ESC Evaluation Services Center

Learning, Engaging, Attaining, and Doing with Guitars Used In Teaching Achievable Real Situations in Science, Technology, Engineering, and Mathematics

2016 Program Evaluation Report

Prepared for:

Sinclair Community College

August 2016

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University of Cincinnati

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Suggested citation: Castañeda-Emenaker, I., Morrison, A., & Dariotis, J.K. (2016, August). *Learning, Engaging, Attaining, and Doing with Guitars Used In Teaching Achievable Real Situations in Science, Technology, Engineering, and Mathematics: 2016 Program Evaluation Report.* Cincinnati, Ohio: Evaluation Services Center, University of Cincinnati.

Learning, Engaging, Attaining, and Doing with Guitars Used In Teaching Achievable Real Situations in Science, Technology, Engineering, and Mathematics (LEAD with GUITARS in STEM)

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2016 Program Evaluation Report

Background and Purpose of Evaluation

The University of Cincinnati Evaluation Services Center (UCESC) was contracted by Sinclair Community College in September 2013 to conduct an external evaluation of the three-year 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. In 2013 Sinclair Community College, as the lead organization, partnered with five other US educational institutions (Butler County Community, College of the Redwoods, Edmonds Community College, Ventura College, and Purdue University). The project uses electric guitars, electronic amplification, and music to train faculty members to teach STEM content to a wide range of middle school, high school, and college students. It collaborates with supply chain networks in an overall partnership of education, business, and industry. This is the second guitar building grant award for this six-institution project team. The first one, from 2010 to 2012, was led by the Butler County Community College in Pennsylvania.

The overall evaluation goal is to conduct a formative and summative evaluation of the LEAD with GUITARS in STEM project, investigating how the project increases student interest in, engagement in, study of, and learning of STEM principles, practices, and careers using STEM Guitar building concepts. This evaluation report focuses on the formative and summative aspects of the project based on the project evaluation questions (see Appendix). The formative aspects focus on the project reach, the guitar building implementation highlights, including the team process, and support provided the participants. The summative aspects include faculty perspectives on the utility of the Guitar Building Institute (GBI) and the modular learning activities (MLAs), faculty reported effects of the GBI on their attitudes and instructional process, and student engagement with, attitudes towards, and skills learned from the project. Planning for sustainability is part of ongoing project activities that transcends the project's formative and summative initiatives.

Evaluation Procedures

Evaluation Design, Instruments, and Participants

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) incorporating a quantitative pre-post-test paired analysis design (Shadish, *et al*., 2002) triangulated with qualitative data. Project documents, including email communications, dissemination information, media exposure, the Boeing competency checklist, and data from a site visit and a faculty follow-up interview survey played key roles in the evaluation and in the explanation of project processes and contexts during this period. Structured processes such as project-prepared "cheat sheet" and guidelines, Quia quizzes, application surveys, Guitar Building Institute (GBI) retrospective surveys, and student follow-up retrospective surveys were some of the instruments used in this evaluation. Participants included 250 GBI applicants, 100 GBI participants, 51 teachers who implemented Quia quizzes, 456 students with completed pre-post Quia quizzes, 65 students who completed the student follow-up retrospective survey, 142 sampled faculty who participated in a follow-up interview survey, and three college faculty who participated in informal interviews during a site visit.

Data Collection and Analysis Procedures

Qualitative data. Project documents were gathered through solicited and unsolicited emails regarding project processes documentation, faculty feedback, shared testimonials, and shared information about project media exposure and dissemination, communication about the project involving the 15 key project personnel from the six project partner organizations, meeting minutes, website documentation, project resource development (such as the modular learning activities (MLAs) and other resources used in curriculum development), summary data from a **follow-up interview survey of sampled participants** conducted by a staff member sponsored by the National Resource Center for Materials Technology Education, and information about the supply chain and business/industry development. These data and documents were compiled, summarized and/or analyzed thematically (Guest, MacQueen, & Namey, 2012).

