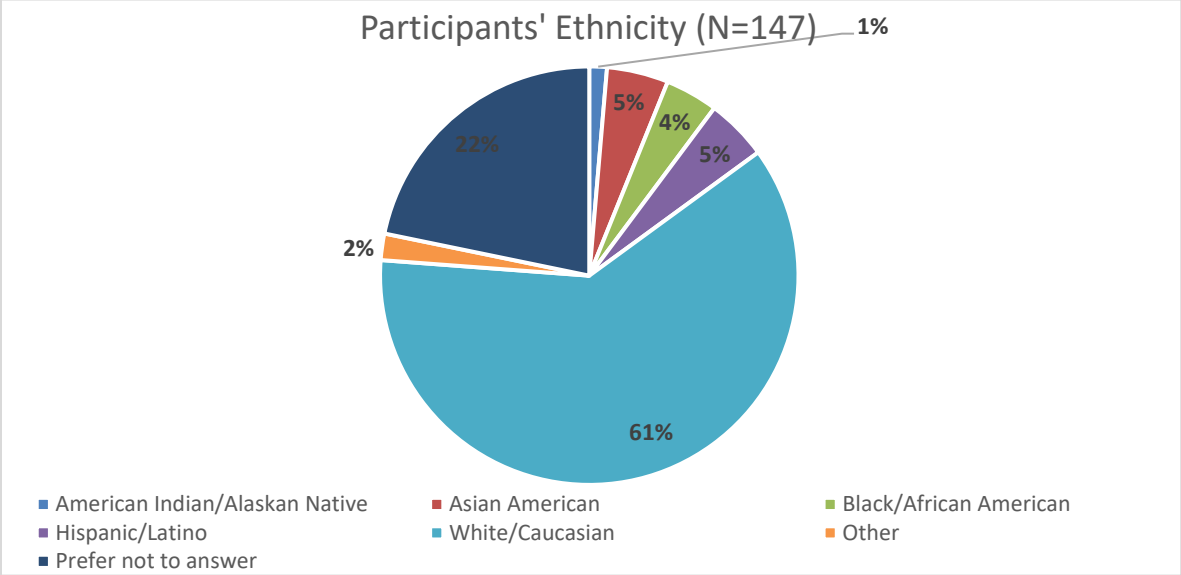
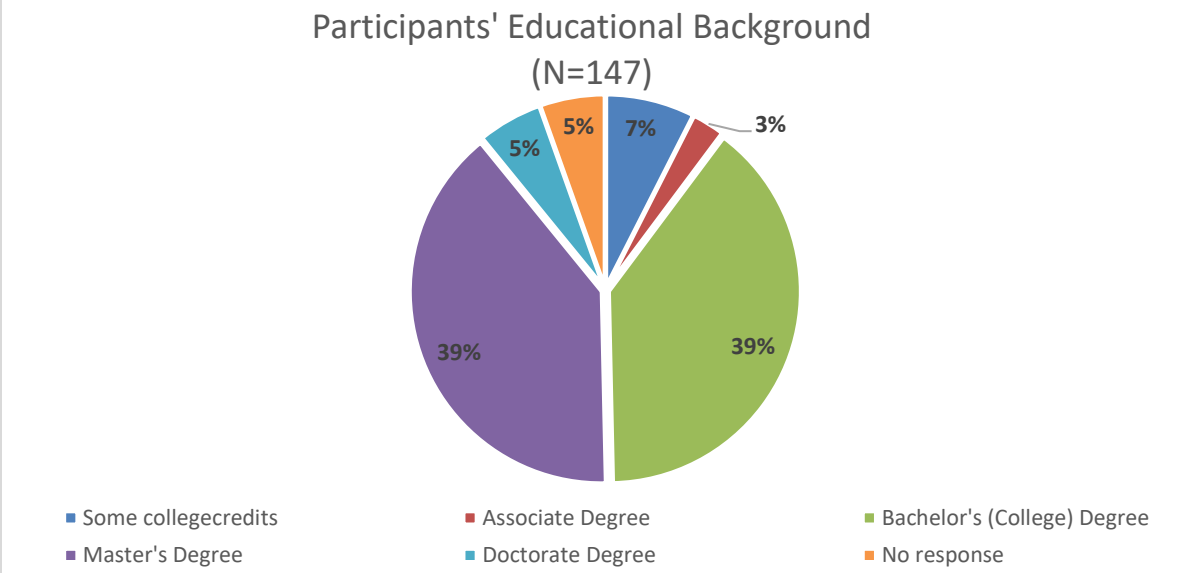


Figure 7. 2019-2020 Participants' Educational Background



Of the faculty GBI participants in 2019,

- 5% more total 2019 GBI faculty reported that more than half of their school population is underrepresented compared with 2018 GBI faculty (55% vs. 50%).
- Only 81 out of 109 2019 GBI faculty reported the free and reduced lunch situation of their institutions. Among those reporting this, about the same percentage (50%) as 2018 GBI faculty reported that their institutions have over 50% free and reduced lunch students.
- 40% of 2019 faculty belong to institutions from rural areas compared to 38% of 2018 GBI faculty reporting the same; a 2% increase in institutions served from rural areas.

- As in the previous year, majority of faculty trained were high school and were teaching science, math, engineering, and technology and general/integrated STEM courses.
- As in the previous year, the faculty reported learning about STEM-related MLA's during their summer GBIs.

Demographic Characteristics of the GBI alumni (N=144) from the May 2020 survey:

- Female = 27%
- Education > Bachelor's degree + = 54%
- Basically White/Caucasian > 50%, more than half did preferred not to identify ethnicity; around 10% other ethnic groups among those reporting
- Secondary school faculty 58%
- Post-secondary faculty ~11%
- 71% with school population >1,000 students
- 50% of schools represented with population of >51% under free and reduced lunch
- 59% of schools represented with population of >51% underrepresented population
- 45% of faculty teaching >100 students

Effects on the 2019-2020 Program Participants

This section deals with effects of the STEM Guitar program on 2019-2020 GBI participants (Summer GBI and the Golden Colorado GBI), veteran participant groups (particularly the Temecula and Edmonds cohorts), and Women Walking West participants. It includes data from observations of a GBI and a veterans' workshop, interviews with a sample of participants, participant-reported hard and soft skills learned from the program, and intended use of learning (including faculty insights into their learning skills and confidence affecting change of their practices that effect student outcomes).

Skills Learned by Participants

Participants in the 2019-2020 implementation of The STEM Guitar Project learned STEM-related hard and soft skills meant to provide them with employability skills. Figure 8 shows a representation of the different guitar program track processes enabling learning of hard and soft skills. Appendix 2 shows the different skills embedded within the STEM guitar building program that can be learned by participants of the STEM Guitar Project programs.

Figure 8. Enabled Skills Learning Through Guitar Building

Hard STEM Skills Learned

The GBIs involved different guitar processes depending on the program track Institutes (AGBI, EGBI, HGBI). Figure 8 shows some of these processes. Soldering was common to the EGBI, HGBI, and veteran participants. Unique to the HGBI group was the use of the CNC machines; the AGBI participants had to deal with go-bars, body glues, and neck shaping, among others. Learning the use of appropriate tools (power and hand) and machines, measurement skills and iterative application of a process are employability skills and important activities experienced by the participants.

There were common STEM-related hard skills learned by the three sets of participants (faculty, veterans, and outreach) especially related to guitar set-up, finish, quality control, and intonation reported in the Institute/workshop surveys as shown in Table 1 below. It appears that the participants placed highest importance on their learning regarding overall guitar assembly and set-up as well as guitar finish and quality control.

Table 1. Participants' Learned Hard Skills

Specific STEM Hard Skills Learned	Most Important Learning Ranked by the 2019-2020 Participants…			
	GBI Faculty N=109)	Veterans (N=15)	Outreach Golden Colorado GBI (N=14)	Outreach Participants (N=9)
Measurements [in design models/CNC coding, fabrication, electronics, set-up]	1st	NA	NA	NA
Body shaping and sculpting [bracing, gluing. fitting)	2nd	1st	NA	NA
Guitar finish, buffing, and finishing for gloss, coating process, beautification (& quality control)	2nd	3rd	2nd	3rd
Laser and engraving	8th	7th	NA	5th
Overall guitar assembly and set-up, final assembly	1st	2nd	4th	1st
Proper use and selection of hand tools and joining processes	7th	5th	3rd	2nd
Shop safety and procedures [safety in use of machines and apparatus]	6th	4th	4th	7th
Soldering and electronics, and intonation [sound box construction for AGB]	2nd	8th	1st	7th
Use of tools like sander or drill, tool usage	NA	6th	4th	3rd

Soft Skills Learned

The embedded skills in the STEM Guitar program 21st Century-related skills is detailed in Appendix 3. Table 2 shows that productivity and accountability, flexibility and adaptability, and critical thinking and problem solving are the three most-valued soft skills learned by ALL 2019 participants per their self-report through Institute and workshop surveys**.**

Table 2. 2019 Participants' Learned and Honed Soft Skills

P 21 Century Soft Skills Categories	Most Important Learning Ranked by the 2019-2020 Participants…			
	GBI Faculty (N=109)	Veterans (N=15)	Outreach Golden Colorado GBI (N=14)	Outreach Participants (N=9)
Communication and collaboration	7th	5th	4th	5th
Creativity and innovation	2nd	6th	4th	5th
Critical thinking and problem solving	3rd	3rd	3rd	1st
Flexibility and adaptability	3rd	2nd	2nd	3rd
Grit, initiative and self-direction	5th	4th	1st	3rd
Productivity and accountability	1st	1st	3rd	3rd
Leadership and responsibility	8th	7th	4th	7th
Social and cross-cultural skills	6th	NA	4th	NA

Specific Veterans' Soft Skills

External evaluator interviews with veterans were met with challenges as they seemed to have "trust" issues. Of all the veterans who participated in the guitar building workshops since 2018, the external evaluator had success talking even briefly with eleven veterans (four from Twang I, two from Twang II and five from other cohorts from the previous two years). Veteran interviewees indicated affirmation of learning the embedded soft skills inherent in the STEM Guitar program implementation despite differences in their ages, educational background, and field of service. They indicated that they were moved out of their comfort zone through their guitar building experiences. The interviews echoed not only the importance of the soft skills mentioned above but indicated other important skills gained that seemed to be unique to the veterans. The interview responses were coded and categorized into themes. Along with the Twang II workshop observation themes, five themes unique to the veterans emerged and were used in the applied thematic analysis (Guest, MacQueen, and Namey, 2012): (1) confidence, (2) PTSD relief, (3) camaraderie, (4) shared experience, and (5) excitement. Typical quotes are presented below.

- Workshop observation indicated that as the veterans came into the workshop, they were all seated all and stayed basically each to oneself. As the workshop progressed, veterans were observed asking questions from the instructors and fellow veterans and

comparing their individual progress with fellow veterans. Six out of the 11 veterans interviewed expressed personal improvement of personal confidence because of guitar building:

> *The STEM Guitar Project provided an idea of being able to self-doubt and experience some fear but at the end, finishing a playable guitar along with fellow veterans gave me confidence. This applies to other stuff in life…if you can achieve…you can accomplish anything.*

- Workshop observation indicated at least five "loners" at the beginning of the workshop; these same individuals were seen sharing stories with fellow veterans by the third day of the workshop. Five out of the 11 veterans expressed at least temporary alleviation from their worries/stress due to PTSD. This particular veteran also expressed the effect of guitar building in improving her personal confidence.

> *When I retired, I separated myself fully from my military experience…I was suffering from PTSD. I started to take my MA in Engineering Management but I was getting frustrated and about to quit. The guitar building experience came in time for me to get back my confidence to pursue my MA. I completed my degree. The experience gave me confidence to network and work with people. It gave me the confidence to develop relationships and give back. As a woman veteran I am now working with other women in military.*

- Workshop observation showed that all veterans mingled with teach other and enjoyed listening to music; jamming started by some who knew how to play music. Five out of the 11 veterans interviewed expressed how the guitar building helped develop camaraderie among fellow veterans.

> *We developed a camaraderie during the workshop and now we got a support group among ourselves; we continue connecting with fellow trainees - we see each other and help support each other.*

- Although their responses could still be related to camaraderie, three out of the 11 veterans interviewed specifically noted how their shared/common experience helped them relate more to each other.

> *This* [guitar building] *is a brotherhood that connects us with similar shared experience…civilians don't understand how it feels; it feels good to have that camaraderie*.

- From the workshop observation, participant excitement was obvious even at the start when they got their guitar bodies and neck, more so when they got their guitar jigs at the end of the workshop. Two out the 11 interviewed expresses excitement about the guitar building project.

This [the guitar building] *is very exciting! I feel like a kid in Disneyland!*

The Director of the Veterans Resource Center of Edmonds Community College had a multi-faceted sense about the STEM Guitar program. He shared different perspectives about the learned hard and soft skills experiences saying that the program has *a long-lasting effect*. He was a workshop participant and saw for himself what the program does for him personally and for all other veterans. According to the Center Director, the STEM Guitar workshop for him was *a combination of three things: I loved woodworking, music, and interaction with fellow veterans; three things that come together. This is the closest thing to heaven here on earth - being in the shop around a bunch of people!*

The STEM Guitar program inspired the Center Director to develop and adjust some of the programs and activities in the Veterans Resource Center. He helped raise funds for the Center seeing that being in the Center is *a way that they* [the veterans] *can belong somewhere. It is nice when people come in and they have a place to hung around; we invite people to play; they jam, come to school after two hours. play guitar after their bout with traffic – this releases tension.* He said that the STEM Guitar program presented a mutual shared challenge for the veterans and getting through a successful guitar build helped the veterans overcome their challenge. He thought that the STEM Guitar program helped *develop a bond among the veterans that they can't get any other way; by the end of the three days, they had a mutual shared experience.*

The Center Director also thought that the guitar building program is similar to a manufacturing process with hands-on activities and artistry. He thought that the program can have a plan for minimizing waste thinking about every dollar put in business. It can focus on efficiencies and learn about people's talents. He believes that the guitar building experience lends to the entrepreneurship experience of risk of failure. He said that there is a need for confidence to overcome failure because it represents money. People have to be passionate about what they're doing…so passionate that they can do it…. they know that they have the skill, -build confidence, enthusiasm, creativity. He added that the STEM Guitar program as an entrepreneurial activity would help veterans know what they can be capable and confident with things even not done before.

Intended Use of Learning

Focus on Effects on Veterans and Outreach Participants

The two veteran groups (Temecula and Edmonds) and the Women Walking West participants were asked in the surveys about intended use of their learned skills (see Table 3). Both groups rated highly personal improvement such as enhancing one's hobby and

improving one's lifestyle. It is interesting to note the contrast between the veterans' groups and the outreach participants. The veterans seem very concerned about improving their interactions with friends and community as being in the service likely got them out of that "circulation of socializing". The outreach group, primarily professionals with busy professional lives, were used to dealing with friends and community, but invoked improvement of interactions with family.

Table 3. Intended Use of Learned Skills

Intended Use of Skills	Veterans (N=15)	Outreach Participants (N=9)
Enhancing hobby	2nd	1st
Improving one's lifestyle	2nd	2nd
Setting up his own business	5th	5th
Applying skills in job hunting with a manufacturing company	6th	6th
Improving interactions with family	4th	2nd
Improving interactions with friends and community	1st	4th

Focus on Overall Effects on Faculty

Part of the overall important effects of the STEM Guitar program on faculty participants are indicated through the survey responses of the 2019-2020 GBI participants and faculty responses to the STEM Guitar Materials COVID-related Use Survey, data from the evaluator's GBI Institute/workshop observations, evaluator Summit participant observation, in-person Summit Champion faculty and focused interviews, and administrator interview (refer to Appendix 4).

