ESC Evaluation Services Center

LEAD GUITARS in STEM
Final Evaluation Report
2014 – 2017

Prepared for

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Evaluation Services Center

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Background

This is the final evaluation report for the Sinclair Community College National Science Foundation funded (NSF ATE DUE # 1304405) Learning, Engaging, Attaining, and Doing with Guitars Used In Teaching Achievable Real Situations in Science, Technology, Engineering, and Mathematics (LEAD with GUITARS in STEM) project. The University of Cincinnati Evaluation Services Center (UCESC) was contracted by Sinclair Community College in September 2013 to conduct an external evaluation of the LEAD with GUITARS in STEM project. In 2013 Sinclair Community College, as the lead organization, partnered with five other educational institutions (Butler County Community College in Pennsylvania, College of the Redwoods in California, Edmonds Community College in Washington, Ventura College in California, and Purdue University in Indiana) to implement this project, which used electric guitars, electronic amplification, and music to train faculty members to teach STEM content to middle school, high school, and college students. The project team collaborated with other Advanced Technological Education (ATE) centers (such as the National Resource Center for Materials Technology Education (NRCMTE) in Washington and the National Center of Excellence for Advanced Manufacturing at Sinclair in Ohio as well as with supply chain networks in an overall partnership of education, business, and industry.

During 2014, 2015, and 2016, this project hosted an annual five-day STEM Guitar Building Institute (GBI) to provide professional development for middle school, high school, and post-secondary faculty. Participants were trained in science, technology, engineering, and mathematics topics (STEM) through modules that used hands-on, applied learning techniques in building the components of a solid electric body guitar to engage students in learning the STEM topics. The main goal of the five-day STEM Guitar Building Institute was to train faculty participants through applied methods of guitar building to engage students in STEM learning aligned with the following **project objectives**:

- Use of electric guitars, electronic amplification, and music to teach STEM content to a wide range of students;
- Five-day intensive hands-on workshops focused on grade-level appropriate curriculum modules to apply STEM concepts;
- Collaboration with supply chain networks in an overall partnership of education, business, and industry;
- Professional development that provided training for at least 86 middle school, high school, and college faculty participants;

- Implementation of course curricula in classrooms nationwide, with the potential to reach over 175,000 students; and
- Training a select group of faculty participants, "STEM Guitar Project Champions," to participate as future trainers and providing insights for project leadership.

This project close-out report brings out the formative and summative aspects of the project implementation organized according to Guskey's (2002) model for evaluating professional development emphasizing the formative and summative project implementation components. Guskey's model defines five critical levels of professional development evaluation:

Level 1: Participants' reactions;

Level 2: Participants' learning;

Level 3: Organizational support and change;

Level 4: Use of new knowledge and skills; and

Level 5: Student learning outcomes.

The evaluation team collaborated with project team members in evaluation planning and data collection. Some members of the project team were assigned to be part of an Evaluation and Measurement Committee that worked closely with the external evaluation team during the project period. The **formative evaluation components** (summarized in the Project Description) focused on 1) implementation of the Guitar Building Institute, including team processes and supports provided to faculty participants during and after the institutes; 2) the project's supply chain network partnership among education, business, and industry; and 3) project reach. Data collected for project improvement project have been reported annually (see Castañeda-Emenaker & Morrison, 2014; Castañeda-Emenaker, Morrison, & Dariotis, 2015; Castañeda-Emenaker, Morrison, & Dariotis, 2016).

Summative evaluation components, presented in the Results section, included faculty perspectives on 1) the utility of the Guitar Building Institute (GBI) and the Modular Learning Activities (MLAs); 2) what the faculty participants learned and how they intended to use what they learned; 3) classroom implementations; 4) emergence of teacher champions; 5) effects of faculty participant classroom implementation on students; and 6) project sustainability. This report concludes with insights from lessons learned through challenges and barriers encountered during the project.

Project Description

Program Components and Implementation

Project documents and meeting minutes indicate that each NSF-sponsored summer Guitar Building Institute (GBI) implemented across the United States started with an application process eight months prior to the scheduled start date. High school and college faculty participants[1] were recruited through professional conferences, direct email via listservs, and personal, professional, and institutional connections. In each project year, faculty participants completed an online application that included documentation from their school administrators affirming support for the implementation of a guitar build course following the Summer Institute training. Applicants were informed of their acceptance to the Institute three months prior to the scheduled start. The main criteria for acceptance included intention to implement the program, employment at a high-needs school, written administrative support for implementation, and demographic diversity. For all project years except the first year, before attending the GBI, accepted participants were also required to attend a preparatory webinar highlighting participant expectations, an introduction to guitar parts, and a cost analysis. After the first project year, the webinar was a required component for all faculty participants, whether synchronously or asynchronously, to prepare for the five-day GBI.

Prior to the first GBI, the project team worked with business and industry partners to develop 12 Modular Learning Activities (MLAs) that guided the guitar building process and were aligned with Common Core Standards and Next Generation Science Standards at various school levels. The MLAs expanded and enhanced the curriculum materials developed during the previous STEM Guitar grant, which was based upon the 2012 course text *Technology of the Guitar* by Mark French of Purdue University. An agenda for each five-day GBI was prepared prior to preparatory webinars.

Implementation of the summer GBI followed the same five-day format each year. In general, mornings focused on curriculum discussion followed by guitar building activities in the afternoons. Administrative tasks, including participant selection of unfinished guitar bodies and necks, were addressed during the morning of the first day. During the academic/ curricular portion of the program, faculty participants were introduced to the 12 MLAs corresponding to specific guitar build properties and core STEM activities included in the project (see Figure 1).

[1] Herein “faculty participants” refers to high school and college faculty who received training and taught this content to their students.

Figure 1. Guitar Parts and Build with Corresponding MLAs

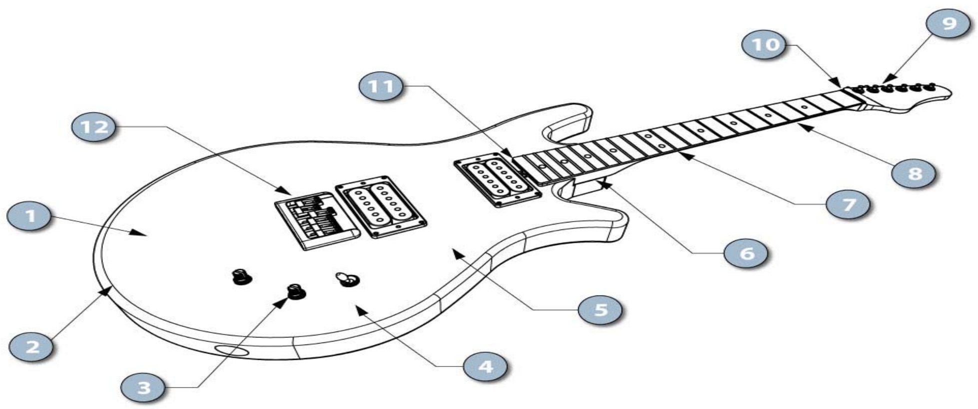


Figure legend: (1) Guitar Geometry, (2) Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM), (3) Electronics, (4) Wood for Guitars, (5) Guitar Anatomy and Cost Estimates, (6) Tolerances in Engineering, (7) Scale Length, Frequency, and Tension, (8) Fret Spacing Calculation, (9) Threaded Fasteners, (10) Set-up, (11) Guitar Neck, (12) Intonation

Each inquiry-based MLA included pre- and post-content assessments designed to be completed by students before and after the corresponding guitar-building module. Faculty participants were introduced to a web-based software package (Quia) as a model to facilitate content assessments. The 12 MLA content assessments were loaded in Quia ahead of time. The project provided each faculty participant with a subscription to Quia for the duration of the project. To support implementation, the faculty could use Quia for STEM Guitar-related assessments as well as additional assessments for other content areas not related to the MLAs during the project period. Faculty participants were encouraged to administer content assessments before and after implementing each MLA. The faculty participants were also encouraged to develop their own MLAs with corresponding assessments. The project team provided participating faculty with an MLA template to use as a guide.

GBI afternoon activities centered on building an electric guitar. Faculty participants saw demonstrations of computer-controlled mass production of guitars through pictures and videos, use of laser engravers, and prototype machines. Hands-on activities during the Institute included guitar headstock design, body sculpting, coating, and finishing, finishing the neck and fretting, installing truss rods and hardware (soldering wiring harness and installing electronics), neck and string installation (including adjustment of bridges, truss rods, and string positions), intonation and tuning, and set-up and problem-solving. Apart from learning different parts of an electric guitar and their assembly, faculty participants also learned critical aspects of dimensions and tolerances in guitar building. The project team created a grading rubric intending to check the quality of the finished guitar at the end of the Institute, but this was not systematically implemented for all guitar products and data are not available.

At the end of the GBI, each faculty participant had his/her own custom-built playable electric guitar upon completion of the 12 MLAs that could then be integrated into their own classrooms. On the last day of the GBI each year, faculty participants were asked to complete a retrospective survey to document their experiences during the Institute, their perceived learning of the content and guitar building process, and their intended applications of this learning once they returned to their classrooms. Faculty participants were strongly encouraged to conduct a full implementation of the GBI training by teaching their students how to build electric solid body guitars and teach STEM core activities related to the different guitar parts, including administering MLAs and related content assessments. The project team designed a process of assigning project IDs to faculty participants and students so student and faculty data could be linked. This was important for tracking student performance related to faculty participants' implementation.