Quantitative data. The main sources of quantitative data during this period included the GBI online application survey data, the GBI retrospective survey data, the student follow-up retrospective survey data, and the pre-post student Quia assessment data related to the 12 MLAs. The **GBI online application survey** was made available to GBI applicants approximately six months prior to the Institute, with the eight identified venues included. Potential participants were asked for their demographic information and about their intention to use the guitar building concepts and curricula. Every applicant was required to submit written administrative approval for project implementation in their schools. An **online GBI retrospective survey** using Qualtrics was given to the Institute participants at the end of the week-long institute to gather their perspectives about what they learned from the Institute. Participants were asked how the Institute changed their attitudes towards STEM guitar-building and its potential for classroom curricular integration. Participants recalled their pre-Institute attitudes retrospectively and reported their post-Institute attitudes on the same survey. Similarly, a **student follow-up retrospective survey** was made available via Qualtrics to all students who participated in the guitar build and academic experience. Faculty informed eligible students about the survey link on the guitarbuilding.org website. Students were asked about their attitudes and persistence in relation to the guitar building experience. **Pre-post student Quia assessments** were administered by faculty immediately before and after a specific MLA was completed in class. Faculty used project-paid Quia accounts (with project-standardized subscription) and were trained in the use of Quia during the Institute. However, students tended to have issues with their project issued identification numbers, resulting in challenges in matching pre- to post-test data.

A retrospective pre-test – known as a "proxy pre-test," according to Shadish, Cook, and Campbell (2002) - was used for several reasons. First, participants might not have been familiar enough with the technical aspects of the project and thus may not have enough information to judge their initial level of knowledge about or attitudes toward the program or functioning related to the program (Howard *et al.*, 1979; Nimon & Allen, 2007). Second, in the case of the students, the implementation period was also relatively short, although the timeline for project implementation in schools varied. Third, this method is not vulnerable to missing data and does not require matching identification over time (Raidl, Johnson, & Gardiner, *et al.*, 2004).

Analytic procedures. Qualitative data were thematically analyzed (Guest, *et al.*, 2012). Paired sample t-tests, Wilcoxon Rank Tests for paired samples, and descriptive statistics were used to analyze the quantitative data. Contextual and other qualitative data were used to help explore project processes as well as teacher and student quantitative results using triangulation.

Results

Results presented in this report are organized according to the formative and summative evaluation questions (see Appendix) addressed during Project Year 3. The formative aspects focus on project reach and implementation highlights. Targeted participants, GBI locations, and areas of classroom implementation, project dissemination, and website access were used to assess project reach. Guitar building implementation highlights include project team processes and support provided to faculty participants. The summative aspects include outcomes such as faculty perspectives on the utility of the GBI and the modular learning activities, faculty reported effects of the GBI on their attitudes and instructional processes, and students' reported engagement with, attitudes towards, and skills learned from the project. Planning for sustainability is part of ongoing project activities that transcends the project's formative and summative initiatives.

Formative Results

Project Reach

Targeted Participants

This project surpassed its targeted 122 faculty trained during the life of the program. As of Year 3, more than 226 faculty have been served: 65 in Year 1, 61 in Year 2, and 100 in Year 3. It is anticipated that more than twice the targeted number of faculty (244) will be served by the end of the no-cost extension year (2016-2017). Faculty participants have diverse demographic backgrounds, and the project team consciously included more female participants in Year 3. The 2016 participants included from seven completed GBIs included 20 females out of 100 participants. In Year 3, 54% high school, 33% college, and 13% middle school faculty participated. The span of subject areas taught by faculty varied, with subject areas like math, science, technology, industrial arts, reading, history, integrated courses, and interface design all represented. A few faculty taught language arts, social studies, music or art. Thirty-three percent (33%) of the GBI participants reported that more than 51% of students were receiving free and reduced lunch in the schools where they taught. Twenty-six percent (26%) of GBI participants reported that their schools had more than 51% students from underrepresented populations.

GBI Locations and Classroom Implementations

Figures 1, 2, and 3 clearly show the progression of the **LEAD with GUITARS in STEM** project reach. Figure 1 shows the four GBI sites in 2014 and the blue shaded areas where GBI concepts were being implemented in Year 1. As this is the second NSF guitar building grant, the blue shaded areas in Figure 1 also include schools implementing as a result of the first grant. This second grant started with four GBIs and implementation extending across 22 states (including Hawaii) in 2014 with 65 faculty participating. In 2015, five GBIs were conducted and the project reached 34 states with an additional 61 faculty participating (Figure 2). In 2016, eight additional GBIs were held and four more states began implementing the program, for a total of 44 (including Alaska) and more than 100 additional faculty participating (Figure 3). As of 2016, only six states have yet to implement the program.