As part of the Institute/workshop surveys, all GBI faculty participants were asked to showcase and comment on their learning. Ninety-six percent (105 out of 109) of the participants provided comments (27 AGB, 49 EGB, and 29 HGB participants). Potentially all of the 105 participants provided one response each for three guitar building phase/categories: (1) guitar set-up, (2) intonation, and (3) soldering, electronics and electricity [for all EGB and HGB participants] neck shaping [for AGB participants only]. Thus, 315 was used as the base for the response percentage of the generated themes. The responses across three guitar phase/categories were grouped into common themes (see Appendix 3), which when integrated with faculty interviews and Institute observation showcased affirmation of faculty quantitative survey responses about their learning. These were mostly related to skills learned (37% [new =27%, honed =10%]), learning about guitar building process specifics (35%), learning about and use of tools (20%), and application to STEM and classroom use (5%). Twenty-eight percent of the responses were about the participants' attitudes toward the guitar building, many of which dealt with attention to detail, openness to learning, patience, and grit. Examples of comments from each program track along these themes follow:

STEM Guitar (SG) building skills learned [new skills]

The neck shaping was a bit different from the electronic. Adding a laminate piece to the headstock, and layout of tuners, planning on neck pocket insert; working with bevel. [an AGB participant]

I learned so much about woodworking and how to use specific tools! [an EGB participant]

Understanding how to design the guitar blank in Fusion 360 was incredibly fun. I learned how to create various shapes and extrude them through Fusion 360. [an HGB participant]

STEM Guitar (SG) building skills learned [honed skills]

I have done guitar set up before, I have attended and teach STEM Electric Guitar Building. This course in Acoustic Guitar Building definitely tightened up my abilities to finely set-up (and teach how to) a guitar. [an AGB participant]

I knew how to solder before the institute however some of the tricks they showed were really helpful. [an EGB participant]

I had always done intonation with the harmonic rather than the open string. I learned it could be both and that it was double the frequency. I had to do the math some rather than look for the pitch to match. [an HGB participant]

Guitar building process specifics

We were shown how to bend sides of what we wanted to outside of class, glueing up the body, adding kerfing to the body, glueing the top and back to the body with the go bar deck. [an AGB participant]

Set-up makes all the difference in the instrument's ability to be functional or not. Measuring the string height at specific points along the neck as well as accurately using nut files to fine tune the nut. [an EGB participant]

I learned way more than I thought that I would at this institute. I learned the entire process that goes into making a guitar and using tools that I have never used before in a wood shop. [an HGB participant]

Learning about and use of tools

I learned about the go-bar decks and bridge clamps. Also, the bracing for an acoustic guitar is much more complex than a ukulele. [an AGB participant]

Utilizing various tools such as drills, sanders, and saws we shaped, customized, painted and created guitar shapes objects prior to wiring electronics at it. [an EGB participant]

It was systematic and precise. It took a lot of grit to get through it. We used rocker gage, fret press, fret files, fret hammer, and fret polish. It was pretty technical to setup a guitar and there are a lot of variables that have you have to take into account of. [an HGB participant]

Application to STEM and/or classroom use

This course in Acoustic Guitar Building definitely tightened up my abilities to finely set-up (and teach how to) a guitar. [an AGB participant]

The biggest thing I learned was the spacing of the frets and all of the math and physics associated with it and the intonation of the guitar. [an EGB participant]

[I learned] *Classroom organizational techniques for guitar making. Tool quantities required to teach a large class.* [an HGB participant]

Attitudes toward STEM guitar building

I learned it was difficult to shape the neck evenly on both sides. I marked a centerline and a few reference points and still had difficulty keeping it even. I used the barrel sander, in a drill to shape the neck. [an AGB participant]

Wow, again everything. I could not possibly repeat all that I've learned. I did not even understand the term intonation when I came here and now, I can use my phone to measure the hertz for the different strings, adjust the height of the strings, and also the length etc. [an EGB participant]

The intonation process was a tedious process, and took a lot of patience. This was a difficult process, but well worth it to make the guitar sound great. I used string gauges, screwdrivers,

allen wrenches, nut files, sandpaper, and string tuners in order to get it all properly intonated. [an HGB participant]

Eighty percent of the 2019 Summer GBI faculty reported they learned about the Science/Engineering-related modular learning activities (MLAs), 73% noted learning more of the technology-related MLAs, while 67% reported learning about the math-related MLAs. About the same proportion of the Golden Colorado participants also noted learning about these STEM-related MLAs ranking them as first, second, and third respectively. The program content is STEM-based; however, only a few of the GBI participants' responses (5%) explicitly mentioned connections of the program to STEM and/or classroom use during the GBI evaluations.

The 2019 Summit Faculty participants affirmed the positive effects of the STEM Guitar program on their practices and showcased some of the exemplars they have been using in the implementation of the STEM Guitar building in their institutions. Data gathered from these groups affirmed faculty improved their classroom practice and implementation of the STEM guitar program. As a faculty posited, *it's changed the way I teach STEM in my classroom. Now, I always try to relate the guitar building techniques to real-world examples students may encounter on a day-to-day basis.* More often, these changes in teaching practices happen when faculty also experience great support from their administrators and community.

Regardless of the mode of implementation (in-class within the year, in-class within the semester or term, summer, or out-of-school program), the faculty noted students' improved motivation and attendance in class, observed student improvement in the 21st century skills, improvement in use of hand-tools, and for some, the use of CNC machines and overall knowledge of guitar parts and process of building a guitar.

Support for STEM Guitar Program Faculty Implementation

This section focuses on different supports for faculty implementation of the STEM Guitar program in their institutions. This includes the Project's established best practices and support materials for faculty teaching, facilitation of administrative support for faculty, and the adherence to sustain the Project's Applied Learning Community.

Institute Agenda, Established Practices, Support Materials for Faculty Teaching

The third level of Guskey's evaluation of professional development has something to do with support for faculty program implementation. As has been the STEM Guitar Project practice, the Project Team continues to think about and prepare for different ways of supporting the STEM Guitar program implementation. Continuous capacity building and honing of the team's innate evaluative thinking encourage Project Team members to reflect on this phase of the program, ask more questions, and help establish the necessary supportive Project structures and practices. Despite the uncertainties posed by the corona virus pandemic, plans for the 2020 Summer GBIs are underway. The Project Team is

working on the guidelines and process for participants' in-depth Institute participation, as well as making available learning/teaching materials participants can take with them immediately after the Summer Institute (e.g. teaching/learning portfolio documenting participants' own learning and program process). These learning/teaching materials are meant to support participants' learning, as well as help them in their classroom implementation. Revisions ad improvements on the pre-Summer GBI webinars are being done, making sure that the GBI participants could optimize their Institute participation with the necessary preparations prior to the Institute.

Development of best practices is on review. Along with thinking about elements of implementation, some questions are raised for reflection. These are meant to facilitate the development and process for establishing guidelines, structures and important practices that can be replicated in terms of:

- particular experiential learning activities that are "musts" during the Summer Institutes to help participants experience critical aspects of the program and demonstrate implementing guitar Project with fidelity when participants start implementing guitar building;
- the common implementation guidelines and processes that would help participants implement with fidelity the guitar building Project-based learning even at different levels (middle school, high school, college, 4-year university, mixed levels) and different ways (in-classroom full year, in-classroom semester, in-classroom term, out-of-school or alternative school within school year, out-of-school summer, etc.) of implementation;
- how variances in school resources, facilities, and program support are received affects program implementation, accounting for the varying levels of participants' guitar building and teaching experiences to support them in actual program implementation.

Establishing these Project guidelines and structures, and ensuring adherence to established practices, will help showcase how well participants use what they learned from the guitar program; as well as effects of the program. Gathering data facilitated by these structures, established practices, and support for faculty implementation are indicative of Guskey's (2002) 4th level of evaluating professional development.

While the project has established best practices, the follow-up survey in May 2020 provided information about the GBI alumni's implementation and use of the available guitar building materials. Response rate was 46% (144 out of 311), a response rate which is beyond the 29% 2019 benchmark average for an online survey (Average email response, 2020). Five of the respondents did not identify their program track. More than 30% (45 out of 139) of the GBI alumni faculty are building guitars during the period of school/college closures. Forty out of 45 of these respondents who said they are building guitars added comments about how they are handling guitar building. The following are typical respondents' comments:

Seventeen out of 40 (~43%) who started build the guitar in the semester simply said the build will have to be incomplete because the classes were suspended.

> *We started builds prior to "stay-at-home" orders, however after lockdown we suspended it.*

Twelve out of 40 (30%) said they used online materials and videos with one saying they did online quizzes.

> *We are using this opportunity for deeper learning of Guitar Electronics and Setup & Intonation. Students have watched Tim's guitar electronics videos, Doug's PowerPoint and videos, and some setup/intonation videos by Sweetwater. They've also created and completed quizzes on the videos and completed MLA quizzes on Guitar Anatomy and Intonation.);*

Five out of 40 (~13%) tried lending tools to students and provided support via telephone and other social media; connected remotely with students.

> *Students are building their guitars at home with support from teachers by phone, email, or video.)*

Three out of 40 (~8%) said they got students some borrowed tools but really are not sure about moving forward.

> *We started builds prior to "stay-at-home" orders, however after lockdown we suspended it.*

Of those building guitars during the period, more than 60% of them used instructional videos in their online teaching, more than 50% used the instructional modules, and more than 40% used the wiring diagrams (see Table 4 for materials usage by GBI alumni within program tracks).

Table 4. Materials Used by Program Track

Materials used	Acoustic (n=11)		Electric (n=18)		Hybrid (n=16)	
	Number	Percentage (within track)	Number	Percentage (within track)	Number	Percentage (within track)
Instructional videos	7	70%	11	61%	10	63%
Instructional modules	6	60%	9	50%	8	50%
Wiring diagrams	4	40%	7	39%	8	50%
CAD model of guitars	0	0	5	28%	4	22%
STEM guitar phone app	0	0	0	0	0	0
Other (n=6)						

To understand the GBI alumni's use of Project materials, they were directly asked if they used these or not. Only 90% (130 out of 144) responded to this question. Of this group, 75% (90 out of 130) reported they did not use the Project materials.

Twenty percent of the non-users outright said they were not teaching the course; 46% noted the materials do not apply to their remote instruction; 24% did not know the materials were available; 17% said the materials were too hard to include in their online learning; 3% said their students either had limited or no online access at home; 3% indicated no school support or using in-house materials; one of them said he did not even think to use the website.

The Project Team wanted to know what other guitar building online support the faculty may need, especially during the school/college closures and included a question on this in the May 2020 survey. More video and curriculum in individual modules were the preferred program materials support identified by more than 60% of the survey respondents (N=144). Table 5 summarizes the responses to this by program track. These responses serve as guide for the Project Team in planning its program efforts moving forward. Additional comments from about 6% of the respondents dealt with online materials and videos but requested more organization and logical sequence of materials. One requested immediate response when Project is contacted (There have been so many times I have emailed the "contact us" email listed on guitarbuilding.org with questions, and I have not received ANY responses. This is so frustrating! Please make sure the contact info is correct, and the contact email is checked regularly!). Another requested shared resources and peer-review of content (Consider having a "Shared STEM Guitar Resources" area for educators to upload and share content (maybe also peer-review of content by others).

Table 5. Preferred Support by Program Track

Preferred support	Acoustic (n=27)		Electric (n=66)		Hybrid (n=46)	
	Number	% (within track)	Number	% (within track)	Number	% (within track)
Providing materials (video, curriculum) in individual modules	13	48%	40	61%	31	67%
Developing a complete Electric Guitar canvas class available for use.	9	33%	31	47%	21	46%
Providing an online "ask the expert area"	6	22%	27	41%	23	50%
Other (n=5)						

Academic Institution Support for Faculty Implementation

Data indicating organizational support and change are very important in ensuring success in implementation of the program. The continued practice of getting the formal signed administrators' support during the STEM Guitar GBI application is the only mode of data collection that indicates evidence of administrative support for all faculty participants. This happens every year and, of course, during the 2019-2020 STEM Guitar GBIs. Otherwise, data from administrators' perspectives were relatively limited. Some data were generated from some discussion with participants and Faculty Champions, the administrators' testimonials as evident from the Administrator Video, and an interview of at least one high school administrator.

Applied Learning Community [the 2019 Summit]

. The STEM Guitar Project is facilitating its brand of a replicable and sustained Community of Practice with its Applied Learning Community as a major part of support for the faculty. The most organized and formal part of the STEM Guitar Applied Learning Community is the STEM Summit. The STEM Summit is an endeavor engaged in by the Project in the past year but has been consciously brought into the current and future Project years as a systematic way of following up with faculty participants who serve as "champions" in implementing the STEM Guitar curriculum. There were 25 2019 Summit participants, five female and the rest male. 75% of the participants were high school faculty. Twenty-two of the participants presented exemplars in relation to their STEM Guitar implementation through the years. The External Evaluator attended the Summit, co-presented a paper with one of the faculty, observed all presentations and Summit events, conducted a focused interview with a small group from this Summit's participants, and conducted in-person interviews with four other faculty. Data gathered from these groups affirmed faculty improved their classroom practice and implementation of the STEM guitar program with great support from their administrators and community. Regardless of the approaches to STEM Guitar implementation (in-class within the year, in-class within the semester or term, summer, or out-of-school program), the faculty noted students' improved motivation and attendance in class, observed student improvement in the 21st century skills, improvement in use of hand-tools, and for some the use of CNC machines, and overall knowledge of guitar parts and process of building a guitar.

Student Effects: Toward Determining Student Outcomes

The STEM Guitar program effects on students reported here are shown by the case study survey data [including the evaluator field notes from a classroom observation], student- learned skills from in-person interview and self-reported learning data, faculty reported student learning, and review of related faculty archival data/email. (see the summarized data in Appendix 5 - Effects on Students).

The Case Study

A single case study design using a pre-post posttest control group design (Shadish, et, al. 2002) with a longitudinal retrospective and prospective study of cohorts {Lamorte, 2017) in a high school in Washington was recommended in the 2018-2019 school year. The study includes examining comparative student attitudes toward STEM, as well as academic data that may have been affected by students' involvement in the STEM Guitar Project. Initial data from this study were generated from a pre-post survey administered during the 2018-2019 school year for both the case study group and the control group. The survey is about students' persistence and attitudes toward STEM. Sunny's (2018) Attitude and Persistence towards Science, Technology, Engineering, and Mathematics (APT-STEM) Instrument/Questionnaire was used to gather this information about STEM Guitar students and the comparison Non-STEM Guitar group of students (those not involved with the STEM Guitar program). Challenges in institutional situations limited data collection to the case study class. The revised plan is to follow through on the performance of three different academically performing individual students: high-performing, mid- and low academic performing students. The survey administration in 2019-20, using the same APT instrument as last year, was limited to a one-time survey in February 2020. By then, this case study class was almost two-thirds through its implementation. Data from this survey, faculty and student interviews, and classroom observation are included in this section. The intent to do another survey toward the end of the school year became moot because of corona virus-related closure of schools.

The case study is partly influenced by an anthropological research method approach (Bernard, H. R., 2006) where participant observation was made part of the data collection and field work viewing the case in terms of the class' census, map, and calendar. This school is one of 34 schools in the district. The case study class is also diverse but does not quite approximate the school district student diversity (see Table 6). The District and the case study class had a majority of White/Caucasian students**.** In past years, the class had some Hispanic/Latino and Black/African American students; however, the 2019-2020 class has no Hispanic/Latino or Black/African American students.

Table 6. Student Diversity in 2019-2020

Ethnic Groups	District	Case Study School (N=17)
Asian	13%	6%
Black/African American	7%	0%
Hispanic/Latino	21%	0%
White/Caucasian	47%	65%
Other [including American/Indian/Alaskan Native, Hawaiian/Pacific Islander]	13%	29%

Faculty interview and case study data submitted indicated that there were STEM Guitar participants since 2012-2013 taught by the faculty immediately after her GBI training in 2012. The Robotics program is the "star" STEM-related program in the district but the STEM Guitar generated interest among students at different grade levels and accommodates a horizontal grade grouping. Ninety-five students had been trained in STEM Guitar since 2012-2013 until 2018-2019. There are 17 students in the current 2019-2020 class. Although there were eighth-grade students in the previous years' class, there are no eighth-grade students in the 2019-2020 class (see Table 7).

Table. 7. Horizontal Grade Mix of Students in the 2018-2019 Case Study Class

Grade Level	Case Study School (N=17)
9th grade	29%
10th grade	47%
11th grade	6%
12th grade	18%

The gender mix in the class remains diverse through the years with a low range of 24% to a high range of 38% female students every year; the 2019-2020 has the low range of 24% (N=17) female students.

Classroom observation and faculty interview indicated that the faculty in this STEM Guitar class had been very flexible and ingenious in teaching the class in "creative" classrooms with many challenges. Until the last three years, for the previous five years, this STEM Guitar class had been taught in a make-shift locker room where students were transported weekly to the locker room building for every STEM Guitar class period, which is a couple of hours per week.

Figure 9. The Case Study Creative Classroom

Classroom observation verified the current STEM Guitar classroom, the docking area; a make-shift room but more or less permanent for the class. It has its own challenge with ventilation so the doors are left open throughout the class period. Per the faculty, *quite a challenge during the winter period.* The room though has access to a water faucet and sink. A small adjacent room has been reconfigured to accommodate storage for the tools and different materials for the Project. The class uses the docking area, as well as the front outside part of the area (see Figure 9 on the left).

Interview data indicated that the faculty implements the STEM Guitar program promoting the learning of attributes that support the district goals (equity of opportunity, strong community, high expectations, global readi**ness,** and culture of kindness) in mind. Per the faculty, the STEM Guitar program is open to all students at different grade levels, diverse backgrounds, and learning abilities; thus, the equity of opportunity.