Program Improvements

Project documentation played a key role in this evaluation to explain project processes and contexts. Qualitative data were gathered from the following project documents: project process documentation and communication involving key project personnel from the partner organizations; minutes of meetings; documentation regarding website and project resource development (such as the modular learning activities (MLAs) and other resources used in the curriculum development); documentation of project dissemination from faculty participants, supply chain and business/industry; and project promotional efforts and media exposure.

Based on evaluation feedback, implementation processes were clarified, including the informed consent process and the Quia software administration of pre- and post-content assessments. A videotape of the consenting process was produced in 2016 to ensure that communication about IRB requirements remained consistent across the 18 GBIs conducted during the latter part of the project period. During the project, a Quia information access video was enhanced to offer participants further clarity about providing "just-in-time" feedback through Quia, and to offer an opportunity for faculty participants to use the Quia results as guide for differentiated, individualized instruction for students. The webinar agenda was revised to include pre-Institute activities and homework for faculty participants to prepare for the GBI, which allowed more time for the curriculum and the actual build activities. In response to faculty participants' suggestions for improvements, the guitar build process was streamlined and the sequencing of the academic and guitar build components of the GBI were revised each project year. The adjustment of the process made more sense to the faculty project implementation in classrooms. The project PI saw the increase in guitar kit orders over time as evidence of guitar builds occurring in classrooms, since all guitar kit sales were made to faculty and educational institutions. Faculty participants' use of the MLAs increased over the project years as well as student completion of Quia content assessments, as shown in the Quia results through the years.

Team Process

Across the project period, the project PI worked with 15 key project personnel from six partner organizations to implement the LEAD with GUITARS in STEM project. Continuous planning and development were integral parts of this project. The project team developed a collaborative group process of meeting regularly (twice a month) via telephone to discuss the project, confer about project issues, and make decisions. Representatives of member institutions were assigned to participate in various project task forces that were established to focus on 1) budget and finance, 2) performance measurement, 3) reporting and publishing, and 4) partnership management. Membership on the task forces remained consistent across the project period. At least once per year the entire team met in person for a major debriefing and to plan for the upcoming year. Project implementation was a collaborative process that included continuous planning, recruitment of faculty participants, implementation of Guitar Building Institutes, website and resource development, supply chain and business/industry development, promotion and media development, and support for faculty participants implementing the guitar build and MLAs.

As part of the project team, the Executive Director of the National Resource Center for Materials Technology Education (NRCMTE) provided resource support for data gathering from the Center. An interviewer was designated to help follow up with a limited sample of faculty participants from previous years in both 2015 and 2016. The sample was a convenient sample based on contact information shared with NRCMTE and availability and faculty participant response when the NRCMTE interviewer called. In 2015, the NRCMTE interviewer asked 142 previous GBI participants one of two questions along with demographic information: (1) whether the faculty participant taught a guitar building class (full implementation – guitar building and inclusion of STEM curriculum – or a focus on guitar building in class or after school); or (2) if they did not implement a guitar building class, what barriers they had encountered that prevented implementation. In 2016, the NRCMTE personnel added three questions: (1) whether the GBI prepared them to teach a guitar building class; (2) what student impact they noticed; and (3) what support they needed to start/continue the guitar building class class.

Project Reach

The LEAD with GUITARS in STEM project reach is described below in terms of the numbers of GBI training sites across the United States; faculty who implemented the program, in full or in part, and their participating schools; guitar kits ordered; students who completed the content assessments; and students touched through project exhibits (e.g., the April 15, 2016 Convention Center exhibit in Washington, DC). When available, demographic characteristics were reported to the project team to assess the extent to which the project reached underserved populations.

The LEAD with GUITARS in STEM Project conducted 18 GBIs and trained a total of 238 faculty. In 2014, 65 faculty were accepted out of 128 applicants; in 2015, 69 were accepted out of

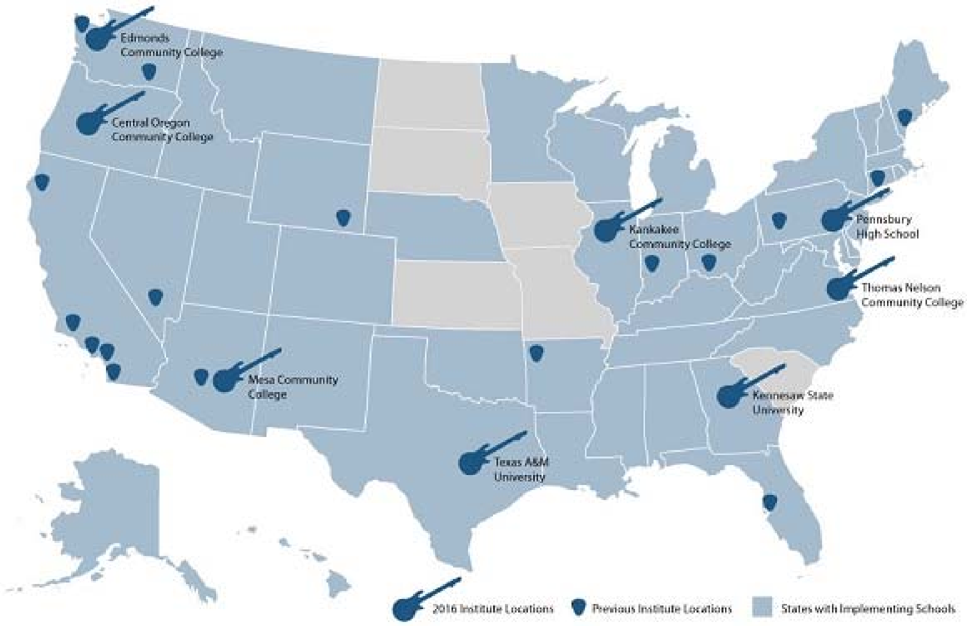
115 applicants, and in 2016, 104 faculty were accepted out of 132 applicants. Participants and schools were distributed across many states, including Alaska and Hawaii (refer to Table 1 and Figure 2). The principal investigator reported at the end of March 2017 that guitar kits were ordered from 47 states during the three-year project period, including orders from Iowa, Kansas, and Missouri that are not reflected in the shading in Figure 2. Figure 2 shows the map of the United States and does not include the one faculty participant from Canada in 2015. The project has yet to involve participants from North Dakota, South Dakota, and South Carolina.

Table 1. Applicants and Faculty Participants for GBIs

Project Year	Number of GBIs	Applicants	Participants	Number of Original States where Participants' Schools are Located	Total Number of States Reached during GBIs
2014	4	128	65	25	25
2015*	5	115	69	12	22
2016	9	132	104	8	30
Total	18	375	238	45	

*The 2015 project includes one participant from Canada not included in the mapped participants.

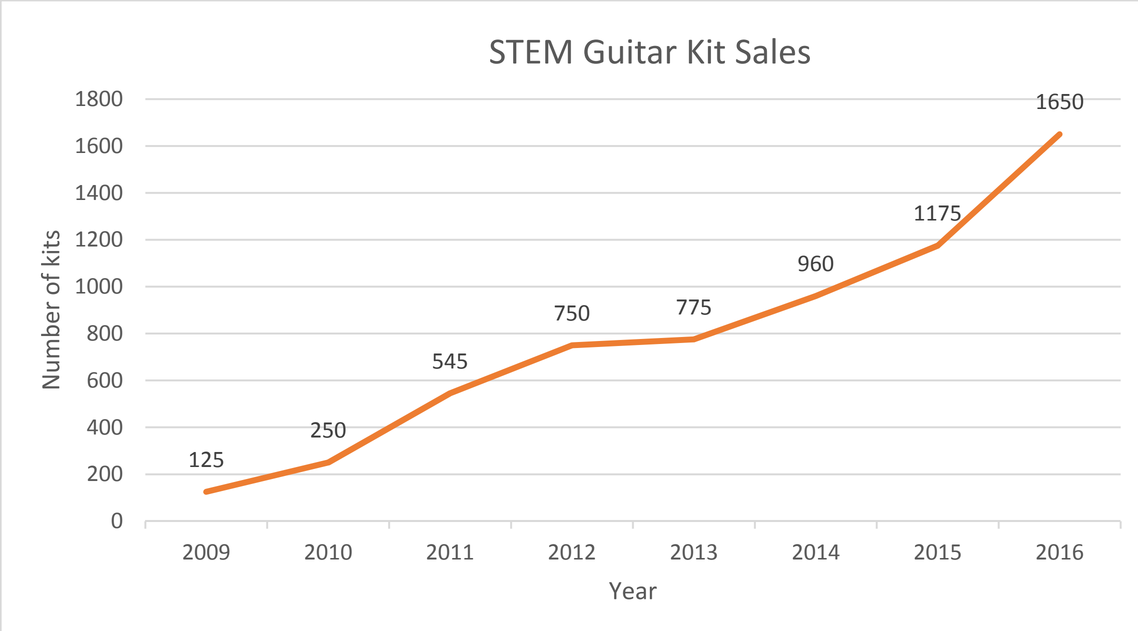
Figure 2. Project Reach



Beyond the project's domestic reach (Figure 2), participation from Canada started in 2015. Three other countries outside the United States have expressed interest in the guitar project: Colombia (South America), Australia, and the Philippines (Asia). This potential for international reach emerged via contacts from the team members and from the website.