Figure 1. GBI Locations and Sites for 2014 Classroom Implementations

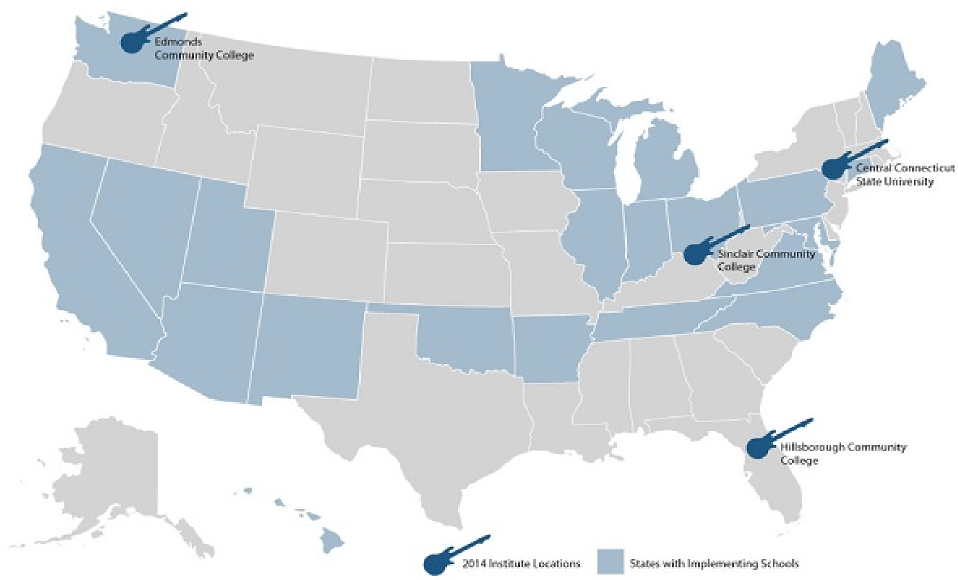


Figure 2. GBI Locations and Sites for 2015 Classroom Implementations

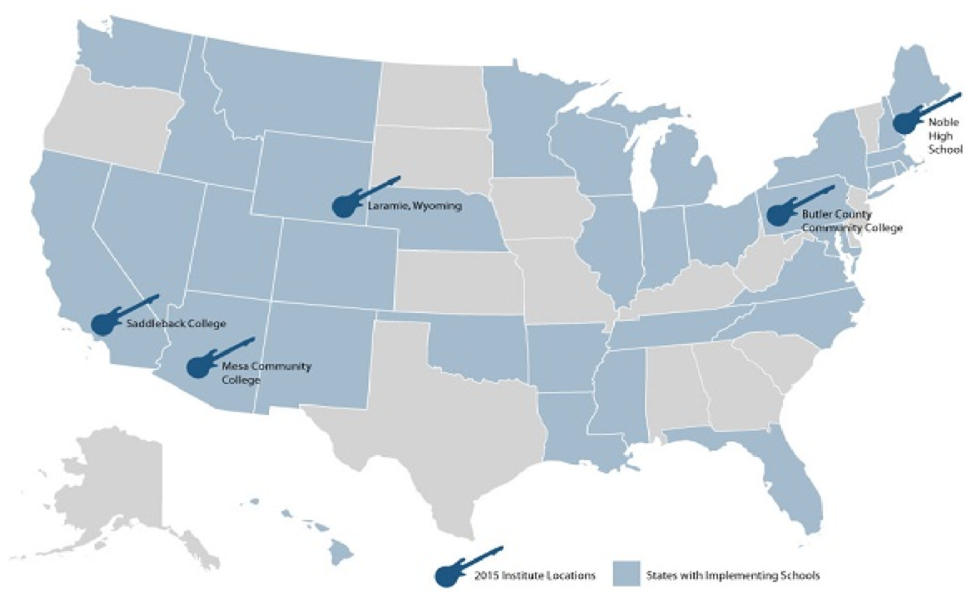
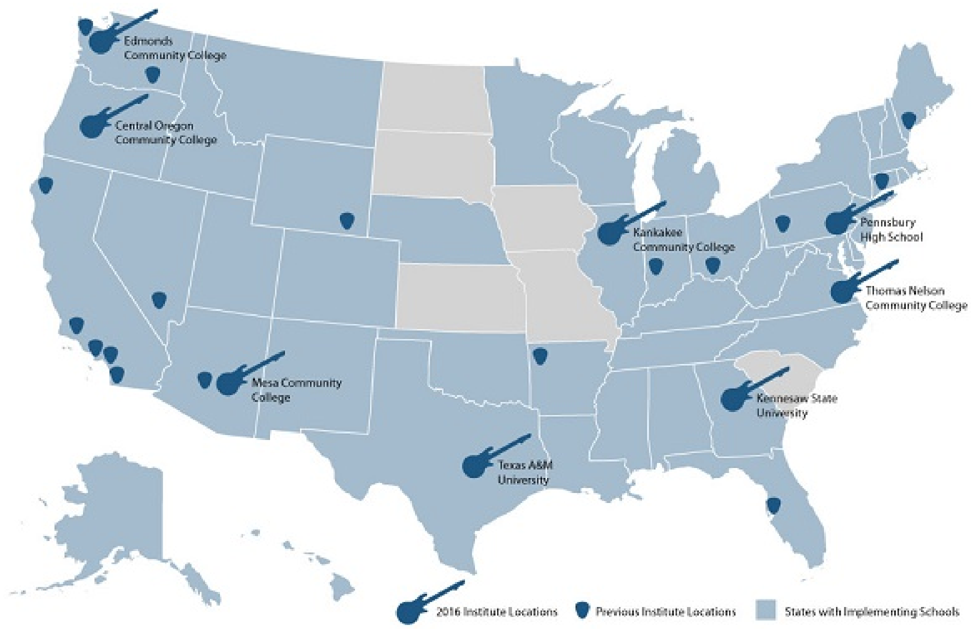