The STEM Guitar building implementation naturally invites cooperation and helping each other, thus, the potential for building a strong community. High expectations and global readiness are part of the outcomes from involvement in the program since students are expected not only to perform well in their other academic courses, but also to go through the complicated guitar building process - complete the guitar, take pride in it, and learn all the hard and soft skills embedded in the actual guitar building. These skills embedded in actual guitar building have been vetted and aligned with employability skills; thus, attaining these skills will help prepare students for global readiness. The faculty models the culture of kindness and respect dealing with all students; students in turn pick this up and behave in the same manner toward their classmates. Students cooperate, consult with, and help each other throughout the build**.** Figure 10 on the right shows some of these aspects. The school administrator affirmed alignment of the STEM Guitar program implementation in their school with their district goals.

Figure 10. Skills Learned by Students

Survey results indicated that the 2019-2020 STEM Guitar students have learned through STEM through guitar building different STEM-related skills, the importance of STEM in real-world applications, and honed their grit and confidence in achieving their goals (see Tables 8, 9, and 10.

Table 8. Beliefs and General Attitudes Toward STEM

Students believed that:	**Rank Order**
• it is important to be respectful and be willing to listen to team members while working on team Projects in STEM.	1st
• studying science, technology, engineering, or mathematics can lead to good jobs.	2nd
• science, mathematics and technology have real-world applications.	3rd
• science, technology, engineering, or mathematics solve problems in society and help people.	4th
• science, technology, engineering or mathematics classes teach critical thinking skills that will help me later in life.	5th

Table 9. STEM-Related Knowledge and Opportunities

Students liked:	Rank Order
• to come prepared for my mathematics and science classes.	1st
• to problem solve or find solutions to science and mathematics problems.	2nd
• to better myself in science and mathematics by seeking opportunities in these areas.	3rd
• to go above and beyond by exploring science and mathematics outside my classroom.	4th
• to work with an engineer or a doctor or a scientist.	5th

Table 10. Confidence re: STEM-related Skills and Attitudes

Areas where students indicated tenacity and grit:	Rank Order
• I am responsible for my own learning and experiences.	1st
• I get better at science and mathematics skills when I practice a lot.	2nd
• I am not discouraged by criticism while working on science or mathematics Projects.	3rd
• I don't give up trying even when I am at first unsuccessful while working on science or mathematics Projects.	4th
• I set long term goals and don't get frustrated when it takes a long time to achieve my goals.	5th

The faculty requested two of the STEM Guitar student leaders from this case study group to help with the STEM Guitar workshop with veterans. The two students were capable and well organized although the faculty noted that one of these students is more academically challenged. He is the academically-low performing student subject included in the revised case study. The evaluator actually observed these students' qualities when she watched the students during the veterans' workshop. In-person interviews with these students affirmed their knowledge of the guitar building process, handling and organization of the different tools, the leadership and the confidence to help the veterans because they knew what they were doing. As the students said:

> *It is cool and fun to make art. I like building guitars and it feels great helping the veterans.*

> *I enjoy organizing things and I'm glad to be of help. I now know a lot more of power tools…kinda like life…getting to know more about it.*

As it was, observing and talking with this one supposedly low-academic performing

student indicated his improved knowledge about STEM guitar and his great motivation for learning. The faculty is still collecting academic-related data for the revised case study subjects. It will be interesting to see how STEM Guitar building would have affected skills development of the different academic ability levels of students. The faculty shared information about a previous student who benefited from his guitar building experience. This student went on to complete a woodworking program and now works making custom cabinets and furniture. If this is any indicator of future development of STEM Guitar building students, this society will have lots of productive citizens.

Student Learning from Integrated Data

Role of Faculty and Students Reached

There are common attributes especially among the STEM Guitar Faculty Champions interviewed and implementing the STEM Guitar program, regardless if they had their GBI experience one year or nine years ago: a strong sense of learning, dedication to teaching, venture into complexities and experimentation, exploration of techniques and materials, continuous improvement and innovation, and strong desire to help students succeed. In many ways, the faculty improve on their curricula (e.g. the electronic unit – made it simple; most students do not have electronics experience) because a lot of things are all new to them. As a faculty posited, *Students, are not really technically-oriented; give them a little taste of it, a basic understanding.* The 2019 Summit Faculty participants exhibited expertise in curricular adjustments and shared their perspectives as they did their Summit presentations. Other Faculty Champions interviewed affirmed these attributes.

The faculty indicated that they had different approaches for implementing the STEM Guitar program in their institutions (in-class full school year, semester or term class, summer, class, or as an out-of-school/extension class), all with intentions of helping students learn the STEM-related hard and soft skills inherent in guitar building. About 70% of the GBI participants are high school faculty; the rest are teaching in community colleges. This distribution was affirmed in the representation of 2019 Faculty Summit participants. Regardless of the approach used by faculty and the institutions they belong to, all are adhering to at least 78-hour basic build time. Each faculty had a range of six through 20 students per class, with a mode of 12 students. The faculty were also quick to note the challenge of teaching bigger classes (with 19-20 students) where students' performance sometimes may suffer. With all the faculty trained through the GBI all these years, the Project reach is about 11, 000 students or more, at least across the United States, by now.

Student Stem knowledge and Academic Performance

Faculty members shared their own success stories about their students. (refer to Appendix 5 - Effects on Students). A faculty reported the impact of the STEM Guitar program on students' STEM knowledge such as measurements and the integration of wood shop with the guitar build. As he said, *my students understand working with wood and applying measurements to handle it.* Another faculty reported that one of his students was

awarded a scholarship because of the STEM knowledge gained from the STEM guitar build. Another faculty confirmed what was indicated by the case study students in learning about STEM concepts and how they are applied in real-life situations.

Faculty Champions affirm that the STEM Guitar program helps improve their students' academic performance. One of the Faculty Champions, who has become part of the Project Team in the past two years, indicated productive and consistent impact of the guitar building implementation on his students' academic performance. He shared the progression of his classroom implementation and the academic performance of his students. He explained his criteria for grading included ratings for quality of work (end results and pride on their work) and overall work ethic, which include how they listened and how they helped each other (team work). He started teaching STEM Guitar in the Fall of 2016 teaching a total of 178 students within 11 cohorts from that time until spring 2020. Except for the students in the Fall 2017 cohort (n= 19 students, 11% of the total students taught), the academic ratings for all 11 cohorts of students indicated a range of 88% to 100% of them receiving a rating of B+ and above; in fact, all students in two of the 2017 cohorts received "A" ratings; one cohort of which had 16 students.

Another Faculty champion, who is currently a member of the Project Team, shared successful stories about his former STEM Guitar students from some years back He added that his students credit their time in the guitar program with helping them choose their college paths. One of the students had been in trouble with the law and was very likely not to graduate from high school. He reported that the lure of the guitar and being enamored with the painting process led him to an after-school job at an auto-body shop, painting primer on fenders, which in turn led to painting both color and clear coat, and doing buffing. He ended up graduating high school and is working in auto-body repair. He reported that many of his other STEM Guitar students are now attending various universities to pursue studies in engineering and other STEM related fields: architecture, agricultural engineering, civil engineering, computer engineering, and mechanical engineering technology. He added that one student got a Fulbright scholarship to Trine University in Environmental Engineering. One former student is presently working on a Master's degree in Agricultural Engineering at Purdue University.

Hard Skills Learned

A Faculty Champion shared that his students learned math and hands-on skills (especially doing the fret spacing), science and lab, multiple ways of solving a problem, and coming up with multiple solutions. He said*, students had a little taste and basic understanding of electronics, were comfortable in using machines, and learned about woodworking and different characteristics of wood*. Among the three most important skills students learned in his class are: soldering, hand tool use (having to experience and practice with the use of it like, initially, the use of band saw, etc.), and machine use (lately students started using Fusion 360).

Interviews and observation of the case study student leaders who served as helpers

in one veterans' workshop, as noted above, showed the students learning about different phases and aspects of electric guitar building (from body shaping, separating and joining processes through the finished product and quality control) and the tools needed in these to build the guitar. Another student leader who was requested by one of the Faculty Champion trainers to help in the veterans' workshop was also interviewed. He reported his confidence in soldering. He said, "*I learned soldering in 9th grade when I first took STEM Guitar building. I am in 11th grade now. I built on what I have been learning… am happy to help the veterans with this process.* Interviewed faculty verified the students' reported skills learning through their involvement with the STEM Guitar building. In classes where CNC/CAD design was introduced, faculty reported that their students learned 3-D designs and how to model their guitar parts. One faculty alumni of the Hybrid-CNC guitar building in Connecticut reported through the April 2020 issue of the FDMC-online.com [https://www.fdmc-online.com/fdmc/april_2020/MobilePagedReplica.action?pm=2&folio=16#pg18] that his students were using the CNC, as well as designing and cutting their own guitars. He also indicated that the technical skills students learned in his class are employability skills marketable to the different companies and industries around their community.

Soft skills

Faculty and students asserted that soft skills, especially those referred to as the 21st Century Learning Skills, were important in one's personal and professional life. Survey data from the case study noted above indicated that the 2019-2020 STEM Guitar students have learned through guitar building different STEM-related skills, the importance of STEM in real-world applications, and honed their grit and confidence in achieving their goals. One faculty said that *STEM Guitar is a hook to do better in school*. Another faculty noted, *Overall, my students were motivated, wanted to learn more, and found the class as fun, although sometimes, especially the unmotivated students, they cannot differentiate between fun and work.* Faculty members were unanimous in saying that STEM Guitar changed students' attitudes toward school and helped improve student attendance. As one faculty posited, *Kids like going to school to work on their guitars.* Another faculty noted, *the school had to get court order for some of our students to attend school; with the guitar build, the students are the ones asking to be in school even an hour earlier.* One faculty said that *The STEM Guitar building is a multi-faceted Project that becomes a great unifier.* One other faculty remarked, *Kids develop critical thinking problem-solving skills, they take pride in their work and get community recognition.* As one faculty said, *STEM Guitar literally made my student a rock star.* Another said, *Students get to talk about compelling stories about their guitar.* Other soft skills specifically noted by faculty are productivity and time management.

Wider Spread of the STEM Guitar Project and Overall Project Sustainability.

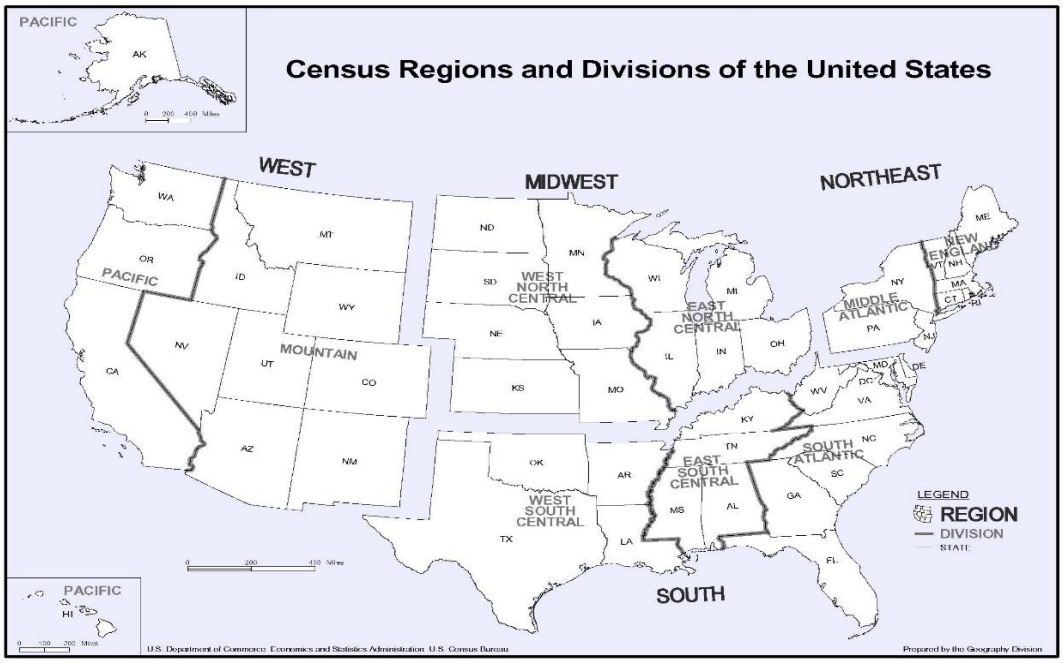
The wider spread of the STEM Guitar Project extent is evidenced by the Project extent and span of implementation, as well as coverage and magnitude of interests in the Project. The Project's sustainability efforts involve promoting the supply chain as well as encouraging program media exposure, attendance in STEM-related/guitar-building/music-

related events and conference presentation/ publications, and building academic, business/industry and community partnerships. Relationships with academic, professional associations, business/industry, and the larger community promote Project buy-in, acceptance, relevance, crowd-sourced funding, and more visibility for Project promotions and funding support. Currently, the Project Team is also reviewing the potential for other funding support.

Project Spread Across the United States

In the third year of implementation (2019-20) of the current STEM Guitar Project grant, it continued to serve veterans, faculty, and institutions across the United States. Figure 11 shows the census regions and division of the United States. Region 1 (Northeast [Division 1-New England & Division 2-Mid-Atlantic]); Region 2 (Midwest [Division 3-East North Central, Division 4-West North Central]); Region 3 (South [Division 5-South Atlantic, Division 6-East South Central, Division 7-West South Central]); Region 4 (West [Division 8-Mountain, Division 9-Pacific]).

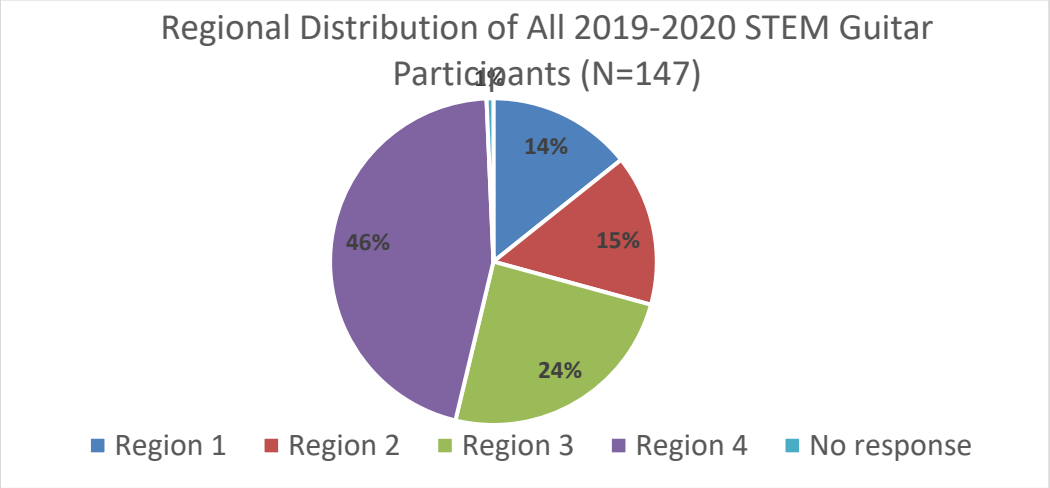
Figure 11. US Census Regions and Divisions



Source: https://en.wikipedia.org/wiki/List_of_regions_of_the_United_States

Data in Figure 12 indicate the wide extent of distribution of the 147 STEM Guitar 2019-2020 participants (109 faculty, 14 Golden Colorado GBI participants, 15 veterans, and 9 outreach participants) across the country. Most of the participants (46%) came from Region 4 while Region 3, with 24% of the participants, came in second.

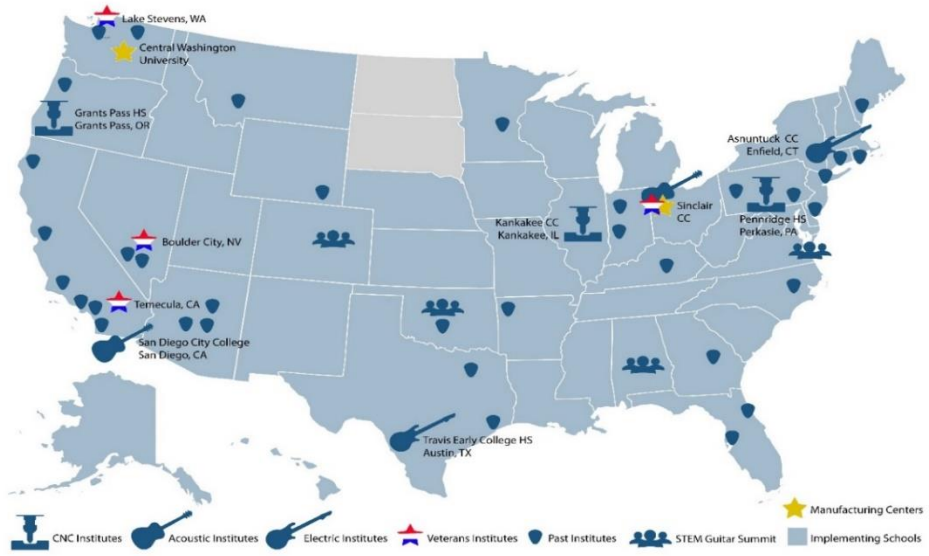
Figure 12. 2019-2020 Participant Distribution Across the United States



The Span of Faculty Implementation in 2019-2020

The STEM Guitar Project has reached all four census regions and divisions of the United States, not to mention a province in Canada, and a school in Colombia, in terms of the veterans' sites, other workshop sites, and the GBIs training sites. Figure 13 shows all implementing schools since the start of STEM Guitar Project implementation over the period of the three STEM Guitar NSF grants. The GBI Alumni surveyed in May 2020 has similar geographic distribution (Region 1, 17%; Region 2, 15%; Region 3, 24%; Region 4, 42%). More than 60% of this group continued to use the STEM Guitar Project instructional videos and modules, and about a third of this group continued building the guitar in their online teaching, even during the school/college closures.