Project reach is also shown through the number of unique guitar kit customers and the number of orders, not only in terms of increased numbers, but also in terms of kits ordered by faculty outside of the 2014, 2015, and 2016 GBIs. Figure 3 shows guitar kit orders from 2009, which was the time of the first grant. The orders from 2014 through March 2017 totaled 3,785 kits, or 61% of the total accumulated guitar kit orders of 6,230 kits. Of 281 unique guitar kit customers, 49 (17%) were identified as participants in the 2014, 2015, or 2016 GBIs, and approximately 40% of the guitar kit orders were from those 49 GBI trainees. Of the 232 customers who were not GBI trainees from 2014, 2015, and 2016, a total of 113 (49%) ordered guitar kits between 2014 and March 2017. According to the project PI, all guitar kit sales were made to faculty and educational institutions and 95% of guitar kit sales were for classroom use; therefore, approximately 3,595 kits were used in classrooms from 2014 through March 2017.

Figure 3. Guitar Kit Sales



The project PI also reported that the project exhibit at the Washington Convention Center in Washington, DC in April 2016 was attended by 150,000 people. He noted that the project touched over 15,000 people at the event, where 4,000 mini-guitars were given away to children; along with these, children were able to observe demonstrations of the operation and use of lasers and the Computer Numerical Control (CNC) router in the project exhibit.

Participants

Project participants were limited to the pool of applicants through the project years. However, the project team consciously pursued an increased involvement of participants from schools with more than 50% free and reduced lunch and more than 50% underrepresented groups (see Table 2).

Table 2. Distinguishing Characteristics of Participants' Schools

	2014	2015	2016
More than 50% eligible for free and reduced lunch (low SES)	13%	21%	38%
More than 50% underrepresented groups	3%	14%	13%

Faculty Participants

The project intended to recruit faculty participants from grades 9-12 and college. About 75% of the participants over three years were male, 85% were white, and the majority came from relatively small schools with student populations of less than 2,000. Classroom sizes reached by faculty varied in size from five to 50. The evaluator collected data from project participants who included GBI applicants (N=375); GBI participants (N=238); faculty participants who completed full implementations of the STEM Guitar curriculum (guitar build and implementation of MLAs with quizzes in Quia) (N=36); faculty champions who participated in a focus group discussion (N=16) held in Tulsa, Oklahoma, on November 5, 2016; and three college faculty participants who participated in informal interviews during a site visit in Cleveland, Ohio, in October 2015.

GBI faculty participants were recruited through direct email via listservs, professional conferences, and personal, professional, and institutional connections. Each year, potential participants completed an online application process that included a commitment from their school administrators indicating support for implementation. There were 238 total faculty participants trained, which surpassed the project target of 186 participants. The project PI limited participant selection to the pool of applicants who completed online applications during the three-year project; he reported that the project team made conscious efforts to accept greater proportions of applicants with diverse ethnic backgrounds from multiple grade levels and subject areas taught. Table 3 shows the demographic make-up of the project's faculty participants over the three-year period.

Table 3. GBI Faculty Participants' Demographics by Project Year

	2014 (N=65)	2015 (N=69)	2016 (N=104)
Demographics			
Gender			
Male	71%	76%	80%
Female	29%	24%	20%
Ethnicity			
American Indian or Native American	0	0	4%
Asian American	1%	2%	1%
Black	3%	0%	4%
Latino/Hispanic	0	7%	5%
White	96%	80%	80%
Pacific Islander	0	3%	2%
Prefer not to answer	0	8%	4%
Grade Levels Taught			
Grades 6-8	7%	13%	12%
Grades 6-12	16%	17%	9%
Grades 9-12	57%	37%	46%
Grades 13-16	18%	33%	33%
Other	2%	0	0
Subject Area Taught			
Science	34%	16%	13%
Technology	63%	14%	14%
Engineering	41%	15%	21%
Mathematics	20%	17%	17%
Other	38%	38%	35%
Educational Background			
Faculty participants with an associate's or bachelor's degree, or some college credits	50%	46%	38%
Faculty participants with a master's or doctoral degree	50%	54%	62%

Additionally, 142 faculty participants responded to the NRCMTE interview respondents in 2015 and 29 responded in 2016. These were included in the 2015 and 2016 project evaluation reports (Castañeda-Emenaker, Morrison, & Dariotis, 2015, 2016.).

Student Participants

Student participants included 769 students who completed their Quia assessments, 62 students who completed a student follow-up survey, and 1,200 students of faculty participants interviewed by NRCMTE staff in 2015 and 2016. It should be noted that these numbers are not necessarily mutually exclusive, since the 62 follow-up student completers were part of the Quia completers and some of the Quia student completers were included in the 1,200 students of faculty participants interviewed by NRCMTE.

Three-year student participation data (shown in Tables 4) was collected via the Quia software system (N=769) and reported by the project team in March 2017 (Hauze, S., French, D., Castañeda-Emenaker, I., French, M., & Singer, T., 2017 March) at the Integrated STEM Education Conference (ISEC) held at Princeton University by the Institute of Electrical and Electronics Engineers (IEEE). This table reflect the number of students taught by faculty participants who came from the 2014, 2015, and 2016 GBIs. Thirteen students in this group were taught by faculty participants prior to 2014, an indication of project implementation of faculty trained from the previous grant. Additionally, student participation included responses to a student follow-up survey (N=65) reported in 2016 (Castañeda-Emenaker, Morrison, & Dariotis, 2016). According to Quia data, student participants were primarily at the high school level (grades 9 to 12). As the project progressed, there was an increase in students who were eligible for free and reduced lunches and were from underrepresented groups.

Table 4. Student Respondents by Grade Level– Quia

Grade Level	Students of implementers trained in 2014 (n=260)	Students of implementers trained in 2015 (n=321)	Students of implementers trained in 2016 (n=175)	Students of implementers trained before 2014 (n=13)
Middle School (6th to 8th grade	0	0	8%	0
High School (9th to 12th grade)	50%	89%	47%	100%
College (13th - 16th grade)	50%	11%	45%	0
Total	**100%**	**100%**	**100%**	**100%**

Table 5 outlines the demographics of the students who responded to the survey in 2016. Two thirds were male, almost half were white, just over half were between 16 and 18 years old, and just under half were in grades 9 through 12.

Table 5. 2016 Student Survey Respondents (N=62)

Gender	%
Male	65%
Female	35%

Ethnicity	%
American Indian Or Native American	2%
Asian American	6%
Black	3%
Latino/Hispanic	16%
White	48%
Prefer not to answer	25%

Age Range	%
Less than 16 years old	10%
16-18 years old	55%
19-20 years old	8%
21 years and older	27%

Grade Level	%
6-8th grade	6%
9-12th grade	48%
13th-16th grade (1st to 4th year of college)	23%
Other	3%
Prefer not to answer	20%

Methods

Design, Data, and Analysis

The evaluation design for this project highlights the project's formative and summative initiatives using a mixed-methods data collection and analysis plan (Creswell & Plano-Clark, 2011). Three sets of data were used for this evaluation: (1) project documents and project-related data, (2) Faculty participant-related data, and (3) student-related data.

Project-related data played a key role in the evaluation to explain project processes and contexts. Project documents included solicited and unsolicited emails; documents and meeting notes about project planning; application data; GBI agendas; faculty participant survey responses about the GBI training and environment; guitar kit orders; communications about the project among the 15 key project personnel from six partner organizations; website documentation; project resource development (e.g. existing and newly developed MLAs) and other resources used in curriculum development); evaluator notes regarding GBI implementation; focus group discussion data from faculty champions; and information about the supply chain, supports, and partnerships. The main project meeting documents were compiled in a "rolling agenda with notes" by the principal investigator and this was shared with the project and evaluation teams online.

Faculty-related data included survey responses about confidence in learning during the GBI including participant-identified perceived content learned and intent to use content from the open-ended questions (see pages 22-23 below); faculty project implementation; summary data from follow-up interview surveys of sampled participants conducted by a staff member sponsored by the National Resource Center for Materials Technology Education (NRCMTE); information shared by faculty about project exposure via television, radio, and newspaper and other dissemination, focus group discussion data from faculty champions, and site visit interview notes from three college faculty participants in Omaha, Nebraska, in October 2015. Quia content assessments were designed to measure student performance on the 12 Modular Learning Activities (MLAs) that made up the guitar build. All 238 faculty participants were provided with a Quia account as part of their training and participation in the project, yet only 36 faculty participants chose to integrate Quia assessments in their schools. A total of 25 of 36 faculty participants (~70%) were high school teachers; the rest were teaching college.

Student-related data included results of Quia content assessments reported by the project team (Hauze, S., French, D., Castañeda-Emenaker, I., French, M., & Singer, T. 2017 March), results from the student retrospective survey included in the 2016 evaluation report (Castañeda-Emenaker et al., 2016), and faculty reports about project effects on students. In addition, annual Picture Story Books were published by the project team and submitted to the National Science Foundation. These Picture Story Books depicted the guitar build process and student engagement and interaction that reflected soft skills development.

Instruments and Measures

The main sources of quantitative data were surveys administered at the end of each GBI, student Quia content assessments, and the student follow-up retrospective survey conducted in 2016. The faculty survey assessed the extent to which faculty participants' confidence in learning about STEM, implementing and applying STEM into their curriculum through guitar building, exploring the applications of the supply chains concept, and working with colleagues to explore STEM improved at the end of the GBI. The faculty participants were also asked open-ended questions about content knowledge acquired from the Institute and intentions to implement a guitar build and apply this learning in the classroom. The faculty participant survey was developed in the first year of the project to inform project improvement and was included in the 2014 report (Castañeda-Emenaker et al., 2014).