Figure 3. GBI Locations and Sites for 2016 Classroom Implementations



Beyond this domestic reach, the project has a potential international reach because of the contacts of the team members and the website that provides access worldwide. To date, two other countries outside the United States have expressed interest in the guitar project: Colombia (South America), and the Philippines (Asia). Planning is underway to facilitate implementation in these countries as early as 2017.

Project Dissemination

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 reach shown in the above figures. As a result, different interested audiences have contacted the project team for further information about the project and how they can join. A complete list of citations for all **LEAD with GUITARS in STEM** project dissemination activities across all project years will be included in the close-out report.

During Year 3 (2015-2016), the PI and two co-PIs were keynote speakers at the M-STEM conference in Florida as well as a STEM-related conference in California. Project team members also presented at conferences like the American Association of Physics Faculty, held in New Orleans, the Association of Science Faculty Educators/National Faculty Association Conference, in Reno, Nevada, and the NSF ATE conference in Washington, D.C. One co-PI was invited as a speaker at NASA Goddard in Maryland and has an article currently in review with *American Lutherie*.

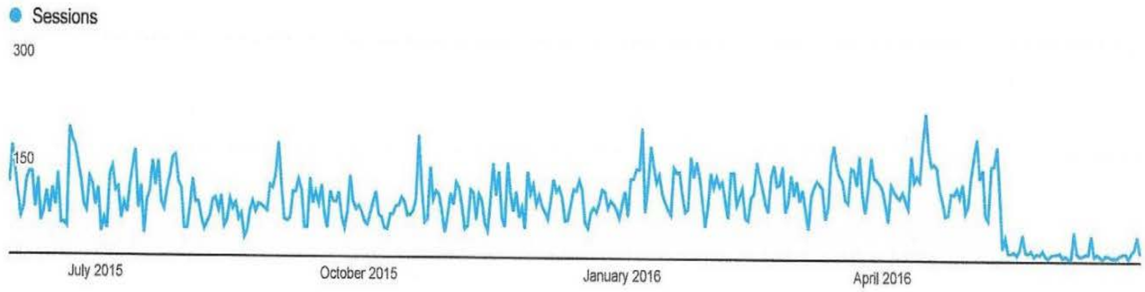
The highlight of project dissemination activities for LEAD with GUITARS in STEM in its third year was the invitation by the National Science Foundation (NSF) for the project to be featured as the opening plenary forum at the October 2015 NSF ATE National Conference in Washington, D.C. Five faculty and four students shared testimonials about the project (Figure 4; photo credit: James Cordero). Faculty highlighted how they integrated the guitar building concepts in their math, physics, technology, and industrial arts classes. Students shared how their experiences in their guitar building classes help them gain skills and knowledge that they continue to use as they complete their high school and college courses.

Figure 4. The LEAD GUITARS Project Team at the NSF ATE Conference Plenary

Website Access

Access data for the project website (http://www.guitarbuilding.org) has been recorded over the past year (see Figure 5). It is interesting to note that the website had high spikes of usage during the school year (from July 2015 through May 2016) compared to the months after the school year, supporting the fact that people are interested in the project and the information contained on the website. Google Analytics indicated that the website had close to 22,000 users across 31,000 sessions who accessed an average of two pages per session, with each session lasting, on average, about two minutes. About 70% of the web accesses were from new visits; 30% were from returning users.

Figure 5. Website Overall Access and Usage



As the project PI said, "The project's curriculum, available free at http://www.guitarbuilding.org, supports the *Next Generation Science Standards* (*NGSS*) and *Common Core State Standards,* and features plug-and-play modular learning activities [faculty] can use for any type of course, whether it's science-based, engineering-based – even [for] English you could use some of our curriculum." The faculty participants truly appreciated these materials. A typical testimonial of one of the faculty participants in an unsolicited email supports this: "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."