Figure 13. The STEM Guitar Map of Program Implementation



Source: STEM Guitar Project website (http://guitarbuilding.org)

In Figure 13, there are two US states (North and South Dakota) without schools implementing the STEM Guitar curricular program. However, last year the STEM Guitar website usage indicated that there were STEM Guitar program enthusiasts across all 50 US states; new data for 2019-2020 has yet to confirm if this is sustained.

Coverage and Interests in the Project

The coverage and interests in the STEM Guitar Project were reviewed in terms of extent and seasonality of the Project website (http://guitarbuilding.org/) usage, the STEM Guitar Project Facebook (FB) account postings and interactions expressed in terms of "Reach" and "Impression", as well as the Project coverage through the extent and seasonality of the guitar kit sales.

Extent and Seasonality of Website Usage

Figure 14 provides insights into the ebbs and flows of interests in the STEM Guitar Project across the 2019-2020 Project period through website access or page views.

Figure 14. Website Views: April 1, 2019 through March 31, 2020

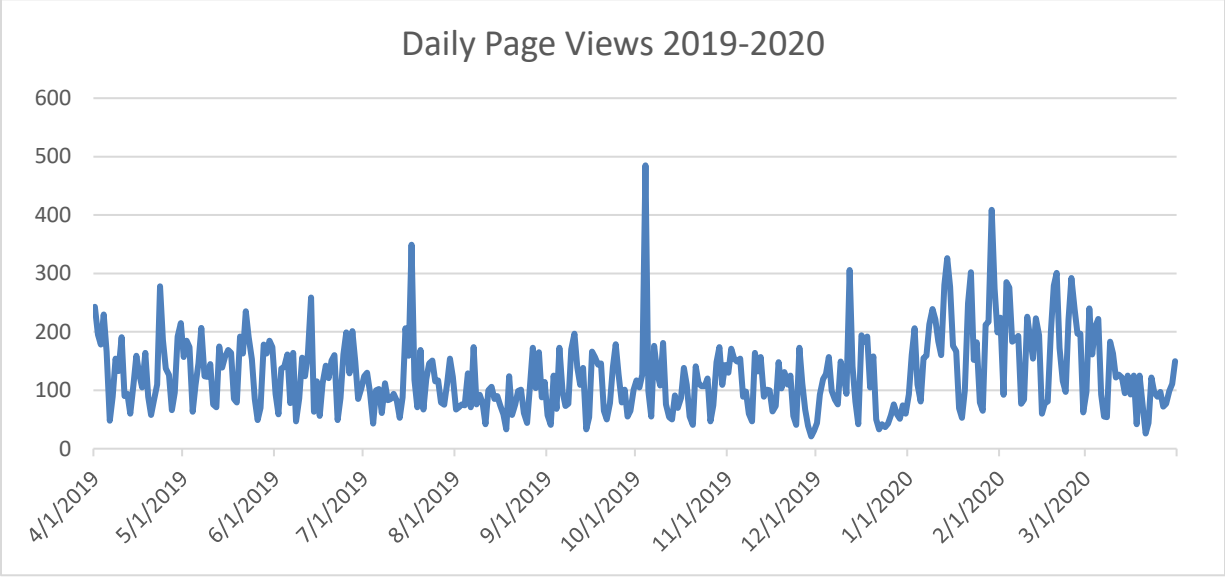
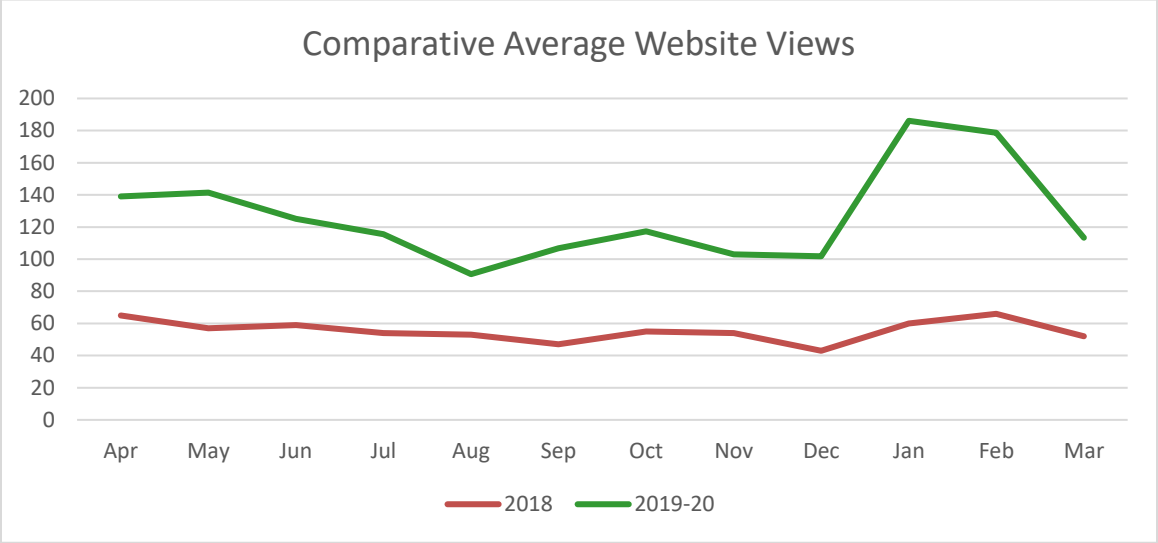


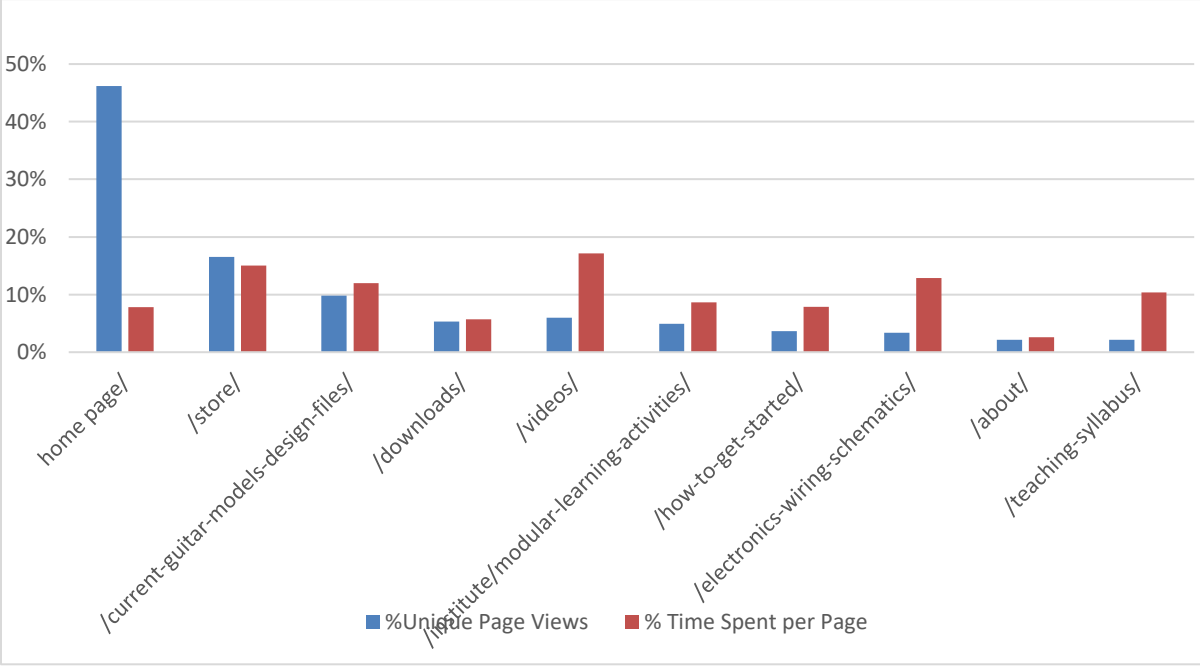
Figure 15 (below) indicates that the STEM Guitar website has been accessed more times in 2019-2020 than the previous year. Although there are daily website views, there appears to be some seasonal trend in the website views, especially during fall and winter months and toward the end of school year in March. There appears to be a sharp drop of website views in March 2020, a likelihood of the coronavirus effect and closure of schools during this period.

Figure 15. Monthly Average STEM Guitar Website Views



Interests in the website content are indicated by the proportion of page views and amount of time used in accessing the Project website (see Figure 16). Page views of the "store" is second to the highest. Overall, the page views show interests in learning materials with the viewing of videos as of highest interest.

Figure 16. Unique Website Page Views Over 2019-2020

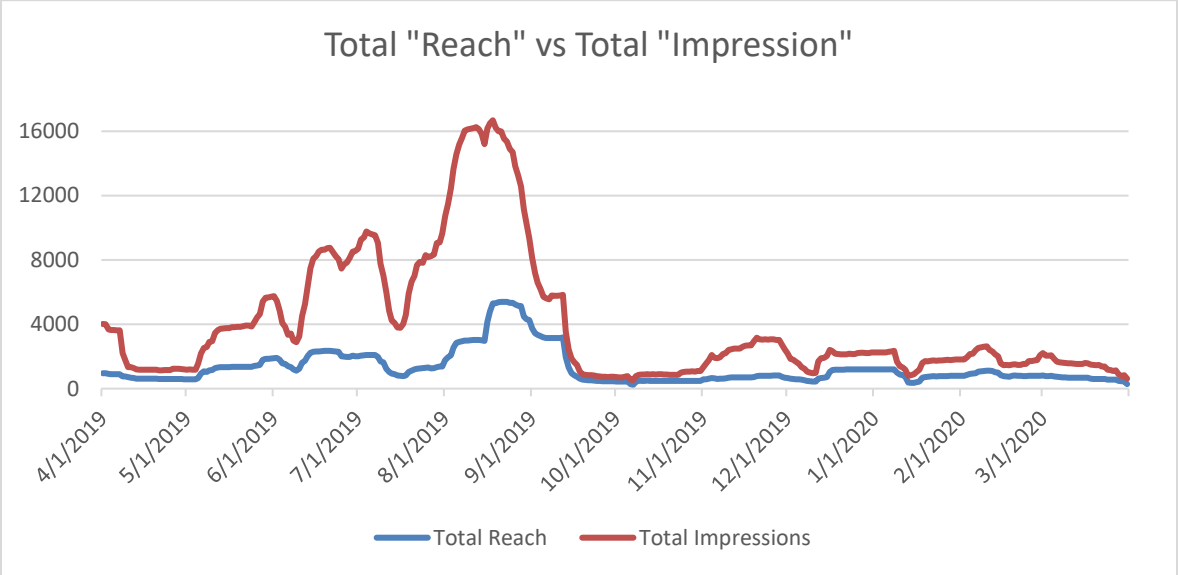


STEM Guitar Facebook Account "Reach" and "Impression"

The STEM Guitar Project Facebook account remains active in 2019-2020. Project

team members and program enthusiasts continue posting through the year. Facebook data analytics for the period April 1, 2019 through March 31, 2020 are included in this report. As in the previous year, data mining of the gathered data analytics was performed to have a sense of how this social media platform affects the STEM Guitar Project. Per the variable definitions provided by Facebook (refer to Appendix 6) users' "Reach" and "Impressions" were noted. York (2019) inferred that "Reach" is the count of people who may have seen Facebook (FB) content when the page or post enters the audience's screen and "Impressions" are the total number of times FB content is shared with other audiences by different people through different posts, and check-ins about the page and posts. The numbers for "Impressions" are usually higher than the numbers for "Reach" as sharing of content are done. Figure 17 shows the comparison of STEM Guitar FB users' "Reach" and "Impressions". This indicates that the FB users actively shared the STEM Guitar content they received with other audiences, especially during the summer period, indicating interactions about the STEM Guitar content during the period. These activities are likely greatly influenced by the Summer GBIs and workshops, as most of the postings and related interactions were referring to the Institutes and workshops.

Figure 17. STEM Guitar FB Total "Reach" vs. Total "Impression" Data



Facebook analytics reported "Reach" and "Impressions" either as **organic** or **viral**. It is organic when it refers to the number of unique people who see the page/post content in the News Feed, without any paid advertisements. The post becomes **viral** when other people interact or engage with the page or post, share this with social information; this also includes liking the page, following and checking into the page, sharing a photo of the page, commenting about the page. Often times, the "total" and "organic" data are about the same while the viral data are usually less than the "organic" data. The viral data are the ones that indicate engagement and interactions about the page and/or posts. During this period, however, this case seems to be true for the "Impression" data (see Figure 18) but not quite with the "Reach" data (see Figure 19). The "Reach" data mean that the same numbers of

unique FB users who may have seen the STEM Guitar content simply liked the page without interacting or sharing the content while the “Impression” data indicate that there were unique FB users during the period who shared the STEM Guitar content without influence of any advertisements and have shared and interacted with the posts and content.

Figure 18. Compared STEM Guitar FB “Impression” Data

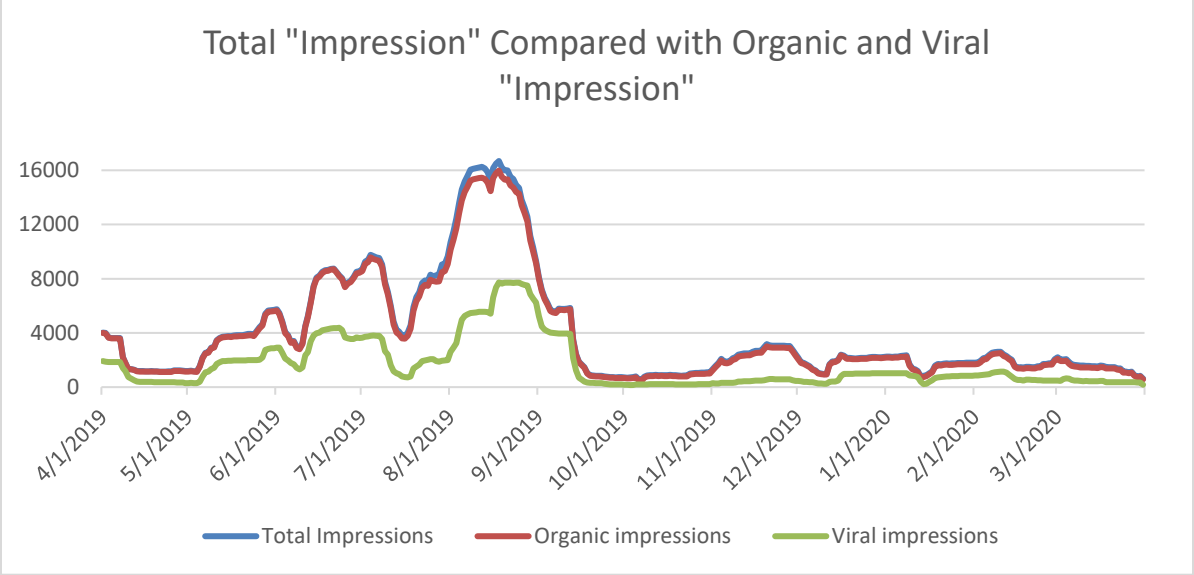
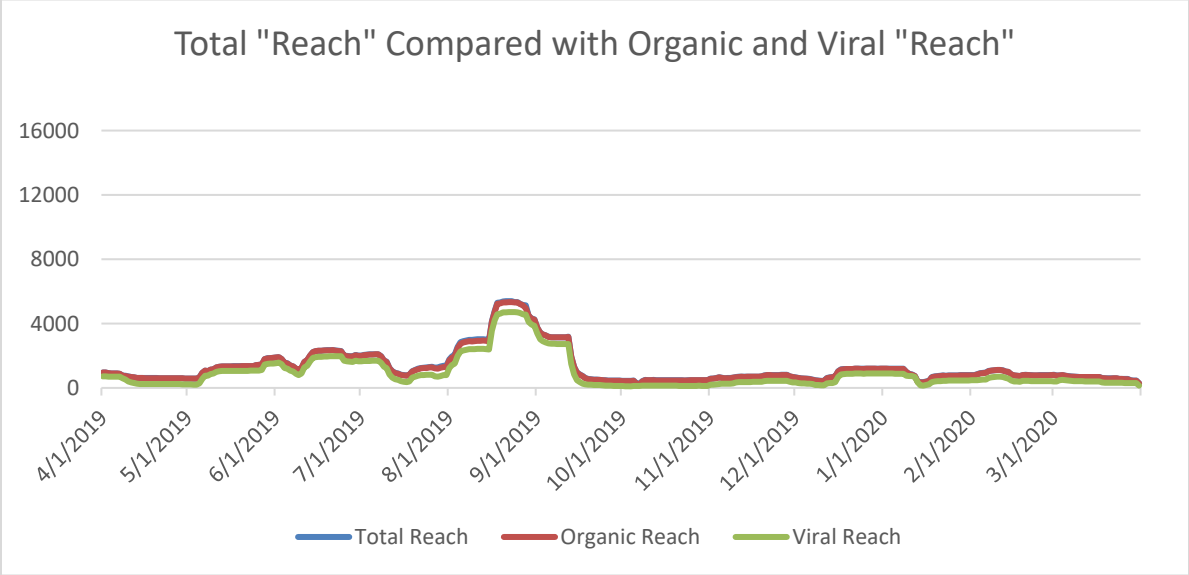


Figure 19. Compared STEM Guitar FB “Reach” Data



The “Reach” and “Impression” data are reviewed for patterns that cut across during April 2019 through March 2020 Project period. It is interesting to see that there are higher spikes in both the organic and viral “Impression” data (see Figure 20) compared with the organic and viral “Reach” data (see Figure 21), during and immediately after the 2019

summer period when the STEM Guitar GBI's were conducted. These are indications of more active sharing of and interactions with posts on the STEM Guitar FB account during that period.