The pre- and post-institute evaluation instrument was designed as a retrospective pre-post survey. A retrospective pre-post-test, also known as a "proxy pre-test" (Shadish, Cook, & Campbell, 2002) was used for both faculty participants and students for several reasons. First, teacher participants might not have been familiar enough with the technical aspects of the project and thus may not have had enough information to judge their initial level of knowledge or attitudes toward the program, or functioning related to the program (Howard et al., 1979; Nimon & Allen, 2007). Second, in the case of student-related data, the implementation period was relatively short despite variation of timelines for project implementation in schools. Third, the retrospective method is not vulnerable to missing data and does not require matching identification over time (Raidl, Johnson, & Gardiner, 2004). In addition to the demographic questions, the retrospective pre-post-test included questions related to five major constructs: (1) GBI content, (2) design and environment, (3) perspectives about the guitar build process, (4) feedback about the MLAs, and (5) faculty participant confidence regarding learning and applying STEM within the context of guitar building. Three open-ended questions were also included: (1) the most valuable learning from the GBI, (2) how faculty intended to use this identified learning in their classrooms, and (3) what was least valuable from the GBI.

Qualitative data and documents were compiled, summarized and/or analyzed thematically (Guest, MacQueen, & Namey, 2012). Qualitative data included informal interviews conducted with three teacher project champions and other faculty participants who participated in a focus group during the final project year.

Analysis

Initial analysis of the sample data for normality and homogeneity indicated the non-normal nature of the data. Paired sample t-tests, Wilcoxon Rank Tests for paired samples, and descriptive statistics were used to analyze the quantitative data. An alpha level of .05 was used for all statistical tests. Contextual and other qualitative data were used to help explore project processes as well as teacher and student quantitative results using triangulation. Descriptive statistics, paired t-test analyses, and data displays were generated from these surveys and reported annually to the project team. Results of thematic analysis of project documentation, including formal and informal feedback were also included in annual evaluation reports provided to the project team. Annual evaluation results became the basis of the project team's project adjustments and improvements.

Results

The summative evaluation component included reactions (faculty participants' perspectives on the utility of the GBI and the MLA); learning (what faculty participants learned and how they intended to use what they learned); organizational support provided; faculty participants' use of new knowledge and skills (classroom implementation and emergence of faculty champions); and student learning outcomes. This section also includes insights into lessons learned, challenges and barriers encountered in the project, and implications for project sustainability.

Organizational Supports

Faculty participants were able to rely on support provided by the project staff as the faculty expressed needed support after the GBI. Support for faculty became a high priority for the project. As in Guskey's (2002) model for evaluation of professional development, support is definitely an important component of any professional development. The project staff provided faculty support in four major areas: (1) expert availability for consultation (face-to-face, telephone, email, vetting of teacher-created MLAs); (2) online resources for curricular materials and other information (such as the project website, www.guitarbuilding.org, and project Facebook account); (3) a supply chain; and (4) opportunities provided for project visibility and community support.

The guitar building experts (instructors) in the Institutes became the main link to the faculty participants who were trained in each GBI. These instructors continued to be a resource for faculty participants, especially for face-to-face assistance. All project team members were available via telephone or email. During the focus group, it became evident that email and phone communication were the preferred ways in which the individual project team members supported the faculty participants. Emails from faculty participants were received almost daily as well as occasional phone calls, either to share their successes or to ask for more help and information. The MLAs developed and submitted by faculty participants were vetted by the project team before they were published on the project website. The following questions were used in assessing the MLAs for inclusion on the website.

- Was the MLA template from our website used?
- Were all sections of the MLA template completed?
- Did the MLA make sense [regarding to the guitar build phase and STEM integration]?
- Were the MLA objectives written as objectives (e.g., Bloom's taxonomy)?
- Was there an assessment piece? Did the assessment have an answer key?
- Was the MLA aligned to NGSS or Common Core standards?
- Were images cited properly?

The project website (http://www.guitarbuilding.org) provided a comprehensive resource for faculty participants and other stakeholders, including school administrators, parents, and the community. In response to faculty participant feedback, the website was reorganized to be more user friendly and to help faculty participants find materials more easily. The website was continually improved and available resource materials were expanded across the project period. The website also served as a repository to distribute new materials (e.g. new MLAs) and as a forum for a faculty participant learning community. Google Analytics of the website access data indicated that the use of the website resources increased across the project period. One of the faculty participants stated in an unsolicited email: "The work that you folks have done on the website is amazing! I have gone through most of the lessons and can see how I can incorporate many of those in my existing classes." In 2016, the project Facebook account was also being used by faculty participants as a digital repository of project implementation pictures and videos and a platform for participant interactions as an emerging learning community.

With more trained faculty and the growing popularity of the project as indicated in the increase in guitar kit orders, the project team exerted more efforts to grow its supply chain. Various options were used, such as soliciting the participation of different schools in the manufacturing of guitar parts as well as checking other material sources and importing them as needed to provide a consistent supply of reasonably-priced guitar kits. As a result, the project was able to offer less expensive kits, noting that budgets and financing were some of the issues schools mentioned in implementing the guitar build.

One of the major targeted efforts of the project team was to provide opportunities for faculty participants to increase project visibility and enhance community support. The project team shared specific suggestions, guidelines, and one-page fliers with faculty participants as well as templates for soliciting traditional media, social media, and other publicity exposure. The project had a marketing expert who targeted publicity for the project locally, regionally, nationally, and, in some cases, even internationally.

Faculty participants' positive experience from this system of support from the project team was echoed by all faculty champions and faculty participants who were interviewed. Specifically, they mentioned responsivity of the project staff to their questions, mentoring and sharing of project expert knowledge, modelling provided by the project staff during the GBIs, and resources made available for faculty participants.

Participants' Reactions

Participants' reactions to the GBIs and MLAs were collected in the GBI retrospective surveys, the focus group discussion with 16 faculty champions, and three faculty site visit interviews. Respondents reported positive reactions to the Content (e.g., institute objectives, information, materials, and activities) as well as Design and Environment (including the physical environment, pacing of activities, working with teams/colleagues, and support provided by the project team) on the retrospective surveys (see Table 6). Additionally, the NRCMTE follow-up interview with 29 in 2016 faculty sampled from previous years' GBI participants provided additional project reactions.

Table 6. Faculty Perspectives about Content and Design

	2014			2015			2016		
	Pre	Post	T-Test (Sig.)	Pre	Post	T-Test (Sig.)	Pre	Post	T-Test (Sig.)
Content									
Mean	4.42	4.82	$t_{(47)}$= 5.20	3.99	4.64	$t_{(68)}$= 5.55	4.53	4.79	$t_{(103)}$= 4.89
Std. Dev.	.576	.265	p< 0.000**	.942	.543	p< 0.000**	.626	.533	p< 0.000**
Design and Environment									
Mean	3.92	4.31	$t_{(47)}$ = 3.14	3.80	4.57	$t_{(68)}$ = 6.78	4.67	4.66	$t_{(103)}$ = 3.49
Std. Dev.	.567	.404	p< 0.006**	1.008	.452	p< 0.000**	.790	.553	p< 0.001**

Scale: 1 = strongly disagree…5 = strongly agree
Significance level: **p*<.05; ***p*<.01; t-test was paired t-test, 2-tailed.

Statistically significant pre-post changes were recorded from GBI survey responses of the three cohorts of GBI participants (2014, 2015, and 2016). The favorable perspectives were supported by yearly comments about the GBI Design and Environment, including the adequacy of time for the GBI sessions, especially for the actual building of the guitar. A limitation is the number of 2014 respondents who completed the retrospective survey: only 54 of 65 participants completed the survey, and pre-post responses were able to be matched for only 48 of the 54 responses. Feedback from GBI instructors in 2014 noted that faculty participants were intent on finishing their guitar build during the last day and this may have caused them to miss completing the retrospective survey. In 2015 and 2016, a designated time for taking the retrospective survey was included on the last day so all faculty participants were able to complete the survey.

During the focus group discussion (FGD) conducted in November 2016 in Tulsa, Oklahoma, all 16 faculty champions indicated the GBI they attended provided them with meaningful experiences. Below are examples of faculty quotes.

- *Excellent. This was easily the best workshop conference I have ever attended. It allows teachers to take the training and "run with it".*
- *It was a great opportunity for me to learn about guitars and the application in education.*
- *Awesome experience. The different disciplines involved was an amazing experience.*

All 16 focus group faculty participants mentioned above shared their appreciation for the project, especially the GBIs they attended and the support they got from the project team.

- *I could not have implemented the program in my school if not for the help of instructors of my first GBI.*
- *They have been available and willing to help in every way from support to implementation.*

Faculty Participants' Experiences

Confidence in Teaching STEM

Table 7 shows paired pre-post sample t-test results for faculty participants reporting their confidence in teaching STEM during the 2014, 2015, and 2016 GBIs. Respondents rated eight questions regarding confidence (about learning STEM content, implementing STEM content, exploring more applications of guitar building in various aspects of STEM, exploring learning connections for students through STEM, working with colleagues to expand learning connections for students, exploring applications, of the supply chain concept, and making commitments to participate in the project follow-up activities) on a five-point scale (1=poor, 2=below average, 3=average, 4=very good, 5=excellent) that loaded on one factor labeled "Confidence in Teaching STEM" on a retrospective survey given the last day of the Institute. At the beginning of the GBI, a majority of respondents, when asked to reflect on their confidence about learning STEM, implementing and applying STEM concepts through guitar building, and working with colleagues to explore STEM rated themselves *average*, and reported, on the same survey at the same time, *very good* levels of confidence with teaching STEM and learning about STEM at the end of the GBI. Respondent comments on the GBI retrospective survey reflected increases in their confidence in teaching STEM. Faculty participants responded to open-ended questions regarding their most valuable learning from the Institute and how they intended to use this learning to change or improve their instructional practices. Faculty participants' coded responses indicated that they connected their most valuable learning from the GBI training to their intentions for improving their teaching strategies. Participants' comments reflected this:

- *I built a lot of confidence from being part of this training. The instructor's endless knowledge on this subject was inspiring. The integration of STEM into our daily* *lessons became very transparent after taking this training. I feel very fortunate to be part of this experience and I am very eager to get students working on guitars very soon.*

- *I think my experience with building the guitar helps me to understand all of how it works, and this helps me to know the underlying mathematics involved. Mostly, I just find any experience I have with STEM helps me know how I can integrate it into my classroom; otherwise I'm shooting in the dark.*
- *I can now envision the structure of a STEM guitar course at my school (a 4-yr private liberal arts college). Without the activities of this week, that would not have been possible.*

Table 7. Confidence about Teaching, Implementing, and Applying STEM

	2014			2015			2016		
	Pre	Post	T-Test (Sig.)	Pre	Post	T-Test (Sig.)	Pre	Post	T-Test (Sig.)
Participants' Confidence about Teaching									
Mean	3.64	4.74	$t_{(47)}$= 8.43	3.41	4.61	$t_{(68)}$= 6.78	3.85	4.75	$t_{(103)}$= 11.23
Std. Dev.	.887	.343	p< 0.000**	.953	.705	p< 0.000**	.859	.455	p< 0.000**

Scale: 1 = poor…5 = excellent
Significance level: *p<.05; **p<.01; t-test was paired t-test, 2-tailed.