Project Implementation Highlights

Project Team Process and Involvement in Planning Process

As in the previous years, the project PI, together with the 15 key project personnel from the six project partner organizations, worked together in implementing the **LEAD with GUITARS in STEM** project. Project implementation included continuous planning, recruitment of faculty participants, offering 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 (with corresponding Quia pre-post assessments). Quia remains the software used by the project for administering pre- and post-test student content knowledge assessment. The Year 2 report explained the background and the use of this software for the project (Castañeda-Emenaker, Morrison, & Dariotis, 2015).

Continuous planning and development is a hallmark of this project. The project team has developed a collaborative group process of meeting regularly (twice a month) via telephone to discuss the project, confer about project issues, and make decisions as necessary. The four project team task forces - budget and finance, performance measurement, reporting and publishing, and partnership management - remained the same during Year 3.

At least once a year, the team meets face-to-face for major project debriefings and learning as well as planning for the upcoming year. Figure 6 shows the team in a huddle during its face-to-face meeting in Mesa, Arizona. Not all team members were in attendance during this session, but all were provided with updates and information via email and telephone follow-up conversations.

Figure 6. Face-to-Face Team Meeting

Photo credits: James Cordero

Another key aspect of the project team's continuous planning and development was the development and execution of plans for the 2016 STEM Guitar Building Institutes (GBIs), which were held in seven different locations. Another GBI, the 8th one in 2016, is ongoing as of this report. Applications for GBI venues were accepted and vetted in late winter before the eight final sites were determined. Recruitment email information was sent through different email listservs and organizations, and was also published on the website. Over 250 high school and college faculty completed the 2016 Institute online application. The main criteria for acceptance were intention to implement the program, high-need schools, written administrative support for implementation, and demographic diversity of applicants.

Implementation of the Guitar Building Institutes (GBIs)

As the team prepared for the GBIs, continuous review of curriculum design and content and the MLAs as well as the support provided to faculty were important aspects of project planning and development. More than just alignment with Common Core, Next Generation Science, or other district standards, and industry skills competencies, the team was sensitive to what is important to faculty and conducted implementation follow-ups and reviews of processes in response to expressed needs and challenges from faculty. A webinar with accepted applicants was conducted about two months before the start of the GBIs to provide more information and context for the project and the Institute. Implementation processes were clarified, including the

IRB consent process and the use of Quia. A videotape of the consent process was produced to ensure that communication about IRB requirements is consistent across all GBIs. The Quia information video was also enhanced for further clarity. The actual guitar build process was streamlined and the sequence of the academic and actual guitar build part of the GBI was also altered. Faculty participants rated the Institute and the Institute instructors using a five-point scale (1 = poor, and 5=excellent); the average overall rating was excellent (M=4.4, SD=1.52, n=100). The following comments are representative of typical faculty participant responses:

> *Thank you. This experience was outstanding and I look forward to utilizing this engaging medium to inspire students to develop and advance their natural curiosities in the problem solving languages and science and mathematics. Instructors were clearly experienced professionals, capable of managing a diverse group of participants, some with little or no knowledge of math, others with little or no knowledge of tools, others with little or knowledge of music/instruments.*

> *There are so many positive parts to this institute. The most important thing that I took away from this experience was that it is all for us (students) and that the people doing this are not here to collect a paycheck. They are passionate professionals that do this because they want to not because they are getting paid to be there. Thank you all.*

Participants were very much enthusiastic about the actual guitar build. Figure 7 shows participants in different phases of the actual guitar build.