Figure 20. Compared STEM Guitar FB Organic Data

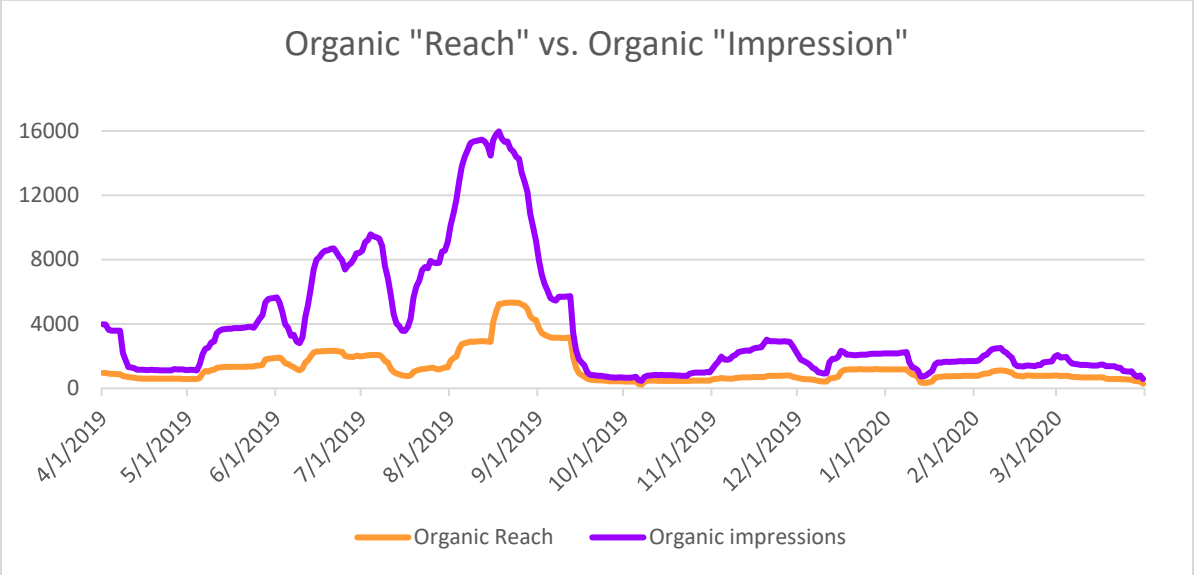
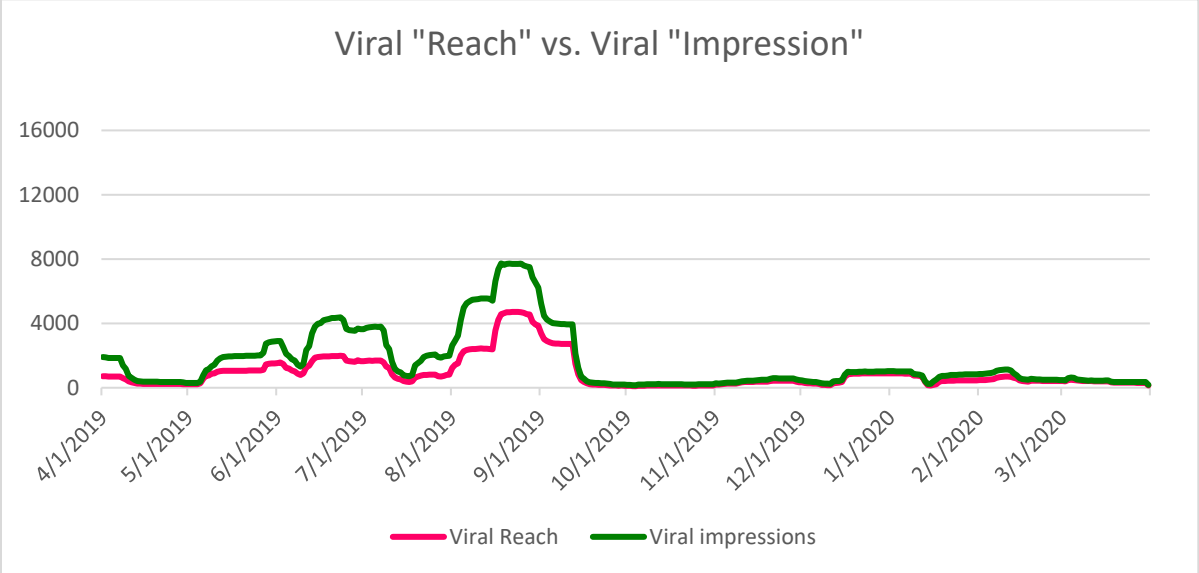


Figure 21. Compared STEM Guitar FB Viral Data



Aggregated percentage of seasonal FB "Reach" and "Impression" data highlight the distinct spikes of these interactions during the summer period (see Figures 22 and 23).

Figure 22. Aggregated % FB Total "Reach" vs. Total "Impression"

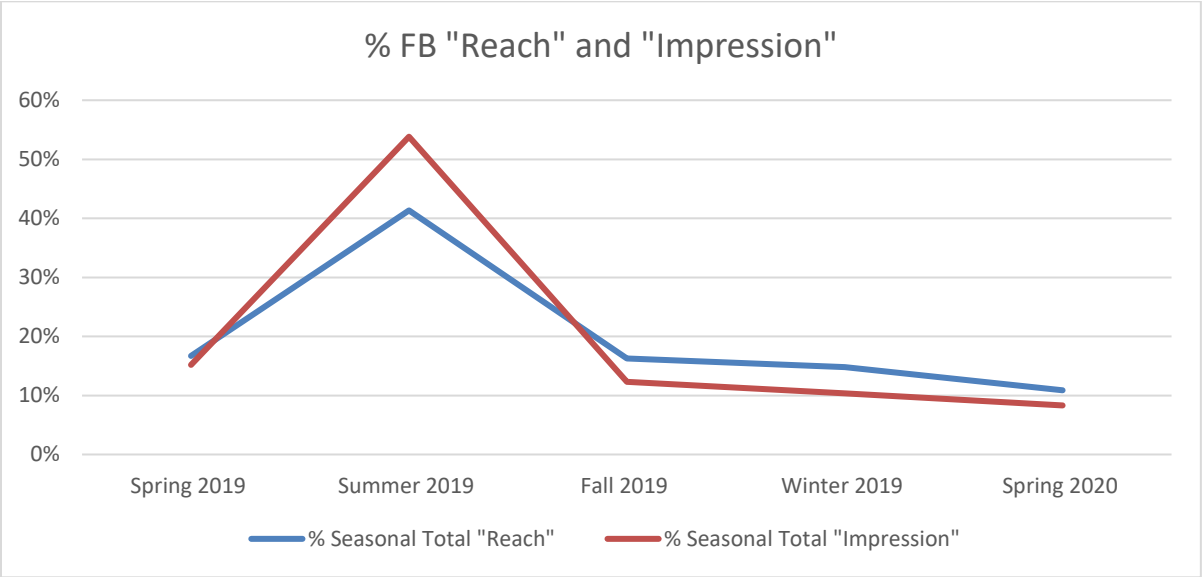
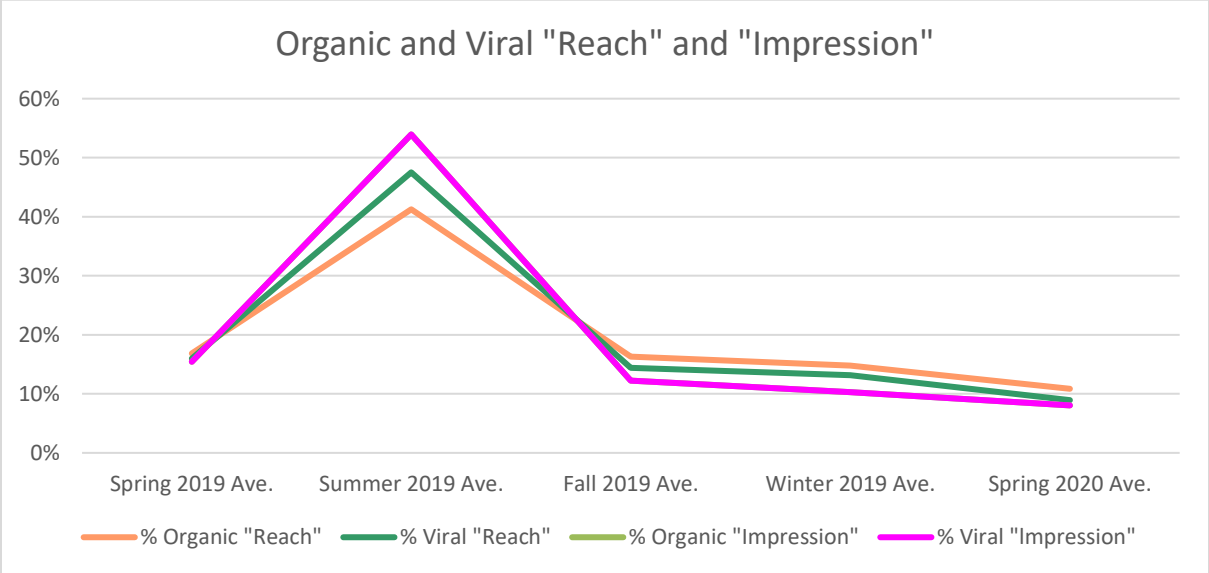


Figure 23. Aggregated % of Organic and Viral "Reach" and "Impression"



Extent and Seasonality of Guitar Kit Sales

Part indicator of the Project sustainability is the guitar kit sales. The Storefront on the Project website has links to url addresses for ordering guitar kits and supplies:

Acoustic guitar kit and supplies
http://guitarbuilding.org/store/#!/Acoustic-Guitar-Kits-and-Supplies/c/34779027

Classroom pack guitar kits
http://guitarbuilding.org/store/#!/Classroom-Pack-Guitar-kits/c/22671276

Individual guitar kits
http://guitarbuilding.org/store/#!/Individual-Guitar-Kits/c/22006028

Body plank and partially milled guitar kits
http://guitarbuilding.org/store/#!/Body-Blank-and-Partially-Milled-Guitar-kits/c/22671282

Guitar hardware kits plus neck and fret board options
http://guitarbuilding.org/store/#!/Guitar-Hardware-kits-plus-Neck-and-Fret-board-Options/c/23151741

Guitar tools and supplies
http://guitarbuilding.org/store/#!/Guitar-Tools-and-Supplies/c/22671272

The number of institutions ordering guitar kits and supplies in 2019-2020 indicates the classroom implementation during the school year. The 104 institutional clients for the Guitar kit sales in 2019-2020 are all across the four different regions of the United States represented only by 44 US states**.** The following figures show the clients within the states in the particular region that implement the program (new clients – Figure 24; repeat clients- Figure 25). Of the 104 client institutions in 2019-2020, 25% of them are repeat customers.

Figure 24 shows that there are greater numbers of new institutions represented by participants from states within Region 4 that ordered guitar kits and supplies relative to all other regions; indication of more new institutions in Region 4 (compared to the other Regions) implementing the guitar program.

Figure 25 shows that greater numbers of repeat customers from institutions represented by participants from states within Region 2 ordered guitar kits relative to all other regions implicating that more of the Region 2 institutions have on-going guitar building implementation programs.

Figure 24. 2019-2020 STEM Guitar New Guitar Kit Sales Order

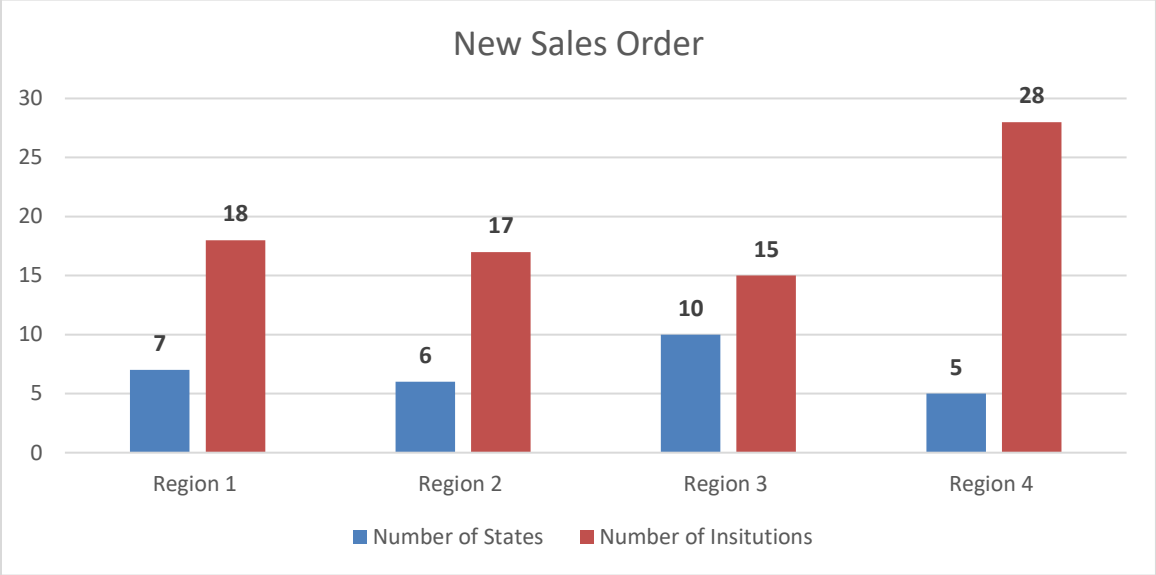
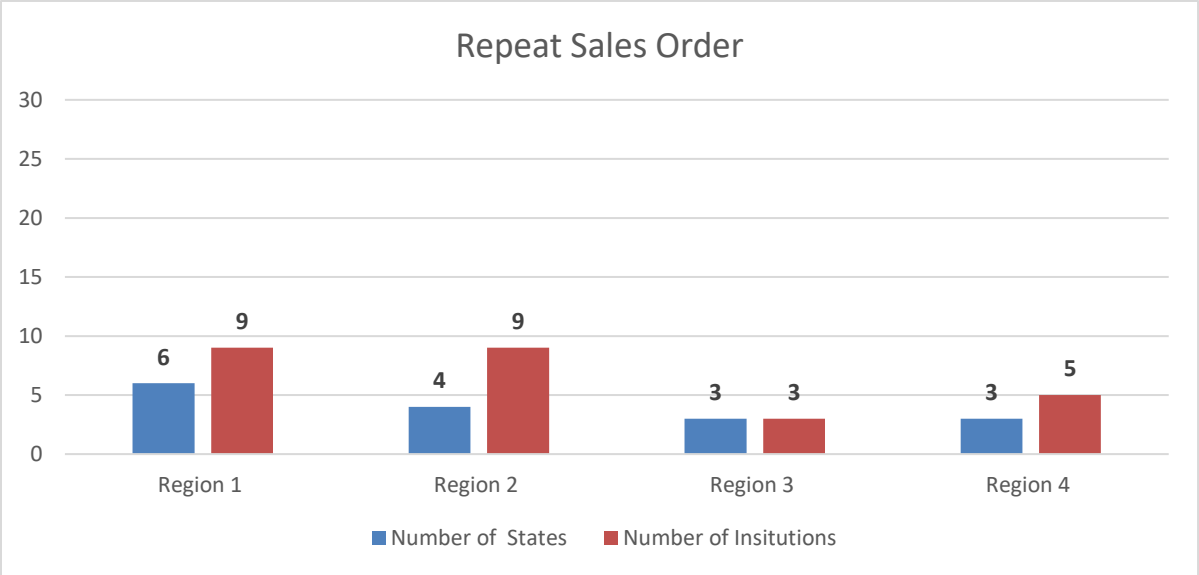
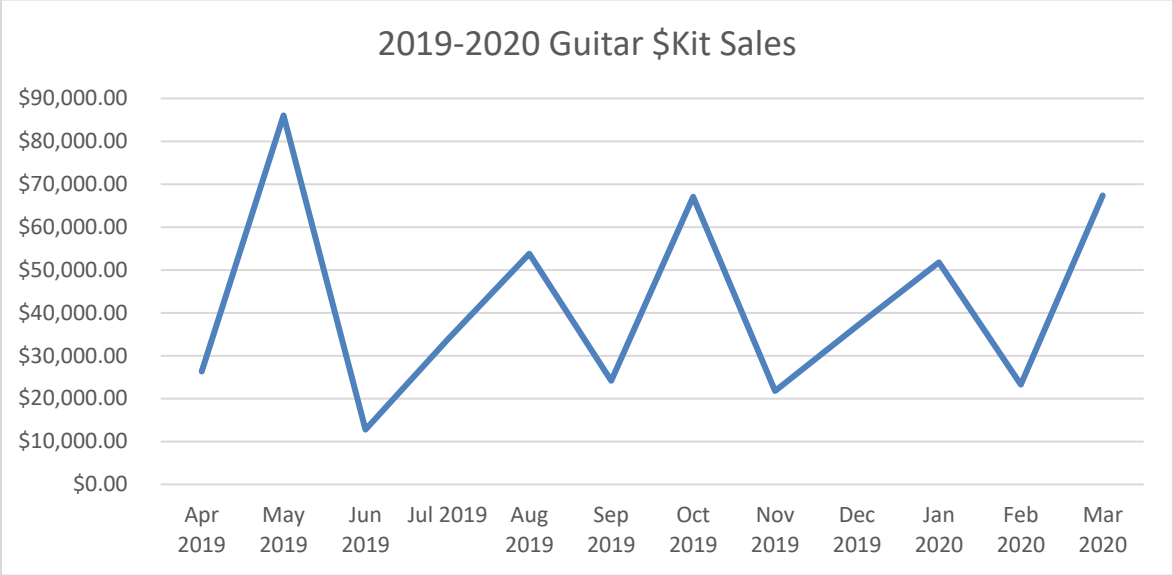