As shown in Table 7, results indicate that faculty participants in the the GBIs showed statistically significant improvement in confidence in teaching and exploring STEM guitar-related concepts and activities. Similar to evaluation of Content and Design and Environment, the number of 2014 respondents on the retrospective survey was a limitation; only 54 out of the 65 participants in 2014 completed the survey, and pre-post responses for the "Confidence" construct were matched for only 48 of 54 respondents.

What Participants Identified as Valuable Learning from the Institute

The GBI retrospective survey asked faculty participants about the most valuable learning from the Institute. Thematic analysis of the qualitative responses was conducted and themes were quantified in order to show what the faculty participants considered most valuable across the project period. Faculty participants identified learning about concepts, STEM interdisciplinary connections of concepts, connecting concepts with classroom work, and learning about guitar parts, tools, and related resources as valuable. Fewer than 10% of faculty noted the MLAs or use of Quia assessments as valuable (see Table 8).

Table 8. What Participants Identified as Valuable Learning

Identified as Learned	2014 (N=54)	2015 (N=69)	2016 (N=104)
All concepts; hands-on and connections with classroom	41%	28%	24%
STEM interdisciplinary connections	21%	25%	32%
MLAs and use of assessments	2%	7%	4%
Guitar parts and related tools to use; other resources	21%	32%	32%
Collaborate with colleagues	13%	4%	8%
Other (new activities; getting buy-in)	2%	4%	0%
Total	100%	100%	100%

Similar to questions regarding what was learned during the Institute, the faculty participants were asked about their intentions to use learning identified as valuable after the GBI. A summary of themes was generated from the responses; percentage comparisons of reported intentions across the project period are presented in Table 9. The top responses across the project period related to application in classrooms. Compared to 2014 participants, a greater percentage of faculty participants in 2015 and 2016 (over 50% in 2015) reported intentions to engage students using STEM integration in the classroom.

It should be noted that an emphasis on reflection and thinking about applications of the learning activities (as homework) were included in the 2015 and 2016 GBIs from day one but were not part of the 2014 GBI. However, the 2014 GBI included curriculum development break-out sessions (less than two hours) as well as a discussion about curriculum plans for about an hour and a half. Including reflections and curriculum development in the GBI was seen as helping faculty participants think about lesson development and integrating the STEM Guitar curriculum. GBI instructors noted the 2014 faculty participants' reactions to the "novelty" of the Quia software system and the classroom integration of the guitar building STEM-related concepts. About 10% more of the 2014 participants reported applications in the classroom and intentions to use MLAs and assessments in class compared to 2015 and 2016 participants (Table 9). Feedback collected by the team in 2015 and 2016 included faculty uncertainty about the complexity of logistics to integrate Quia with existing curriculum, particularly faculty participants in schools with pre-determined curricula.

Table 9. Intentions to Use Learning

Intent to Use Learning	2014 (N=54)	2015 (N=69)	2016 (N=104)
Apply in the classroom	**41%**	32%	30%
Engage students with STEM integration	2%	**51%**	**38%**
Develop lessons, map with standards	23%	7%	13%
Use MLA and assessments	13%	3%	4%
Build guitar models, extensions	7%	0%	0%
Collaborate with Colleagues	1%	4%	12%
Other (get funding, access and set-up resources)	9%	0%	3%
Not sure; no response	4%	3%	0%
Total	100%	100%	100%

Participants' Use of New Knowledge and Skills

Classroom Implementation and Emergence of Champions

The NRCMTE 2015 interview data from 142 sampled faculty indicated that about 91% of the faculty were implementing the guitar building and concepts in their classes. These results were included in the 2015 report (Castañeda-Emenaker, Morrison, & Dariotis, 2015). Slightly more than 9% (13 out of 142) of the sampled faculty who responded to the NRCMTE interview reported such barriers to guitar building in full class implementation as lack of administrative support, funding (including the need for tools and equipment), and lack of clarity in terms of concept applications in class. It was clear that Quia assessments were not done if there was no full class implementation.

Of the 29 faculty interviewed by NRCMTE personnel in late fall of 2016, 11 reported they completed full implementation, (meaning the complete guitar build and all MLAs with corresponding assessments). Ten of the 29 reported they implemented partially as they integrated the guitar build into their electronics, technology, or wood working classes, distinguishing a focus on the guitar build as contrasted with implementation of the MLAs and use of the assessments. Eight (two high school teachers and six college faculty) of the 29 reported they were not able to implement the STEM guitar curriculum at all. The most common barriers noted by these participants (8 out of 29) included constraints of their school's curriculum and difficulty in integrating the guitar building course, and lack of funding and administrative support.

Faculty participant responses to the NRCMTE interview and email communications indicated that "implementing" meant conducting a guitar build and some MLAs without necessarily completing content assessments for students and/or asking their students to complete the student follow-up surveys. As reported in 2016 (Castañeda-Emenaker, Morrison, & Dariotis, 2016), site visit conducted by the evaluator with an implementing college in Omaha, Nebraska, in October 2015 supported data from the follow-up interview survey that indicated faculty were implementing guitar building concepts and were enthusiastic about the guitar build and integration in their classes, but did not see the relevance of the use of Quia in their classes. For instance, although the faculty participant at the college in Omaha did not use Quia in his classroom assessments, he went beyond the guitar build curriculum by exploring and extending the idea to build a "shamisen," which incorporated cigar boxes and common hardware that was financially feasible.

The emergence of faculty champions was confirmed during the focus group discussion conducted with 16 faculty champions on November 5, 2016 in Tulsa, Oklahoma. Nearly all (15) of them used Quia content assessments, and 13 of 16 indicated full classroom implementation with curricular integration. One of the champions trained in 2016 had not completed implementation but expressed plans for full implementation in the coming year and was identified as a champion because of his innovative approach to facilitating inclusion of the guitar building curriculum into his college curriculum per his report in a presentation during the November 2016 conference in Tulsa, Oklahoma. This faculty champion noted that guitar building is now central to a junior-year one semester (15 weeks) design prototype/build course taught in three engineering technology concentrations (industrial, manufacturing, and product development). Two champions did not offer details of their implementation but indicated they submitted MLA results to the project staff. At least nine faculty champions who participated in the focus group discussion recognized the alignment of the MLAs with their standards. One of the faculty commented, "Since we are delivering a Manufacturing Engineering Technology Program, the MLAs support almost everything we are teaching. They support our student learning objectives as well." Another faculty participant commented, "I embedded them [MLAs] in my course and developed new ones based on current MLAs." They expressed improvement in their classroom strategies using what they learned from the GBI. These sentiments reported by champions were reflected in typical comments below:

- *The GBI enabled me to use it* [the guitar building process and MLAs] *as a valuable strand in teaching STEM education.*
- *We have used the curriculum to enhance our current scope and sequence.*

The faculty champions reported that their attitudes toward teaching were affected by their involvement with and use of the STEM Guitar curriculum. They reported improved teacher efficacy, being energized, having more empathy for their students, and improving their classroom strategies, especially in increasing student engagement, interest, and motivation in their classes. These were reflected in the following faculty champion quotes:

- *This* [guitar building curriculum] *helps me with innovation and making more creative options for learning.*
- *I have reenergized my focus in teaching.*
- *I have more empathy towards students. I respect their sense of being confused or frustrated by aspects of a daunting project.*
- *I've moved socially away from lecture-based, "sage on the stage" format to more open-ended, laboratory-based courses (AKA: Experiential Learning)*
- *Student attendance increased as a result of this project. They were excited about learning.*
- *My course is at the very end of the school day, and they LOVE it… so they stay in school for the whole day!*

Although there were challenges in classroom implementation noted during the focus group (e.g., funding), the teacher champions indicated they were able to transcend challenges by employing innovative techniques of reaching the students (e.g. through student clubs) and increasing interest in the project. Examples of teacher comments supporting this include: "Students led the fundraising [for guitar build materials] and multi-discipline integration with curricula yearlong." Some teachers used economical resources by developing extension products (e.g., building ukuleles using cardboard boxes or cigar boxes), raising funds through the guitar build itself, involving the community through "crowd sourcing," and getting buy-in from administrators through curricular development and integration.