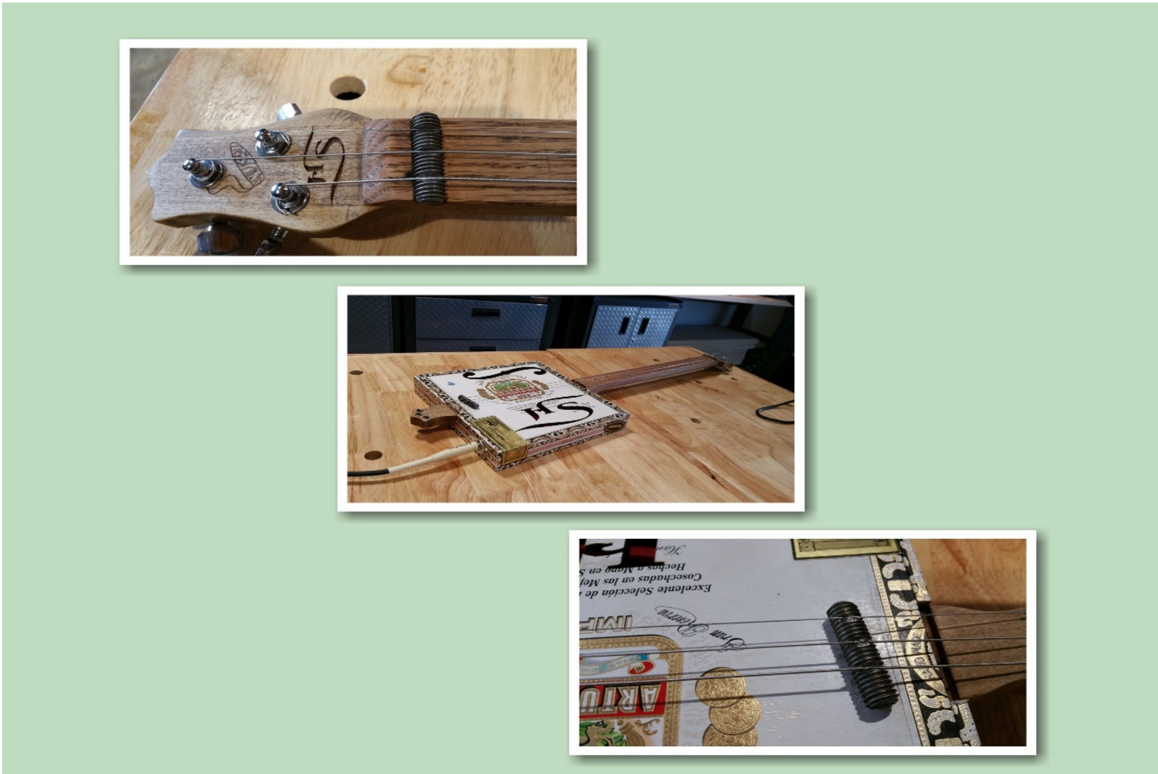
Figure 7. Faculty Participants in Different Phases of Guitar Build

Photo credits: James Cordero

The project team regularly reviews the project portfolio, which includes financial incentives and faculty materials to encourage project implementation (use of the MLAs and the actual guitar build) in classrooms. Emails from faculty and guitar kit orders indicated that they continued to implement guitar building and integrate the MLAs in their classrooms. Newly submitted MLAs were reviewed by the project team before being released on the website as additional resources for other participants. As of this report, less than 10 faculty have submitted new MLAs. In 2015-2016, the following orders for kits and materials needed in guitar building were recorded: 1,345 Full Guitar kits (Guitar+Bass+Econo+Strat Style), 136 Electronics kits, 51 Classroom Start-up Tool kits, 44 Drill Block kits, and 23 Sandpaper kits. Even with provided incentives, Quia data gathered as evidence of MLA implementation and the faculty and student follow-up surveys were relatively few. The highest number of faculty who reported using MLAs was 51 (out of 126 faculty from Year 1 and Year 2), and only six faculty completed the follow-up survey (out of 126). Only 450 students' pre-test data could be matched with their post-test data, and only 65 students provided completed retrospective surveys. Faculty reported experiencing project implementation challenges because of the demands on their professional time as a result of new Common Core / Next Generation Science Standards, district standards, standardized testing preparation, and faculty performance evaluations. Data from the follow-up interview with 142 sampled faculty indicated that about 91% of the faculty were implementing the guitar building and concepts in their classes. It is clear from these responses and email communications that "implementing," for faculty, means conducting a guitar build and doing some MLAs without necessarily completing assessments and/or surveys for the needed project data. Slightly more than 9% reported barriers such as administrative support, funding (including the need for tools and equipment), and lack of clarity in terms of the concept applications in class.

A site visit conducted by the evaluator with an implementing college in Omaha, Nebraska, supported the data from the follow-up survey that faculty are implementing guitar building concepts and are enthused about the guitar build and integration in their classes, but do not necessarily see the relevance of the follow-up data and the use of Quia in these classes. Although this college in Omaha did not use Quia in its classroom assessments, it went beyond the guitar build curriculum by exploring and extending the idea to building of a "shamisen," which also proved to be financially feasible for them. Figure 8 shows the picture of the "shamisen" built in a class in Omaha. Note the use of tobacco box container and the readily available hardware bought supplies and materials.