Figure 25. 2019-2020 STEM Guitar Repeat Guitar Kit Sales Order



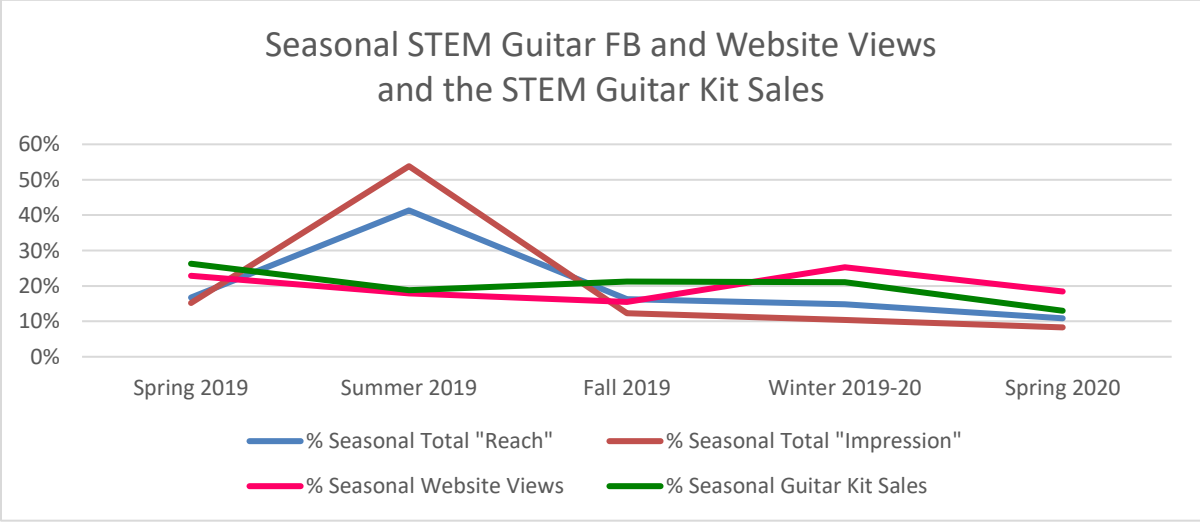
Wider coverage and interests in the STEM Guitar Project are evidenced by the consistency in terms of participants' and guitar building enthusiasts in the access and usage of the STEM Guitar FB accounts, the STEM Guitar website, and the orders of guitar kits and supplies. While guitar kit and supplies sales move up and down, there seems to be continuous interest in the program with the peaks corresponding to the fall and spring of the school year (see Figure 26).

Figure 26. 2019-2020 Guitar Kit Sales in Dollars: Volume and Timing



Triangulating seasonality of the website usage, FB "Reach" and "Impression" and guitar kit sales, there appears to be an inverse trend in FB usage compared to the website access and guitar kit sales (see Figure 27). Understandably, there appears to be greater FB usage and access during the summer period compared with website access. Increasing website views and guitar kit and supply orders starting fall appear to be coinciding with the school year as most of the website accesses were either guitar kit orders or access of learning materials and videos. The evolving peak in summer could be correlated with the conduct of the Summer Institutes; additionally, the increasing website views are evidence of increasing interest in learning/teaching materials available on the website. More follow-up to understand this trend is being considered.

Figure 27. Seasonal Access of SG FB Account, Website, and Guitar Kit Orders



Project Dissemination and Media Exposure

STEM Guitar Project dissemination during this period focused on different ways guitar building can be used in problem-based learning in K-16 classrooms. This was made possible through presentations made by the Project Team and STEM Guitar Champions in different avenues. Seven STEM Guitar Project Team members along with 15 other STEM Guitar Champions showcased their continued active involvement in the Project by sharing best practices and student outcomes in the November 2019 Summit held in Golden, Colorado. Project Team members presented in four national conferences (one in the NSF-ASEE Conference held in Florida in June 2019, one in the National Science Foundation (NSF) Hi-Tech Conference held in Missouri in July 2019, one in the Association of American Physics Teachers – AAPT held in Utah in July 2019, one in the NSF_ATE Conference held in Washington DC in October 2019).

Special feature for the STEM Guitar Project dissemination is the STEM Guitar Story Book that had been presented to the National Science Foundation for different industry, business, community, school supporters, and various STEM Guitar enthusiasts. To date, there were six STEM Guitar Story Books that had been published from the period 2014 through 2019 showing the STEM Guitar Project growth through the years. These are all available at the Project website: http://guitarbuilding.org/about/grant-evaluation/. Each year focuses on highlights of the year's training and implementation, building up to the year's program evaluation report. The 2019 story book highlighted the Project's contribution to increasing employability skills through STEM education and showcased the wide Project extent with formal and informal Project dissemination.

Through the initiative and networking efforts of the Project Team, there were three news Project features and seven articles that originated regionally but had national, and potentially, international, exposure because of their online nature. The news features were: 1) through the sponsorship of the Boulder City Rotary Club in the Las Vegas Now television Network in May 2019, 2) through the New York News in New York City in July 2019, and 3) Project feature through the National Association of Music Merchants (NAMM) Show in California in November 2019. The seven articles were written by one of the original members of the STEM Guitar Project Team: one published in January 2020 through The Conversation, a network of not-for-profit media outlets that publish news stories written by academics and researchers; one published in February 2020 through the Purdue Polytechnic Institute Research, and five articles (four articles in 2019 and one in Spring 2020) published in the American Lutherie through the Guild of American Luthiers based in Tacoma, WA. Recent media feature in the April 2020 issue of the FDMC-online.com, a national woodworking manufacturing publication [https://www.fdmc-online.com/fdmc/april_2020/MobilePagedReplica.action?pm=2&folio=16#pg18] highlighted one of the faculty alumni of the Hybrid-CNC guitar building in Connecticut.

Involvement of veterans in guitar building contributed to Project dissemination as well. The media coverage about the Temecula Heroes' Build in The Press-Enterprise published July 3, 2019 (https://www.pe.com/2019/07/03/why-five-inland-veterans-spent-days-building-electric-guitars/) noted how the veteran participants felt safe and positive experiencing the guitar build with other veterans; they felt free to talk and underwent some healing sharing the guitar build with fellow veterans. Media exposure for the veterans build held in Edmonds, Washington in November 2019, referred to as "Twang II", was facilitated through the auspices of MatEdU Public Relations/Marketing representative; promotions and information about the 2019 "Twang II" event was published through two local television news affiliates: Q13 Fox News Seattle and KING 5 NBC News Seattle.

Overall Project Sustainability

The overall Project sustainability is a continuous Project concern as overall sustainability efforts were part of the Project activities since the beginning of the grant. These activities involve the development of the supply chain, the development and maintenance of Project partnerships with the academic institutions, the business/industry, and the larger community, including exploring other funding support.

The Supply Chain

There has been an exponential increase in demand for guitar kits and supplies through the years. Most of guitar kit demand has been supplied by the guitar kit Manufacturing/Production Team at Sinclair Community College (SCC), a self-sustaining entity not included in the grant expense budget. There is stability with the current guitar kit manufacturing at SCC; it has developed its infrastructure, process and practice. The guitar kits, as ordered, are distributed to different educational institutions around the US by the SCC Manufacturing/Production Team. Although the Project's three program tracks (AGB, EGB, HGB) provide more complexity for guitar kits and supplies, the HGB faculty Institutes seem to provide additional resource, thus, expanding the supply chain especially for pre-cut body parts. Demand for pre-designed/pre-cut guitar parts has been decreasing after the HGB program track has been introduced.

The STEM Project Team continues to exert more efforts to grow its school supply chain. The Project Team continues to reach out to participating institutions who may have facilities that can handle the manufacturing and preparation of guitar kits. Potential groups are those institutions with facilities and capabilities and where there are Faculty Champions dedicated to implementing the guitar-building problem-based learning program. The Project Team continues to explore other sourcing possibilities like local manufacturing, which may be interested in making guitar kits, as well as importing materials that may help optimize costs.

Project Partnerships with Academic Institutions

Reaching out continuously to academic administrators became part of the primal effort of the STEM Guitar program to promote the STEM Guitar program buy-in. Curricular

integration of the STEM Guitar program is critical to realizing the Project goals. The Project continues to experience wider span of academic partnerships as more and more participants around the US states and other countries such as Australia, Canada, and Colombia are becoming involved in the Project.

The impending launch of the Administrator Video is a way by which the Project can also promote the academic institutional partnership. Faculty interviews indicated that they are receiving administrative support in their institutions. Typical quotes from faculty are:

> *My administrator is supportive of it* [STEM Guitar]; *our school community 100% behind it.*
>
> *My administrator joined a GBI training; that helped in his understanding about the Project. I will start a full STEM-guitar class in 2019-2020.*
>
> *I started with STEM Guitar implementation as out-of-schoolwork. With our local media support and administration support; I will introduce this* [STEM Guitar course] *as a regular class in Engineering technology.*
>
> *I am getting a new building for my class* STEM Guitar class]*; 30% bigger than my current small room.*

The academic institutions' Summer GBI hosting in 2020 shows the viability of the STEM Guitar connections with different institutions across the United States. New host connections are established for the 2020 GBI: San Diego City College, San Diego, CA; Travis Early College HS in Austin TX and Anuntuck Community College in Enfield, CT. The stability of the Project's connections is shown through the repeat GBI hosting in 2020 of institutions like: Sinclair Community College in Dayton, OH; Pennridge High School in Perkasie, PA; Grants Pass High School in Grants Pass, OR; and Kankakee Community College, Kankakee, IL.

One of the Faculty Champions teaching at Kankakee Community College (KCC), who is now a member of the Project Team, taught the STEM Guitar course at KCC in the fall of 2015. The STEM Guitar GBI had a great impact on the current college President as he was one of the first group of KCC's STEM Guitar students. The Dean of KCC's Technology Division was one of the GBI participants when KCC hosted it in 2016. The KCC administrators consider using the STEM Guitar course as a model for other Project-based STEM courses in the College. The College started its first STEM 3-D Printers course following the STEM Guitar model.

Every year since the start of the first grant, Faculty Champions emerge. The Faculty Champions serve as the best ambassadors to academic institutions as they model the

STEM Guitar curricular Project-based learning implementation in their institutions. Faculty Champions are invited to join the yearly Project Summit where they are able to show positive program effects in their classroom practice and their students. The 2019 Faculty Summit staged exactly these same effects regarding their classroom practices and students as they presented exemplars of their STEM Guitar-related program implementation. These revolved around classroom best practices, ideas for new Projects, as well as impacts on students (school performance, learning more about STEM concepts, gaining STEM-related hard and soft skills, and improving students' attitudes and interest toward STEM and STEM careers).

Partnerships with professional associations through the team members' professional conference presentations, and for some members, memberships in these associations, are continued and pursued. Additionally, the Project maintains its connections with different NSF Advanced Technological Education (ATE) Centers such as the National Center for Manufacturing Education (NCME) and Materials Education (MatEdU); these centers are committed in providing up-to-date information on manufacturing processes and information on various materials needed to make a guitar (e.g., metal, wood, polymers, etc.) and the properties of each of those materials.

Continuing Business and Industry Partner Development

Project minutes of meetings show that the STEM Guitar Project is able to explore and develop continuing business and industry partnerships with business/industry connections. Relationships with business and industry contribute to the Project buy-in, acceptance, relevance, crowd-sourced funding, and more visibility for Project promotions and funding support. In the last few months of the STEM Guitar Project, the Project Team would like to be aligned and working seamlessly in conjunction with industry partners, hopefully with additional supplemental funding. The Team would like to enhance employability skills through the Project's Institutes/ training by creating an industry-recognized badging or skill identification system, and standard-based certification. The skill sets will be cross-walked with the Project's educational competencies developing a process of skills recognition learned from the STEM Guitar programs that would equate to industry service technician levels. Additionally, there is interest in digital badging that can be used to electronically award badges to participants upon completing the certificate requirements. Among specific industry partners being tapped for the skills certification venture are: Fender Musical Instruments, Taylor Guitars, Martin Guitar and Heritage Guitars, and Credly, which has emerged as the leader in digital badging. Professional networking sites, such as LinkedIn and ZipRecruiter, will also be explored in relation to this venture.

Project minutes of meetings and records show the Project's existing corporate partners (All Parts, Black Diamond Strings, D'Addario, Forest Scientific Corporation, FML (Frank Miller Lumber), Indasa, ShopBot, Stewart MacDonald) continue to support the STEM Guitar Project by providing personnel expertise and in-kind support to participants. In certain cases, like for some regional participants, financial support through crowd-sourced funding is extended. Boeing Company remains a major partner, especially for the Washington State

participants. Boeing provided input regarding employability hard and soft skills that are important to consider in developing the guitar building curriculum. Continued Project efforts in exploring Project connections with employability technical and soft skills were spearheaded by this initial partnership with Boeing and the support of the NSF funded MatEdU Center in Edmonds Community College located in Washington State. Taylor Guitar Company in San Diego, California, continues to provide a key role in supporting the current grant's new acoustic guitar building track by way of technical support and potentially supplying the educational guitar kit materials for the Project's acoustic guitar build.

Building Partnerships with the Larger Community

Continuous communication and sharing of information are key in developing new and maintaining existing Project partners. Expert guitar builders and music celebrities, who have been oriented to the Project, remain the best Project supporters in the community. Data records from minutes of meetings indicated that the STEM Guitar Project maintains a strong presence during the NAMM conference where connections with music industry-related companies and music celebrities are developed and enhanced. Apart from the authentic merit of the Project shared with the community, interested music celebrities attract more attention, publicity, and media exposure to the Project.

Per interviews with Faculty Champions, their tenacious efforts to reach out to their local media and newspapers, state department of education, and government officials add to the wider exposure and community awareness about the STEM Guitar Project. Often times, these efforts add to the increasing positive image of their class in their institutions, district, and the larger community. Because of his efforts to teach the class and reach out to the local community, the school, the district, and their government officials, his STEM Guitar building class is a district-recognized elective.