In general, the faculty champions successfully integrated the actual guitar build and curriculum in their classes. All faculty champions were involved in development of 11 new MLAs grouped into four areas: three in the CAD-CAM and Economics category, three in Electronics, three in Wood Properties and Finishing, and two in Materials Used in the Build. All new MLAs were developed during the 2016 project year and were vetted by the project team using the MLA template and predetermined standards for project MLAs.

Part of the project challenge was to increase the number of GBI faculty who fully implemented the STEM Guitar curriculum. The project team recognized that even if applicants submitted the required Administrative Support letter that this was not a contract of project implementation. The main goal of the project as planned was the offering of the GBI. After seeing that many GBI participants did not fully implement the guitar building curriculum, the project team provided monetary and "guitar bucks" (points to that can be exchanged for guitar kit orders) incentives that were tied with submission of Quia results and completion of surveys but there were few takers. The Quia software was not used optimally. A total of 87 out of 238 faculty (37%) used the Quia software with 1,225 students; however, only 15% (36 out of 238 faculty) submitted matched pre-post Quia assessments for 769 students. The project team decided the subscription to the Quia account was not a good investment and the project ended the subscriptions to the Quia software in March 2017. Data capture remains a challenge for the project. The submitted written administrative support when the faculty applied for the GBI was not a contract for implementation. As seen above, up to 12% of the faculty interviewed (21 out of the total 171) by the NRCMTE were not supported in their implementation. Faculty participants in the GBIs were strongly encouraged to implement the curriculum but they were not required to do so.

Future Plans for Teacher Implementation

All 16 faculty champions who were interviewed by the evaluator in Tulsa, Oklahoma in November 2016 indicated intentions for full course integration of the STEM Guitar curriculum in the future. The framework for the Next Generation Science Standards (NGSS) supports faculty use of inquiry-based and real world science investigation in a lab, classroom, or in the field; the STEM Guitar curriculum integrates this framework into an applied STEM curriculum. Four of the faculty champions reported their intention to make adjustments for MLAs development in their courses; they expressed interest in exploring prospects of the supply chain, and continuing development of funding and other resource development. Several faculty champions noted the strengths of collaborating with peers and sharing ideas, and expressed the need for a regular forum (possibly online) among colleagues in the future. During the Tulsa, Oklahoma conference and focused group discussion in November 2016, the faculty champions became aware that they were part of a learning community, sharing a similar domain with the Guitar curriculum as their common platform. As the faculty champions presented during the conference, they recognized each other's strengths in the practices they started. The group expressed the desire for future collaboration with the help of the online forum which the project team is committed to facilitating beyond the scope of the project.

Effects of Faculty Instructional Practices on Students

There are three major areas regarding effects of classroom implementation on students reported here: (1) students' content knowledge through the implementation of the MLA-related Quia content assessments, (2) faculty reported student skills learned, and (3) student-reported attitudes toward STEM and their persistence as part of the project effect.

Student Learning Outcomes: Content Knowledge

Student content knowledge was measured by the Quia content assessment results reported in an article/presentation published in the Integrated STEM Education Conference Proceedings of the Institute of Electrical and Electronics Engineers (Hauze et al., 2017). The authors were part of the project team and worked closely with Quia assessments. Tables 10 and 11 and Figure 4 as well as results of the Wilcoxon Signed Ranks tests for all MLAs are borrowed for inclusion in this report.

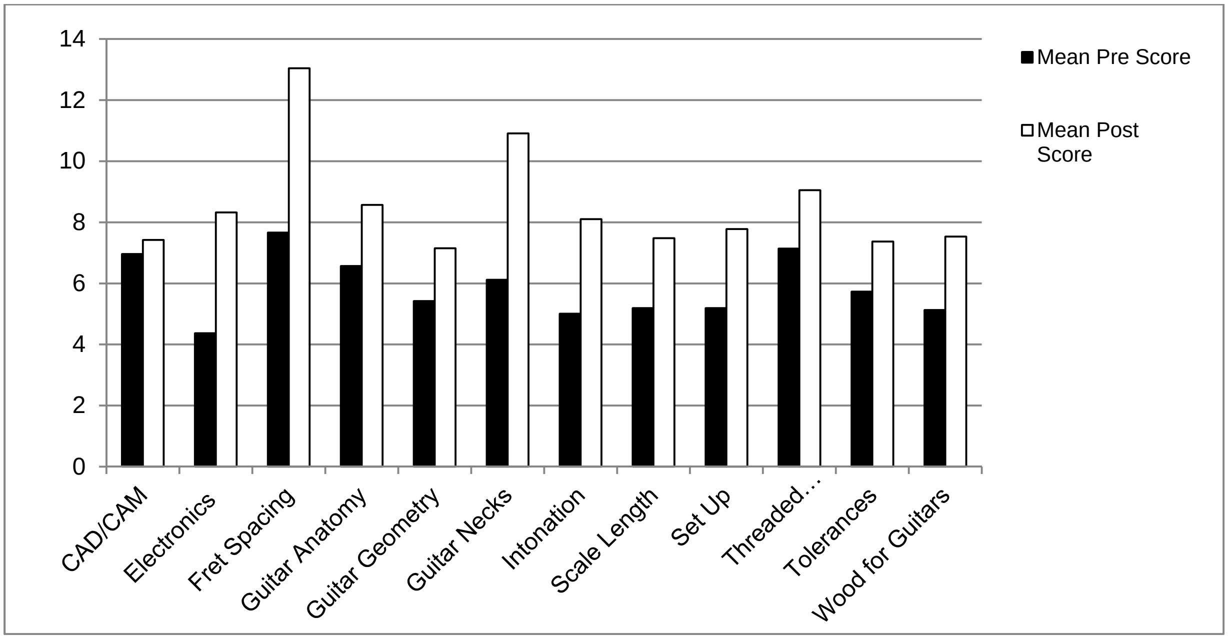
The Quia content assessment dataset included 3,620 student scores (matched to the corresponding MLAs) completed by a total of 769 individual students who were taught by 36 individual teachers. The 36 faculty who implemented the MLAs were primarily teaching STEM core and STEM-related courses: 87% identified as STEM faculty. Of the completed MLA assessments, 20% were completed by students in science courses, 19% by students in technology courses, 30% by students in engineering courses, 9% by students in math courses, and the rest (22%) by students in STEM-related courses. The top five most used MLAs were Guitar Anatomy, Electronics, Threaded Fasteners, Fret Spacing, and Guitar Geometry. All content assessment mean scores for the MLAs are shown in Table 10 and Figure 4. Five MLAs showed 50% or more increases in mean scores from pre- to post-assessment: Electronics (90%); Guitar Necks (78%), Fret Spacing (70%), Intonation (62%), and Set-up (50%), which indicate that the MLAs helped students learn the STEM-related content.

Table 10. Content Assessment Mean Scores, Pre/Post

Assessment	Mean (Pre)	Standard Deviation	Mean (Post)	Standard Deviation
CAD/CAM (n= 57)	6.96	1.439	7.42	1.481
Electronics (n= 173)	4.37	2.491	8.32	2.837
Fret Spacing (n= 138)	7.66	4.073	13.04	4.926
Guitar Anatomy (n= 271)	6.57	2.395	8.57	1.987
Guitar Geometry (n= 115)	5.42	1.999	7.15	1.975
Guitar Necks (n= 27)	6.12	2.417	10.91	2.498
Intonation (n= 43)	5.01	2.074	8.10	2.193
Scale Length (n= 63)	5.19	2.001	7.48	2.045
Set Up (n= 26)	5.19	1.909	7.78	2.306
Threaded Fasteners (n= 149)	7.14	2.746	9.05	2.788
Tolerances (n= 62)	5.73	3.002	7.37	2.651
Wood for Guitars (n= 100)	5.13	1.901		1.928

Data table taken from Hauze et al., 2016.

Figure 4. Content Assessment Mean Score Comparison, Pre-Post



Data table taken from Hauze, et al., 2016.

The Wilcoxon Signed Ranks test results indicate statistically significant changes from pre- to post-assessment, which is evidence of student gain in content knowledge relative to specific MLA content. Student results on the Electronics MLA indicated the most improvement, followed by Fret Spacing and Guitar Anatomy. Student results on the CAD/CAM MLA content assessments indicated the least improvement between pre- and post-assessment (Table 11).

Table 11. Wilcoxon Signed Ranks Pre- and Post-Assessment Results

Assessment	Rank	N	Z	Level of Significance
	Negative	15		
CAD /CAM (n= 57)	Positive	29	-2.464	p < .05
	Tie	13		
	Negative	2		
Electronics (n= 173)	Positive	156	-10.875	p < .001
	Tie	15		
	Negative	22		
Fret Spacing (n= 138)	Positive	106	-8.286	p < .001
	Tie	10		
	Negative	30		
Guitar Anatomy (n= 271)	Positive	192	-10.86	p < .001
	Tie	49		
	Negative	18		
Guitar Geometry (n= 115)	Positive	74	-6.524	p < .001
	Tie	23		
	Negative	4		
Guitar Necks (n= 27)	Positive	20	-3.955	p < .001
	Tie	3		
	Negative	8		
Intonation (n= 43)	Positive	31	-4.172	p < .001
	Tie	4		
	Negative	12		
Scale Length (n= 63)	Positive	40	-4.987	p < .001
	Tie	11		
	Negative	3		
Set Up (n= 26)	Positive	17	-2.811	p < .01
	Tie	6		
	Negative	34		
Threaded Fasteners (n= 149)	Positive	106	-7.056	p < .001
	Tie	9		
	Negative	10		
Tolerances (n= 62)	Positive	44	-4.227	p < .001
	Tie	8		
	Negative	10		
Wood for Guitars (n= 100)	Positive	85	-7.356	p < .001
	Tie	5		

Student Skills Learned

As the STEM Guitar curriculum was developed, the project team took note of the important hard and soft skills that project participants (both faculty and students) could learn from the implementation of this curriculum. Practices included asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information, among others. The National Research Council's (2011) science and engineering practices were useful resources for the team in reviewing the MLAs and the guitar build curriculum alignment as well as including both hard and soft skills, which are life and employability skills.