Figure 8. Picture of "Shamisen" Built in a GBI-inspired Class in Omaha



The project team is now identifying "champions" among faculty who have adhered to the project implementation requirements and have provided their implementation and student data. These champions are being encouraged to present their guitar building experiences and data at the 1st STEM Guitar Summit during the M_STEM conference in Tulsa, Oklahoma, in November 2016.

Project Support for Faculty

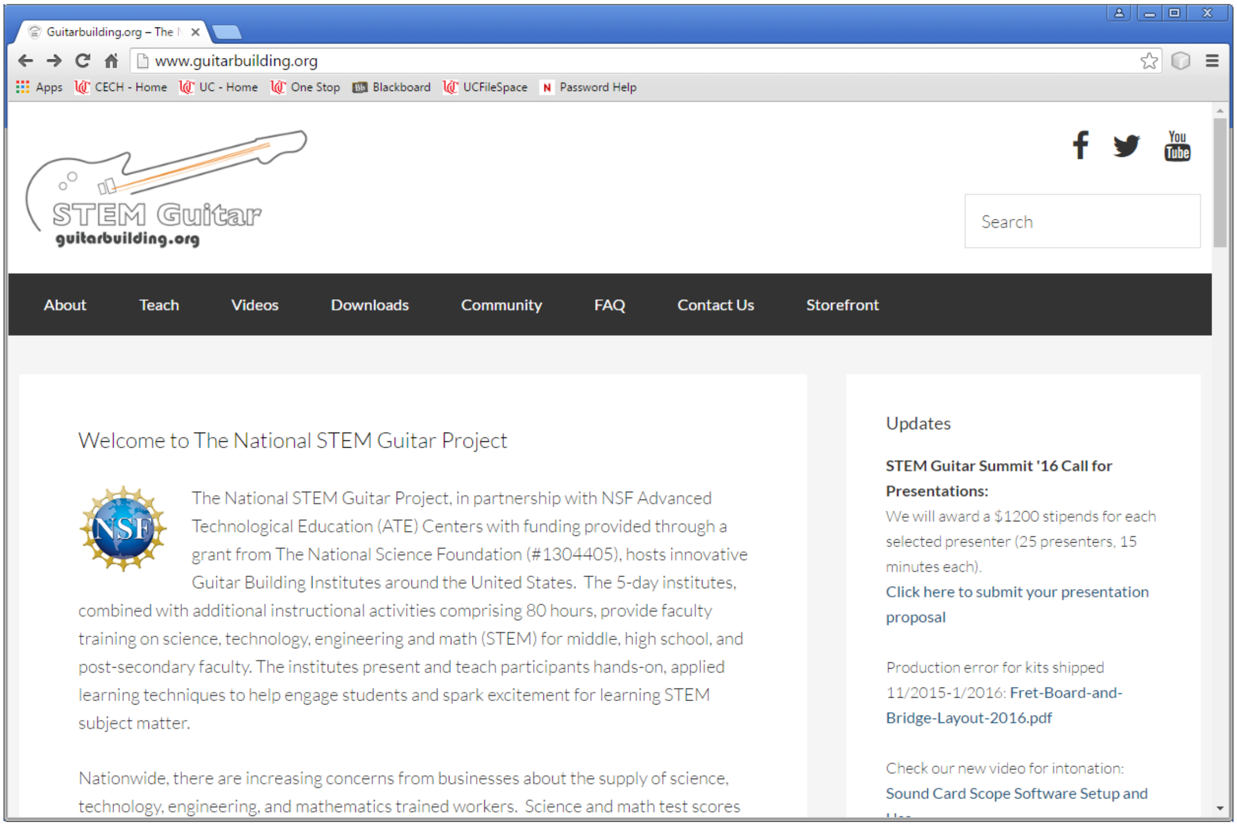
Support for faculty is a high priority for the project as is the evaluation of any professional development program needs to inform support provided to faculty who underwent professional development training (Guskey, 2002). **LEAD with GUITARS in STEM** provided faculty support in four major areas: (1) expert availability for consultation (face-to-face, telephone, email, or webinar); (2) a website (www.guitarbuilding.org) as a resource for curriculum materials and other information; (3) a supply chain; and (4) opportunities provided for project visibility and community support.