These quotes from faculty indicate their established connections with the community as a result of their STEM Guitar implementation:

> *I get more questions from parents that heard about it* [STEM Guitar], *this brings them to class.*

> *I am a technology teacher and I get a lot of interest* [re; STEM Guitar] *from the music department, the art department; not to mention the science and math departments.*

> *It takes a lot of time to invite government officials but it is worth it if you get your federal house representative to your classroom.*

> *This is my 3rd year building a guitar to raffle and raise funds for the program; people are donating money; local newspapers pay attention.*

I get support from some grants in the community with the help of media coverage

The Project activity extension to veterans in the previous years and in 2020 enabled the STEM Guitar Project to establish and maintain connections with different community non-profits and interested groups and organizations in Temecula, CA, Boulder City, NV, Lake Stevens, WA, and Dayton, OH. The STEM Guitar Project also reached out to other outreach interested groups in a county around Greater Cincinnati such as the 2020 activity conducted with Women Walking West.

The STEM Guitar Project is able to continue its outreach program and other program activities without the use of the NSF grant fund because of its emerging popularity and viability. Among these activities are:

- The international STEM Guitar outreach at the University of Medellin in Colombia, through the initiatives of one of the original Project Trainers, in collaboration with and support from his University (Purdue University) – In this outreach, students build guitars and learn the engineering behind them.

- The continuing operation of the STEM guitar Manufacturing/Production Team at Sinclair College, a self-sufficient entity that remains to be the main supply chain for the Project.

Exploring Future Grant Opportunities and Other Funding Support

The Project Team continues to generate ideas for new programs and/or STEM Guitar-related program expansion (new ideas for related guitar-building/music Project-idea as an expansion of the current guitar-building based-learning exploring potential grant opportunities that may fund these endeavors). As of this date, a supplemental grant to the current grant is being reviewed for final submission to the National Science Foundation. The Project Team also continues to explore possible partnership with a group that is willing to help the team in organizing a possible foundation. This foundation is meant to help with the promotion and funding solicitation for the Project.

Conclusions

The 2019-2020 STEM Guitar program evaluation showed encouraging formative and summative results. The External Evaluator continued to help the Project Team in developing their evaluation capacity and evaluative thinking for better evaluation use and continuous program improvement. The STEM Guitar Project further improved its process and outcomes during the 2019-2020 fiscal year as its Project working structure and process remains seamless through several years of Project existence. Overall, with a stable Project Leadership and Project Team structure, the Team was open to a wide variety of things that lend to improving the Project implementation process and results.

Established and improved recruitment and selection of faculty participants helped the Project in reaching out to its targeted participants – underrepresented populations. Selecting three new institutional 2020 GBI hosts established new Project contacts. Maintaining the four other existing institutional contacts as part of the 2020 GBI hosts enhanced this network. Institutional connections through new guitar sales client contracts further widened the Project reach. Guitar kit sales in the school year 2019-2020 increased by 25% over e 2018-2019 sales, indicating continuous guitar building implementation in academic institutions.

The increasing involvement of underrepresented groups in the Project shows the Project's continued quest for community relevance. The plan to enhance employability skills (with both hard and soft skills) through the Project's Institutes/ training by creating an industry-recognized badging or skill identification system, digital badging, and standard-based certification is laudable. Making this possible with faculty and veteran participants would in turn transfer to guitar building students leading the STEM Guitar Project closer to its Project goal of increasing student interest, engagement, and learning of STEM principles, practices, and careers through guitar design and building; better outcomes for productive and skilled members of the community. Indeed, these are great efforts to mitigate the industry skills gap.

"Beyond relevance" is the Project's existence reality. Adjustments to challenging situations like the school/college closures posed a greater challenge to Project-based and hands-on teaching and learning. The Project Team's active involvement in developing more videos and online materials and continuous search for best practices to support the faculty teaching STEM guitar in academic institutions is commendable. Continuous efforts in Project dissemination through conference presentations and media exposure would be greatly helpful in sharing the Project's best practices. The reality of the Project existence is challenged by the need for future funding. Continued Project Team efforts in exploring potential for funding support is vital to the Project's existence. Continuous program improvement is the hallmark of the STEM Guitar Project.

Recommendations

The recommendations here are geared toward maintaining and enhancing the Project's best practices and areas of growth. The Project Team's continuous improvement/development efforts have been vital to the growth of the Project. Thus, some of the Project's best practices are worth maintaining and enhancing, such as:

- Project Team's involvement in developmental evaluation and capacity building to further hone its evaluative thinking skills needed in critical program implementation;
- Project's collaborative and participatory decision-making process for greater Project Team buy-in and optimal decisions;
- Enhancement of the Project's processes, structures, and documentation of the different aspects of the Project for replicability and scalability;
- Regular team meetings and offering of specialty development meetings as the Project need arises; streamlining of efforts for efficiency;
- Continued improvement of the Project website;
- Development and strengthening of the Project outputs;
- Continued exploration of practical ideas to support faculty STEM guitar implementation;
- Development of new and maintenance of existing Project partnerships;
- Efforts to disseminate Project information via conference presentations/publications, and media exposure; and
- Continued effort to solicit Project funding.

The following are areas of growth where the Project is "emerging" and are worth the Project Team's attention and action:

- Robust STEM Guitar institute/workshop agenda revisions to directly reflect fidelity of implementation, entrepreneurship, and employability skills.
- Modelling of any data collection strategy expected of faculty participants during their program implementation within the GBI's.
- Exploring more new ways and materials addressing different approaches to teaching a Project-based/hands-on Project to prepare for uncertainties such as the coronavirus pandemic.
- Coordinating the Project Team's prolific efforts in developing teaching/learning materials for optimal output.
- Launching the distribution of the administrative video and following through the effects of this mode of information and support.
- Monitoring guitar kits and supplies sales closely to have additional indicators of program implementation, as well as program reach and spread.
- Exploring more ways to ensure/motivate faculty sharing of the results and impact of their teaching STEM Guitar; develop more incentive for faculty to continue sharing student data.
- Developing consistent ways to track effects of employability learning and intended use of these skills.
- Exploring different ways to ensure Project viability and sustainability.

Appendixes

Appendix 1. Participants' Institute Experiences

Category	Themes	AGBI (n-27)	EGBI (n=50)	HGBI (n=30)
Implementation Improvements	#praise and gratefulness	26%	58%	67%
		Excellent time at the workshop. All instructors and attendees were great help.	*I REALLY loved it and learned a lot. Thanks so much for sharing this training with us.*	*Truly a great experience. I can't thank you guys enough.*
	#activity pacing & organization, agenda, survey, & scheduling	11%	14%	8%
		The process will need a good deal of streamlining in order to be implemented successfully with a more diverse group of teachers	*I'd also like to see the trainings stick to a stricter schedule. 9 or more hours of workshop, even if it is really fun stuff, can take a toll.*	*I wish they would have told us during these surveys we would have to have certain pictures I misread I took a lot of written notes*
	#diversity of trainers and participants; diversified instructions for participant level [clear instructions; use of visual aids]	0%	10%	10%
			I'd like to see you add more representation of women in this training, could be that you swap out some of your videos of male speakers with female speakers	*An updated, step by step paper copy with photos of the build process would have been extremely helpful. If they could provide that at the beginning of the institute it would have helped me when I was struggling and the teachers were busy helping others.*
Materials, tools, jigs, & fixtures	#adequacy & sufficiency of materials, tools, jigs & fixtures	11%	20%	23%
		It's important that each participant has access to appropriate jigs and fixtures during the building process.	*I would recommend having more of the common tools on hand.*	*Increase wire allotment for guitar kits. Supply a heavier gauge wire for the electronics. Insufficient and thin gauge wire made soldering task difficult.*
	#quality of materials [e.g. videos] & supplies	7%	6%	17%
		The tuners supplies with the kits were the weak link of the entire build.	*The one thing I would improve is some of the videos that we watched. Just a little editing and graphics added plus better close ups of the process being described would make them smoother.*	*Videos - they have great content but the organization and labeling are seriously lacking - there needs to be folders maybe and "WATCH THIS FIRST" on the title of the video*

Category	Themes	AGBI (n-27)	EGBI (n=50)	HGBI (n=30)
Application of learning [comments]	#application in classroom	11%	18%	20%
		I really hope I can pull this into my classroom in the next few years.	*Thank you for providing a very useful training that many kids will benefit from.*	*I really needed something "new" and exciting to do with my students to get me excited about school this year.*
Improvement of Content	#expansion of content [e.g. guitar binding, more CNC activity, live Fusion instruction] & activity [e.g. play the guitar at end of Institute]	7%	2%	27%
		I really would have loved to have had a session on binding guitars.	*Maybe we could work on playing the guitar a little.*	*I'd like to see more teaching and conversation about using Fusion and CNC tools.*
Needed Preparation before Implementation	#handouts, materials before Institutes [complete hand-outs; prep-more instructional videos, prep-materials, communications, & participants]	7%	4%	7%
		Maybe a handout about oils, stains, and options would give attendees something to look over for help so their projects are finished with the same care and attention to detail as the entire build.	*Let people know they need more than one photo of a process. A Checklist would be helpful, like for intonation, check hertz…*	*The pre work was good, but I trouble finding one list of everything I needed to do. Everything came in multiple emails, so having one central location would be a good idea.*
	#necessary pre-work [e.g. neck fitting, prep for personalized materials/designs, list of tools, jigs]	15%	6%	0%
		A list of optional tools that participants could bring, especially those that drive to the workshop.	*Pictures of all the tools used with their names would be an awesome reference.*	*Please send out full schedule with times prior to the institute.*
Site-related	#choice locations; improve site amenities [e.g. AC, spray booth, bigger space, stools, white board]	0%	6%	7%
			Air-conditioned shop •Stools for all students in the shop • A whiteboard and/or projector in the shop	*Have a spray booth for applying clear coat and separate room for drying oil or spray away from sawdust.*

Appendix 2. Skills Gained with Guitar Building

STEM Guitar Project Track	STEAM Classification	Categories [Guitar Building Phase and Basic Core Competencies]	Specific Technical Skills
ALL	Art	All/basic competencies	Music ability
ALL	Engineering	All/basic competencies	Identifying a problem
ALL	Engineering	All/basic competencies	Problem solving
ALL	Engineering	All/basic competencies	Use proper measure tools with accuracy in positioning fret board and affecting guitar setup
ALL	Math	All/basic competencies	Brainstorming to fix a mistake or problem
ALL	Science	All/basic competencies	Asking questions
ALL	Science	All/basic competencies	Problem solving, working through a problem to a solution
ALL	Science	All/basic competencies	Providing and receiving peer review and feedback
ALL	Science	All/basic competencies	Science as an iterative process, not linear
ALL	Science	All/basic competencies	Teamwork of sharing tools and experiences
ALL	Engineering	Curriculum	How to write an MLA
ALL	Art	Design/cnc machining/manufacturing	Design head stock shape
ALL	Art	Design/cnc machining/manufacturing	head stock design - sketching and transfer to wood
ALL	Engineering	Design/cnc machining/manufacturing	Develop and use model skill
ALL	Science	Design/cnc machining/manufacturing	Developing / using models
ALL	Technology	Design/cnc machining/manufacturing	Ability to use tools and machines correctly and safely
ALL	Technology	Design/cnc machining/manufacturing	Process planning
ALL	Technology	Design/cnc machining/manufacturing	Set up / operation of vector / raster lasering, operation of the laser
ALL	Technology	Design/cnc machining/manufacturing	Troubleshooting, problem solving, critical thinking
ALL	Technology	Design/cnc machining/manufacturing	Use of laser and CAD woodworking machine
ALL	Technology	Design/cnc machining/manufacturing	Using design software skills

ALL	Technology	Design/cnc machining/manufacturing	Using H2O and heat to remove wood dents (CNC)
HGB	Art	Design/cnc machining/manufacturing	Art designs and logos
HGB	Art	Design/cnc machining/manufacturing	Gluing up body blanks for CNC
HGB	Math	Design/cnc machining/manufacturing	Ability to calculate chip load in order to efficiently program the CNC router's feed rate
HGB	Technology	Design/cnc machining/manufacturing	Advanced CAD techniques for 3-D cuts
HGB	Technology	Design/cnc machining/manufacturing	Applying tolerances when machining parts
HGB	Technology	Design/cnc machining/manufacturing	Create tool paths from 3D CAD model to machine body
HGB	Technology	Design/cnc machining/manufacturing	Development of tool path and routing
HGB	Technology	Design/cnc machining/manufacturing	Generating and validating tool path (CNC)
HGB	Technology	Design/cnc machining/manufacturing	Operating a CNC
HGB	Technology	Design/cnc machining/manufacturing	Troubleshooting - why tooling fails
HGB	Technology	Design/cnc machining/manufacturing	Turning a CAD drawing into a CNC program
ALL	Math	Fret design/manufacturing & computing	Algebra fret calculation
ALL	Math	Fret design/manufacturing & computing	calculate fret positions given a scale length for a 12 semi-tone stringed instrument
ALL	Math	Fret design/manufacturing & computing	Calculating gear ratios
ALL	Math	Fret design/manufacturing & computing	Measurement
ALL	Math	Fret design/manufacturing & computing	Precision and accuracy in measurement

ALL	Math	Fret design/manufacturing & computing	Radiusing
ALL	Science	Fret design/manufacturing & computing	Precision and accuracy in measurements
ALL	Art	Guitar context & construction	How to book match, use wood efficiently (optimization)
ALL	Math	Guitar context & construction	Calculating the material cost for guitar CNC body blanks
ALL	Math	Guitar context & construction	Using metric or imperial measure conversion in proper drill bit selection
ALL	Science	Guitar context & construction	Cleanup of materials
ALL	Science	Guitar context & construction	Tap testing of hard, soft woods
ALL	Science	Guitar context & construction	Tonal qualities of woods and selections
ALL	Technology	Guitar context & construction	Selection and use of hand tools
ALL	Technology	Guitar context & construction	Skill in technical sketching and geometrical shape description
ALL	Technology	Guitar context & construction	Use of band saw and ROSS? to execute a head stock design
ALL	Technology	Guitar context & construction	Use of power tools and specialty tools & jigs to shape and finish guitar
ALL	Technology	Guitar context & construction	Use of spreadsheet software
ALL	Technology	Guitar context & construction	Using calipers to measure screws and drills
ALL	Technology	Guitar context & construction	Using the fastener MLA to decide what size drill for what size screw hole
ALL	Technology	Guitar context & construction	Wood bonding
EGB, HGB	Art	Guitar context & construction	Body contouring
EGB, HGB	Technology	Guitar context & construction	Guitar, shape, modifications
HGB	Technology	Guitar context & construction	Gluing, process, body blanks [via video]

ALL	Art	Guitar finish/conditioning & finishing	Choosing color scheme, coating processes for beautification
ALL	Art	Guitar finish/conditioning & finishing	Finishing; prep, apply levels & buff & polish finish
ALL	Art	Guitar finish/conditioning & finishing	Guitar finish; finish materials, gloss, matte, & road worn
ALL	Art	Guitar finish/conditioning & finishing	Water slide and logo - artwork to apply on guitar
ALL	Technology	Guitar finish/conditioning & finishing	Apply spray paint without causing runs
ALL	Technology	Guitar finish/conditioning & finishing	Buffing and finishing for gloss, coating for protection and beautification
ALL	Math	Guitar set-up/quality control	Application of golden mean in designing shape of head stock and body
ALL	Math	Guitar set-up/quality control	Symmetry / balance
ALL	Technology	Guitar set-up/quality control	Fret level, crown, polish
AGB	Technology	Intonation/Physics of sound	Neck pocket routing, contour, fitting, and bridge attachment
AGB	Technology	Intonation/Physics of sound	Sound box construction, bracing, rim preparation, gluing and flushing edges,
ALL	Technology	Intonation/Physics of sound	Intonation – measuring oscilloscope and / or use app
ALL	Technology	Intonation/Physics of sound	Measurement, accuracy, inspections, and tolerances
ALL	Technology	Intonation/Physics of sound	Tuner dress rehearsal (fit check, engineering, manufacturing)
EGB, HGB	Technology	Intonation/Physics of sound	Pickup height set up after install to set proper sound
EGB, HGB	Technology	Intonation/Physics of sound	Pickup, ohms, measurement, quality control, engineering, & meter use
ALL	Engineering	Soldering/electricity & electronics	Physical and electrical precision measurement
EGB, HGB	Engineering	Soldering/electricity & electronics	Humbucker, single coil,
EGB, HGB	Engineering	Soldering/electricity & electronics	Selection of pickups and alternate wire options
EGB, HGB	Engineering	Soldering/electricity & electronics	Translating a schematic diagram into a pictorial wiring diagram, soldering