Project staff and faculty communicated their experiences with implementation and noted that project participants (both faculty and students) learned hard and soft skills during the implementation of the STEM Guitar curriculum. Among the hard skills identified were the learning of the technical and manufacturing process involved in building the guitar. As reflected in emails shared with the project team,

- *They learn how pickups work, how speakers work, they learn the technology of waves and how the vibrating strings affect sound waves. That's the academic portion of it and is all curriculum that is part of the program.*
- *Part of what we provide is a writing curriculum. My students actually have to do a research paper as part of the class itself, researching the importation of wood products.*

Another faculty champion reported that students improved their self-efficacy and belief in their self-learning. The students also learned quality improvement and self-direction. As this faculty participant reported via email to the project team,

- *A soft skill I was surprised to see developed by my STEM Guitar students was their taking a quality mindset in their other classes. Many had never really tried to do high quality work in school. But with their guitar they did the best work possible. They were often surprised by their own abilities and some even "complained" to me that now they had to do good work in their other classes as well. Their personal standards for their own work had gone up.*

Faculty champions and project staff identified the emergence of other life and career soft skills such as initiative, problem solving, critical thinking, dealing with complex issues, leadership, collaboration, communication, creativity, and innovation they observed among their students as the project was implemented. These observations were reported and captured through pictures without a common measure used but these learned skills were featured in the Picture Story Books submitted to the National Science Foundation. The project team is seriously considering working on a rubric to be vetted by the team and the project advisers and business partners for future use.

Student Attitudes toward STEM and Persistence

At least ten faculty champions reported that their students' interest, motivation, and engagement in learning STEM and overall learning increased because of their exposure to the STEM Guitar curriculum. Faculty comments supporting this included:

- *They all enjoyed it, but for some students this has been the highlight of school and the only reason to come.*
- *Students were interested in art/music…more connections. I will say that students were very connected in class where they typically weren't.*

At least six among the faculty noted students' enhanced self-efficacy and belief in their self-learning. Among the teacher comments supporting this are:

- *The guitar design prototype build experience, moving them from "art to part"- provides students with competence and confidence and gives them perspective in multiple technical disciplines.*
- *First, they [the students] understand more about the process of building, and second, they build a great sense of collaboration and patience [in learning about the guitar curriculum].*
- *They developed attention to detail in both experiencing processes and executing them…seeing a long term, multi-faceted project through to completion.*

Results of the student survey reported in the 2016 evaluation report (Castañeda-Emenaker et al., 2016) were consistent with the above reports by faculty champions regarding student persistence and attitudes toward STEM and their learning. Table 12 shows statistically significant pre-post changes in students' tenacity and attitudes towards STEM after their involvement with the STEM Guitar curriculum implementation.

Table 12. Student Persistence & Attitudes toward STEM

	2016 (n=49)		Paired Sample T-Test (two-tailed)
Measure	**Pre**	**Post**	
Grit: Tenacity*	M = 3.00 SD = 0.310	M = 3.17 SD = 0.373	$t_{(48)}$ = -3.271, p=0.002*
Attitudes Towards STEM+	M = 3.89 SD = 0.705	M = 4.24 SD = 0.638	$t_{(48)}$ =-5.335, p=<.001**

*Scale: 1 = not at all like me…4 = mostly like me
+Scale: 1 = strongly disagree…5 = strongly agree
Significance level: *p<.05; **p<.001;

Limitations

Except for the Quia pre-post assessment results, one limitation is that these data are mostly derived from self-reports. Faculty participant STEM Guitar instruction effects on students were gleaned from other project documents such as the 2014, 2015, and 2016 Picture Story Books submitted by the project staff to the National Science Foundation and documents shared on the project's Facebook page. Again, these were self-reports and have not been systematically analyzed. Sustainability

Efforts toward sustainability for the LEAD with GUITARS in STEM project were reflected in the project team's development of relationships and partnerships with GBI faculty trainees, schools, business partners, and the community. These relationships paved the way for sustainability of leadership, participation, practice and implementation, and funding. Throughout the project period, the project team increased the number of partners by fostering relationships with business/industry partners as possible suppliers as well as expert partners for curriculum development and implementation. The project continues to support existing partnerships with school, business, and community partners and advisory experts.

Relationships with Faculty and Schools

Relationships with faculty participants and schools will support project efforts to sustain leadership, participation, curricular development, practice, and implementation. These established relationships promote development of faculty champions as well as faculty adoption, development, and adaptation of the STEM Guitar curriculum. Efforts were made during the project period to strengthen the structure and system of supports for faculty and schools to improve STEM Guitar curriculum implementation and project buy-in. The project team's expectation was, "If the STEM Guitar curriculum is adopted or adapted into the existing school/district curriculum, most of the logistical and funding issues will be resolved." However, as noted in this report, the faculty participants encountered issues with administrative support, funding support, and even classroom integration. A recommendation for the future is to have a more systematic plan for implementation, including a contract with school administration, and benchmarks for faculty participants that are associated with incentives. Relationships with faculty participants and schools have the potential to develop additional supply chains with schools that have woodworking facilities which will have the opportunity to utilize these facilities for the guitar parts with woodwork. Through the project period, GBI faculty participants reported statistically significant increases in their degree of confidence in teaching and exploring STEM concepts and activities (which includes exploration applications of the supply chain) with the guitar building curriculum Activities by the project team to enhance the supply chain network included collaboration with education, business, and industry partners. In 2015, plans were developed to reach out more strategically to district curriculum directors and administrators. The special GBI for administrators has yet to come, if new funding is received.

Building Business Partnerships

Building relationships with business partners enhances project sustainability for practice, implementation, and funding. In 2014, the partnerships established with different educational institutions and corporate partners provided various supports for participants in terms of personnel expertise, in-kind support, and, in some cases, financial support. Some of the project's corporate partners are All Parts, Black Diamond Strings, D'Addario, Fender, Forest Scientific Corporation, FML (Frank Miller Lumber), Indasa, Mighty Mite, ShopBot, Stewart MacDonald, Martin & Company, and Taylor Guitars. The project team, especially those located in Washington State, reached out to Boeing to solicit the companies input regarding employability hard and soft skills that can be explored along with the guitar building curriculum. These relationships continued throughout each project year and remain in place and current. In 2015, the project principal investigator ensured that technical aspects, especially with manufacturing of guitar parts and the supply chain, were discussed with business partners. The project team received assurance of potential suppliers in preparation for the projected demand for guitar parts for classroom implementation. Continuous building of partnership connection is important for the project's sustainability. In 2016, the project sustainability effort continued, increasing industry and business partners and creating more robust supply chains that will sustain the program beyond federal funding. For example, a partnership with Boeing will further develop competency skills that match guitar building and curricular program skills with industry needs. This will enhance the employment chances of students trained with the STEM Guitar curriculum. Project faculty continue to maintain contact with connections made through the Advisory Board members and partners. Project team members are aware that promulgation of a solid supply chain and business/industry partnerships has a strong impact on project sustainability.

Building Partnerships with Professional Associations and the Larger Community and Dissemination Efforts

Building partnerships with professional associations and the larger community are also important aspects of the project's sustainability efforts. Relationships with the community (both academic and professional associations and the larger community) will promote project buy-in, acceptance, relevance, crowd sourced funding, and visibility for funding support

The project maintains its connections with different NSF Advanced Technological Education (ATE) Centers. The NSF ATE Centers participating in this project, including National Center for Manufacturing Education (NCME) and Materials Education (MatEdU), are committed to providing up-to-date information on manufacturing processes and how the faculty can share this information as it relates to STEM. In particular, MatEdU shares information on various materials needed to make a guitar (e.g., metal, wood, polymers, etc.) and the properties of each of those materials.

The project team has disseminated information in multiple formats describing the project and what it does for students. These dissemination efforts have contributed to the extended project described above. As a result, different interested audiences have contacted the project team for further information about the project and how they can join.

The highlight of project dissemination activities for LEAD with GUITARS in STEM in 2015 was the invitation by the National Science Foundation (NSF) for the project to be featured as the opening plenary forum at the October 2015 NSF ATE National Conference in Washington, D.C. Five faculty and four students shared testimonials about the project. Faculty highlighted how they integrated guitar building concepts in their math, physics, technology, and industrial arts classes. Students shared their experiences in their guitar building classes and observed that these helped them gain skills and knowledge that they will continue to use as they advance in their high school and college courses.

In 2015 and 2016, the project PI and two co-PIs were keynote speakers at the M-STEM conference in Florida as well as at a STEM-related conference in California. One co-PI was invited as a speaker at NASA Goddard and has an article currently in review with *American Lutherie*. Project team members also presented at conferences such as the American Association of Community Colleges (AACC), the American Association of Physics Faculty, the ATMAE conference, the Association of Science Faculty Educators/National Faculty Association Conference, the Boulder City Rotaries, the Indiana Association of Career and Technical Educators, the Institute of Electrical and Electronics Engineers (IEEE) Integrated STEM Education Conference, the Washington Industrial Technology Education Association, the Washington Association for Career and Technical Education, the US FAB LAB Network, and the NSF ATE conference.