EGB, HGB	Technology	Soldering/electricity & electronics	Testing electrical components before installing, soldering, electricity, shielding, grounding
EGB, HGB	Technology	Soldering/electricity & electronics	Translating the schematic or wiring diagram into a functional physical circuit - wiring, mounting, soldering
EGB, HGB	Technology	Soldering/electricity & electronics	Use of multi-meter

Appendix 3. Embedded Soft Skills (Attitudes) Learned Within STEM Guitar

Communication and Collaboration (C & C)

- Work in teams
- Help others with a problem
- Working collaboratively in a group

Creativity and Innovation (C & I)

- Emotional connection to wood patterns and colors
- CNC - positive feelings of seeing something made from design
- Craftsmanship
- Openness to learning/intellectual curiosity/appreciation for the sense of discovery

Critical Thinking & Problem Solving (Ct & Ps)

- EGB / AGB - guitar setup, engineering; neck, bridge, neck relief, bridge choice, installations, & critical thinking skills
- Brainstorming a fix to a mistake or problem (teamwork, confidence, perseverance) **– also, in G, I, & Sd**
- Develop scientific, logical world view
- Brainstorming to fix a mistake
- Methodical
- Openness to learning/intellectual curiosity/appreciation for the sense of discovery **- also, in S & Cc**
- Problem solving

Flexibility and Adaptability (F & A)

- First algebra success or relevance for many students (fret equation)
- Pretty cool how we were able to figure out fret spacing with math. Didn't know you could do that.
- Digital-age/information literacy
- Multi-tasking

Productivity & Accountability (P & A)

- Quality mindset
- Finishing a Project to completion
- Attendance frequently increases
- EGB- 100% of students who start build, finish build
- Responsibility/sense of Accountability

Grit, Initiative, and Self direction (G, I, & Sd)

- Grit
- Persistence
- Perseverance
- Confidence; self-confidence
- Initiative/self-directive/asking for help when needed
- Attentiveness
- Assuming attention to detail
- EGB- 100% of students who start build, finish build

Leadership & Responsibility (L & R)

- Pride
- Respect for tools, careful use, storage, organization
- Ethical reasoning

Social Cross-cultural Skills (S & Cc)

- Openness to learning/intellectual curiosity/appreciation for the sense of discovery
- Inter-cultural skills

Appendix 4. Effects on Faculty

Themes	GBI Quantitative Survey (N=109)	GBI Qualitative Survey (N=105)	Institute Observation (N=1)	Summit interviews faculty [N=4], small group focused interview [N=1])	Summit participant observation (N=1)	Adm interview (N=1)	May 2020 SG Faculty COVID-Related Materials Use Survey (N=144)
new SG guitar hard skills learned	hard skills related to guitar set-up, solder/neck shaping, and intonation - ranked 1st and 2nd	27% [representative quotes on p. 25]	Instructor demonstration for each phase of the build; faculty on-task without help or sometimes just some minimal help.	NA	NA	NA	NA
honed SG building skills		10% [representative quotes on p. 25]		NA	NA	NA	NA
learning guitar building process specifics		35% [representative quotes on p. 25]		NA	NA	NA	NA
learning about and use of tools		20% [representative quotes on p. 26]		NA	NA	NA	NA
learning about application to STEM and/or classroom use		5% [representative quotes on p. 26]		NA	NA	*Teaching guitar building is definitely STEM teaching.*	NA

Themes	GBI Quantitative Survey (N=109)	GBI Qualitative Survey (N=105)	Institute Observation (N=1)	Summit interviews faculty [N=4], small group focused interview [N=1])	Summit participant observation (N=1)	Adm interview (N=1)	May 2020 SG Faculty COVID-Related Materials Use Survey (N=144)
attitudes toward STEM/guitar building		28% [representative quotes on p. 26]	All participants observed seemed to be enjoying themselves doing the build.	100% in sync with theme *Enjoyed the complexities of the build; more and more improving my confidence in teaching guitar building.*	Observed excitement and enthusiasm among faculty talking about their guitar building experiences.	*Guitar building in this school is successfully sustained by our faculty.*	NA
change in practice/implementation	NA	NA	NA	100% in sync with theme *I have been doing continuous improvement in ways of introducing the build.*	NA	*I expect no less in a project-based curriculum like guitar building; it's like one of our robotics star program.*	>30% in sync with theme Faculty are teaching online guitar building even during school/college closures.
improved curricula	NA	NA	NA	100% in sync with theme *Now, I always try to relate the guitar building techniques to real-world examples students may encounter on a day-to-day basis.*	Presentations indicated innovations, improvements, and adjustments in faculty curricula.	*I think adding guitar building in our curricular options enriched our school curricula.*	>60% in sync with theme Faculty are using instructional videos and modules for their online teaching

Appendix 5. Effects on Students

Themes	Student Case Study Survey	Student Interviews (N=3)	Case study faculty interview (N=1)	GBI Faculty Interviews (N=7)	Summit interviews faculty (N=4), small group focused interview (N=1)	Case study classroom observation (N=1)	Other Sources- Faculty email (N=3)
Learned hard skills & STEM learning & application	Liked to come prepared for math/science class - top rank	100% in sync with theme [representative quote on p. 38]	*My students can follow demonstrations and instructions easily.*	100% in sync with theme [representative quote on p. 36]	100% in sync with theme [representative quote on p. 37	Observed students were able to use tools and did their work on their guitars.	100% in sync with theme *My students are using the CNC, are designing, and cutting their own guitars.*
Academic performance, scholarship, college and career path	Responsible for own learning - ranked 1st; improve in math & science - ranked 2nd; working within STEM and jobs in STEM	100% in sync with theme *I am motivated to study in my other classes too because I am told I have to do good in my other class to get my guitar.*	*Majority of my students do very well, especially in their math classes.*	71% in sync with theme *One of my students was given scholarship because of his knowledge with guitar building.*	75% in sync with theme *Teachers in other classes are saying guitar students are doing well in their classes.*	Heard from talking especially with the identified "low-performing" student about his plan to study college.	100% in sync with theme *I've had dozens of students go on to various universities to pursue studies in engineering and other STEM related fields.*

Themes	Student Case Study Survey	Student Interviews (N=3)	Case study faculty interview (N=1)	GBI Faculty Interviews (N=7)	Summit interviews faculty (N=4), small group focused interview =1)	Case study classroom observation (N=1)	Other Sources- Faculty email (N=3)
motivation, school attendance	Liked to come prepare in math/science class - ranked 1st	100% in sync with theme *I like going to school building guitars.*	*I never have problems with student attendance, especially during guitar building days.*	100% in sync with theme [representative quotes on p.38]	100% in sync with theme [representative quotes on p.38]	Observed how excited the students in class during the guitar build	100% in sync with theme *I had a student – very boisterous – announce the only reason he was coming to school this year was because he thought building a guitar was interesting.*
Critical thinking & problem solving, & applications in real-world situations	Believed connections of STEM & real-world - ranked 3rd	100% in sync with theme *I think learning guitar is good. I think I can do better with my coop later because of this.*	*My top performing student is a good problem solver; I rely on her so much about our room organization & supplies management; she will help me with the veterans build.*	43% in sync with theme [representative quotes on p. 38]	*My students definitely learn critical thinking and problem-solving skills -all the 21st century learning – as they build guitars in my class*	NA	*I had a student who went on a complete woodworking program and now works making cabinets.*

Themes	Student Case Study Survey	Student Interviews (N=3)	Case study faculty interview (N=1)	GBI Faculty Interviews (N=7)	Summit interviews faculty (N=4), small group focused interview (N=1)	Case study classroom observation (N=1)	Other Sources- Faculty email (N=3)
Development of self-confidence, patience and grit	Not discouraged while working on STEM projects - ranked 3rd	100% in sync with theme [representative quotes on pp. 35,38]	*I can see my students being confident with what they are doing on their guitars but some of them are quite impatient, especially as they needed to wait for their turn in using some of the tools.*	57% in sync with theme [representative quote on p.38]	100% in sync with theme [representative quote on p.38]	NA	*My students are very confident with the employability skills they learned in class; they know these will help when they apply for work at different companies in the community.*
Leadership, organization, productivity, and management	Seeking opportunities in STEM - ranked 3rd	100% in sync with theme [representative quote on p.35]	*I can always count on my student leaders in helping organize our class materials and supplies.*	14% in sync with theme *I see my students taking initiatives and managing their time.*	NA	Initiative, organization, and leadership of students observed during class.	*I can see my students listening and helping each other, ensuring quality of work, and developing overall work ethic.*

Appendix 6. Facebook Definition of Data Variables

"Reach"

- Total Reach 28 Days: The number of people who had any content from your Page or about your Page enter their screen. This includes posts, check-ins, ads, social information from people who interact with your Page and more. (Unique Users).

- Total Organic Reach 28 Days: The number of people who had any content from your Page or about your Page enter their screen through unpaid distribution. This includes posts, check-ins, social information from people who interact with your Page and more. (Unique Users).

- Total Viral Reach 28 Days: The number of people who had any content from your Page or about your Page enter their screen through with social information attached. As a form of organic distribution, social information displays when a person's friend interacted with you Page or post. This includes when someone's friend likes or follows your Page, engages with a post, shares a photo of your Page and checks into your Page. (Unique Users).

- Total Reach of Page Posts - 28 Days: The number of people who had any of your Page's posts enter their screen. Posts include statuses, photos, links, videos and more. (Unique Users).

- Total Organic Reach of Page Posts - 28 Days: The number of people who had any of your Page's posts enter their screen through unpaid distribution. (Unique Users).

- Total Viral Reach of Page Posts - 28 Days: The number of people who had any of your Page's posts enter their screen with social information attached. As a form of organic distribution, social information displays when a person's friend interacted with you Page or post. This includes when someone's friend likes or follows your Page, engages with a post, shares a photo of your Page and checks into your Page. (Unique Users)

"Impression"

- Total impressions - 28 Days: The number of times any content from your Page or about your Page entered a person's screen. This includes posts, check-ins, ads, social information from people who interact with your Page and more. (Total Count).

- Total organic impression - 28 Days: The number of times any content from your Page or about your Page entered a person's screen through unpaid distribution. This includes posts, check-ins, social information from people who interact with your Page and more. (Total Count).

- Total Viral Impressions- 28 Days: The number of times any content from your Page or about your Page entered a person's screen with social information attached. Social information displays when a person's friend interacted with you Page or post. This includes when someone's friend likes or follows your Page, engages with a post, shares a photo of your Page and checks into your Page. (Total Count).

- Total Impressions of the Page Post - 28 Days: The number of times your Page's posts entered a person's screen. Posts include statuses, photos, links, videos and more. (Total Count).

- Total organic impressions of your Page post - 28 Days: The number of times your Page's posts entered a person's screen through unpaid distribution. (Total Count).

- Total Viral Impressions of your page posts - 28 Days: The number of times your Page's posts entered a person's screen with social information attached. Social information displays when a person's friend interacted with you Page or post. This includes when someone's friend likes or follows your Page, engages with a post, shares a photo of your Page and checks into your Page. (Total Count).

- Total Engagement 28 Days: 28 Days: The number of people who engaged with your Page. Engagement includes any click or story created. (Unique Users).

- Total Consumers 28 Days: The number of people who clicked on any of your content. Stories that are created without clicking on Page content (ex, liking the Page from timeline) are not included. (Unique Users).

- 28 Days Page Consumptions: 28 Days: The number of clicks on any of your content. Stories generated without clicks on page content (e.g., liking the page in Timeline) are not included. (Total Count).

References

Archibald, T., Sharrock, G., Buckley, J., & Young, S. (2018). Every practitioner a "knowledge worker": Promoting evaluative thinking to enhance learning and adaptive management in international development. In A.T. Vo & T. Archibald (Eds.) *Evaluative Thinking. New Directions for Evaluation*, 158, 73-92.

Average email response rate at 29% [average response rate 2019 benchmark] https://surveyanyplace.com/average-survey-response-rate/ retrieved May 14, 2020.

Bernard, H. R. (2006). *Research methods in anthropology: Qualitative and quantitative approaches*, 4th ed., Lanham, MD: Altamira Press.

Carden, F & Earl, S. (2007). Infusing evaluative thinking as a process use: The case of the International Development Research Centre (IDRC). In J.B. Cousins (Ed.) *Process use in theory, research, and practice. New Directions for Evaluation*, 116, 61-74.

Castañeda-Emenaker. (2019 April). The STEM Guitar Project: 2018-2019 Evaluation Report. Hamilton, OH: REaCHaLL, LLC.

Clarke, V., & Braun, V. (2017). Thematic analysis. *The Journal of Positive Psychology, 12*(3), 297-298. http://dx.doi.org/10.1080/17439760.2016.1262613.

Creswell, J.W. & Plano Clark, V.L. (2011). *Designing and conducting mixed methods research* (2nd ed.). Thousand Oaks, CA: Sage.

Deterding, N. M. and Solmeyer, A. R, (2018). Building evidence in challenging contexts: Introduction to the special section. *American Journal of Evaluation. 39 (1), 24-41.*

Dusenbury L, Brannigan R, Falco M, Hansen W. (2003). A review of research on fidelity of implementation: Implications for drug abuse prevention in school settings. Health Educ Res. 2003; 18:237–256. doi: 10.1093/her/18.2.237.

Grob, G. F. (2018). Evaluation practice: Proof, truth, client relationships, and professional growth. *American Journal of Evaluation. 39 (1), 123-132.*

Guest, G., MacQueen, K.M., Namey, E. E. (2012). *Applied thematic analysis.* Thousand Oaks, CA: Sage.

Guskey, T. R. (2002). Does it make a difference? Evaluating professional development. *Educational Leadership*. 59 (6), pp. 45–51.

Guskey, T. R. (2000). *Evaluating professional development.* Thousand Oaks, CA: Corwin Press.

King, J. A. (2007). Developing evaluation capacity through process use. In J.B. Cousins (Ed.) *Process use in theory, research, and practice. New Directions for Evaluation*.

Lamorte, W.W. (2017). Prospective and retrospective cohort studies. Boston: Boston University School of Public Health. Retrieved from http://sphweb.bumc.bu.edu/otlt/MPH-Modules/EP/EP713_AnalyticOverview/EP713_AnalyticOverview3.html April 20, 2018.

Ledford, J. R., (2018). No randomization? No problem: Experimental control and random assignment in single case research. *American Journal of Evaluation. 39 (1), 71-90.*

MatEdU, Edmonds Community College (2016). *Core competencies pocket reference*. Washington D.C.: National Science Foundation.

Mihalic S. (2004). The importance of implementation fidelity. *Emotional & Behavioral Disorders in Youth*. 4:83–86. and 99–105.

National Research Council. 2015. *Identifying and Supporting Productive STEM Programs in Out-of-School Settings*. Washington, DC: The National Academies Press. https://doi.org/10.17226/21740.

National Research Council. 2010. *Surrounded by Science: Learning Science in Informal Environments*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12614.

P21 Partnership from 21st Century Learning. Framework for 21st Century Learning. (2015 May). Washington DC. Retrieved from: http://www.p21.org/about-us/p21-framework. February 28, 2018.

Patton, M. Q. (2015) Qualitative research & evaluation methods. (4th ed.). Thousand Oaks, CA: Sage.

Patton, M. Q. (2011). *Developmental evaluation*. NY: Guilford Press.

Patton (2008). Utilization-focused evaluation (4th ed.). Thousand Oaks, CA: Sage.

Preskill, H. & Russ-Eft, D. (2016). *Building evaluation capacity*. Thousand Oaks, CA: Sage.

Queen, K.H. (2018). Narrowing the Skills Gap. Smart Manufacturing Magazine. Retrieve from http://www.sme.org. April 10, 2018.

Schwandt, T. A. (2018). Evaluative thinking as a collaborative social practice: The case of boundary judgment making. In A.T. Vo & T. Archibald (Eds.) *Evaluative Thinking. New Directions for Evaluation*, 158, 125-138.

Shadish, W. R., Cook, T. D., and Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference*. New York: Houghton Mifflin Co.

Stabback, P. (2016). What makes a quality curriculum? In Progress Reflection No. 2. Current and Critical Issues in Curriculum and Learning. Geneva, Switzerland: IBE/2016/WP/CD/02. Retrieved from: http://unesdoc.unesco.org/images/0024/002439/243975e.pdf. April 10, 2018.

Sunny, C. E. (2018). *Stakeholders' conceptualization of students' attitudes and persistence towards STEM: A mixed methods instrument development and validation study.* (Electronic Thesis or Dissertation). Retrieved from https://etd.ohiolink.edu/.

York, A. (2018). Analytics engagement, *Sprout Social (Blog*) in https://sproutsocial.com/insights/reach-vs-impressions/, retrieved 4/19/2019.