Faculty participants shared via email local news highlights or articles about the LEAD with GUITARS project activities in their community (Chicago Tribune, Laramie newspapers, Community College Week Magazine), awards received by faculty as a result of the guitar project (e.g., the 2016 Tri-Cities Crystal Apple Award; a Robert E. Yager Foundation Excellence in Teaching Award, Best IEEE Conference Presentation Award), and links to You Tube videos of activities that were highlighted and posted on the guitarbuilding.org website, as well as other media highlights in more than 75 of those emails. The project sustainability efforts seem set to continue beyond the scope of the project to maintain and increase school, business/industry and community partners and maintain and develop more robust supply chains to continue the program even without federal funding.

Discussion and Conclusions

The LEAD with GUITARS in STEM project has been successful in showcasing a new way to present STEM learning for students using the applied method of guitar building. The streamlined STEM Guitar curriculum and systemic project team process enabled the project to conduct 18 successful Guitar Building Institutes (GBIs) that trained 238 middle school, high school, and college faculty across 45 US states (including Alaska and Hawaii), including one participant from Canada. With the average school size per GBI participant of 1,500 students, the project has, at least, provided project exposure to more than 350,000 students across the United States with information about the project in their schools and information dissemination in the community. The project surpassed its target number of participants (238 faculty participated compared to a target of 186) and number of student "touches" (350,700 vs. 175,000) or informed about the project. The project reached at least 47 of the 50 US states based on where guitar kit orders originated. The project also attracted the interest of over 4,000 students who received mini guitars and observed the use of laser and CNC machines during a project exhibit in Washington, D.C.

The project developed at least 16 faculty champions who provided insights to the project leadership and are being developed as GBI trainers. It also generated 11 new MLAs that enriched the STEM Guitar curriculum. Guitar kit orders indicate continued interest in the project. The project tracked guitar kit orders since 2009 that meant participant orders from the first grant. Through the project period, an accumulated total of 6,230 guitar kit sales were ordered, 95% of which were meant for classroom use (per the project PI). Over 3,700 guitar kit sales occurred in 2014, 2015, and 2016, indicating 3, 700 students were engaged with hands-on guitar build experiences during the project years. These numbers included 769 student Quia assessment completers, 62 student follow-up survey completers and 1,200 students of the 88% (150 out of the 171) faculty interviewed by NRCMTE personnel who implemented the guitar building curriculum in some form (guitar build only or full implementation).

The faculty participants reported positive responses towards the GBIs, reported learning about the STEM Guitar concepts and their integration into their classroom, reported positive feedback about the supports they received from project personnel, indicated increased interest in teaching STEM in their classrooms, and reported perceptions of positive effects on students' content learning, as well as hard and soft skills learned by their students. The project taught STEM content using electric guitars and electronic amplification to at least 769 students as indicated by the MLA-related Quia content assessment results. The students manifested persistence in their work, and improved their attitudes towards STEM and STEM careers.

The project has laid the foundation for sustainability as it has continuously included sustainability efforts in project activities. Among these activities were the building of relationships with the faculty, the schools, business/industry partners, professional associations, and the larger community. Sustainability efforts are geared towards maintaining leadership, participation, practice, implementation, and funding.

Limitations, Challenges, and Lessons Learned

The project evaluation had several data limitations because of the nature of project implementation. For instance, faculty participants were accepted to the GBI training but were not required to conduct full project implementation as a condition of acceptance/attendance.

Although applicants submitted written documentation from their school administrators indicating support for implementation of the LEAD with Guitars curriculum, the faculty participants reported challenges with full implementation of the MLAs and Quia content assessments. Only 15% of faculty participants successfully implemented MLAs with Quia content assessments. MLAs with the Quia assessment were not implemented as intended at every school/college for many reasons, including limitations of scheduling, flexibility of existing school curriculum, lack of administrative support for implementation, and low faculty buy-in for the content assessment use.

A focus group conversation was held with the 16 faculty champions only, so voices and opinions of faculty who were struggling with implementation were only captured on a survey that was not completed by all faculty who were trained each year. The NRCMTE personnel conducted interviews with a sample of teachers who were not considered champions. The evaluation team was not involved with the initial development of the NRCMTE interview protocol.

Data about the faculty participants' schools (e.g., school demographics such as free or reduced lunch status or underrepresented group enrollments) were tracked at the school rather than student or faculty level, so it is difficult to fully describe the context in which GBI curricula were implemented, or the potential for reach to underrepresented populations.

Additionally, there was a lack of systematic documentation of one-on-one support provided by the project team. A log of support was suggested, but the project team acknowledged that logs would reduce time available for provision of other support to other Faculty. Tracking participation on the project's Facebook page was a challenge. The project team wanted to create a repository of project implementation documents such as videos and photos, and the project team has yet to develop a systematic way of collecting these data on the Google Docs platform. Google Analytics were used to monitor the project's website and support mechanisms (e.g. email communication about instructions and related information) for project product uploads and downloads. The project team continues to discuss the utility of this process and seeks to improve its monitoring systems.

The high school faculty participants comprised the majority (about 70%) of the GBI trainees and it thereby behooves the GBI instructors to pay attention to this group's issues. Feedback on the GBI survey indicated some high school specific issues. For example, one high school faculty participant reported that during the GBI he was interested in finding practical strategies to navigate his limited school scheduling flexibility to fully implement MLAs and Quia in his classroom but felt intimidated asking about these in the presence of the college faculty participants. The high school faculty participants noted they have relatively less flexibility in their school curriculum compared to their college colleagues. Other issues they identified included challenges with integrating guitar builds with their existing schedules and curricula as well as a lack of buy-in from administrators, especially where there was a change in administrators. Not every faculty participant took advantage of the project incentives and not all completed the incentivized project components (e.g., implementing MLAs, administering content assessments, developing new guitar build MLAs, completing faculty participant follow-up surveys, and facilitating student completion of student follow-up surveys).

Except for the Quia pre-post assessment results, another limitation of the project data is that these data are mostly self-reported. Faculty participant STEM Guitar instruction effects on students were gleaned from other project documents, including the Picture Story Books submitted each year by the project staff to the National Science Foundation, and the documents shared in the project Facebook. These were self-reports and have not been systematically analyzed.

The project designed a process of assigning faculty participants project IDs including student project IDs that could be linked with their faculty. However, these IDs were not used correctly or consistently, making it difficult to link pre- with post-survey data, or even connect students with faculty. Tracking the number of students (as well as their demographic information) enrolled as well as the completion of assessments and/or surveys remained a challenge.

The project can claim that it trained more than 186 faculty through applied methods of guitar building but it will not be able to claim that it conducted professional development for 238 faculty. Proof for Guskey's five levels of evaluating professional development was available for only 36 faculty, or 15% of the faculty participants. The project has yet to show evidence for the remaining 85% of faculty trained during the 2014, 2015, and 2016 GBIs.

Future Directions

The LEAD with GUITAR in STEM project shows an innovative way of integrating STEM learning into a hands-on experience of building a solid body guitar by training faculty who will engage students to learn STEM content and related hard and soft skills. The use of electric guitars, electronic amplification, and music to teach STEM content to a wide range of students appeared to be an attractive and viable way of teaching STEM to both high school and college faculty. Focusing the GBI five-day training agenda and curriculum in differentiating among the faculty trainees to address the varying levels of the participants' classroom needs and interests is very important to ensure project success and implementation.

Strategies of reaching participants from schools serving low-income and underrepresented student populations remain a challenge, especially if acceptance of applicants remains dependent upon the pool of applicants who submit a complete application. The project team continues to explore ways of targeting additional applicant pools from the project's targeted demographics. A more concerted effort of reaching out to groups and schools/colleges that have underrepresented populations and serve low-income students would be helpful. Data should be tracked based on student or faculty level to fully describe the context in which GBI curricula were implemented and explicitly reflect the project reach for underrepresented populations,

Although at least 49 faculty from the 2014, 2015, and 2016 GBI ordered guitar kits for their classes (evidence that they at least completed the guitar build portion of the project), only 36 conducted full STEM Guitar curricular implementation with MLA assessments. Encouragement of faculty champion involvement in communities of practice that could motivate other faculty will be helpful. Also, the faculty champions can serve as resource and mentors for the rest of the faculty participants.

The project's main goal was the offering of the GBI. This was accomplished. Faculty participants in the GBIs were strongly encouraged to implement the curriculum but were not required to do so. Moving forward, rethinking the project's approach to faculty professional development is very important. To date, the project team continues to think about and plan ways of reaching project participants to gather additional data about the STEM Guitar curricular implementation (from the GBI training to faculty learning, organizational support, faculty implementation, and student data showing effects of implementation). Part of the project challenge was to increase the number of GBI faculty participants who fully implemented the STEM Guitar curriculum. Data capture remains a challenge for the project; IDs should be redesigned and implemented fully in the future so student and faculty participant data can be matched pre to post as well as with each other. The submitted written administrative support when the faculty participant applied for the GBI was not a contract for implementation; this should be reconsidered, requiring a commitment on the part of the school. A recommendation for the future is to have a more systematic plan for implementation, including a contract for school administration, and benchmarks for faculty participants that will be associated with incentives. Guskey's five levels of evaluating professional development will be useful in guiding project professional development implementation components.

Building and maintaining relationships with schools, faculty, business, and community is an important strategy that will lead to the project's sustainability. Continuing partnerships with Boeing and other industry partners to further develop competency skills that match guitar building and curricular program skills with industry needs will be important. Additionally, it is important to develop and use rubrics to assess technical and 21st Century skills acquired by participants. The faculty champions are valuable resources to the project: they can provide important project insights to the project leadership and can help as future GBI trainers.

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