The guitar building expert leads (Instructors) in the Institutes become the main link to the faculty trained in that particular GBI. The guitar building experts are the first tier of help available to faculty participants, especially for face-to-face assistance. All project team members are available via telephone or email. Email and phone seemed to be the most common ways in which the individual project team members supported the faculty. Emails from faculty were received almost daily (also, occasional phone calls), either to share their successes or to ask for more help and information. The webinar organized prior to the Institute is now part of the process. In general, faculty feedback about this was positive, but some 2016 GBI participants missed the webinar and were not able to view the webinar video. Other participants reported the need for more focused and useful information from the webinar session. Faculty comments reflect this sentiment:

> *One issue I had was that the webinar was scheduled during the school day, thus not possible for me to attend.*
>
> *I missed the webinar due to it being during my scheduled teaching hours at a public school in Arizona. One thing I would recommend improving is the scheduling of the webinar so participants across the USA can participate. I realize this might be challenging since the West Coast is 3-4 hours behind the East Coast.*
>
> *I wasn't able to listen to the initial webinar, so having it available to listen to later was very helpful. I was fully engaged all the time, in fact it was difficult to stop. I wanted to keep working.*
>
> *I felt that the webinar had a lot of statements like, "We're going to tell you more information about certain aspects..." but none of that information was really delivered until attending the institute. I understand the idea that the webinar is important, but it didn't seem as focused or as tight as it could have been for helping me understand the purpose and goals not only of the institute but looking beyond that.*

Since the start of this project, the www.guitarbuilding.org website has provided a comprehensive source of help and support for faculty and other stakeholders (including school administrators, parents, and the larger community) in the program. The website has been reorganized to be more user friendly and to help faculty find materials more easily. The original "BUILD", "LEARN", and "SHARE" tabs have been removed. All items needed by the faculty for implementation are now contained in one tab, "Teach" (Figure 9). Other resources can be found in "Videos" and "Downloads." The previous reference to website access and faculty feedback about usefulness of materials reinforces the need for the project staff to keep this resource updated.

Figure 9. Home Page of STEM Guitar Website



With more trained faculty and the growing popularity of the project, the project team is exerting more effort to grow its supply chain. Various options are used, such as soliciting the participation of different schools in the manufacturing of the guitar parts as well as checking other material sources and importing them as needed to provide a consistent supply of reasonably-priced guitar kits. The project is now offering less expensive kits, noting that budgets and financing are some of the issues schools mention in implementing the guitar build.

One of the major targeted efforts of the project team is to provide opportunities for faculty to increase project visibility and enhance community support. The project shares specific suggestions, guidelines, and "cheat sheets" with faculty as well as templates for soliciting traditional media, social media, and other publicity exposure. The project has a marketing expert who targets publicity for the project locally, regionally, nationally, and, in some cases, even internationally. Improved project visibility and community support within the school community and the larger community continues every year as faculty share this information on a regular basis. Of the hundreds of emails received on during Year 3, faculty shared either local news highlights or articles in their locale (e.g. Chicago Tribune, Laramie Wyoming Newspaper, Community College Week Magazine), awards received by faculty as a result of the guitar project (a recipient of the 2016 Tri-Cities Crystal Apple Award; a recipient of the Robert E. Yager Foundation Excellence in Teaching

Award), and links to You Tube videos of activities that were highlighted and posted on the guitarbuilding.org website, and media highlights in more than 50 of those emails.

Summative Results

The summative aspects of this report include faculty perspectives on the utility of the Institutes and the MLAs, faculty reported effects of the GBI on their attitudes and instructional processes, and student engagement with, attitudes toward, and skills learned from the project. Planning for sustainability is part of the ongoing project activities that transcends the project's formative and summative initiatives.

Faculty Perspectives on the Utility of the GBI and MLAs

Faculty perspectives about the utility of the GBI and MLAs were reflected in the way they responded to the retrospective survey at the end of the 2016 five-day institute. Participants were asked questions about the sessions, the content, environment and design, and the MLAs.

Faculty participants (n=100) reported that the GBI sessions were very good. This is shown by the average score created using the 14 items regarding various sessions of the institute (M=4.2, SD =0.71). These questions related to the different sessions of actual guitar building (from the guitar primer to the intonation and tuning) and were loaded on one factor construct labeled, "Sessions." The scale used was 1 = poor; 2=below average, 3=average, 4=very good; 5=excellent.

Table 1 shows the paired sample t-test results for the pre-post faculty responses regarding the GBI's content, design, and environment, and the MLAs. Seven questions were loaded on one factor construct labeled, "Content"; 18 questions were loaded on one factor labeled, "Design and Environment," and ten questions were loaded on one factor labeled "MLAs." Means were computed for each factor/construct across the rated items on a five-point scale (1= strongly disagree, 2=disagree, 3=neither, 4=agree, 5=strongly agree). As shown in Table 1, faculty perspectives significantly changed from pre- to post-test for GBI Content, Design and Environment, and MLAs. Before the GBI, the faculty reported some disagreement with the organization and relevance of GBI content but shifted to greater agreement that the GBI content was organized and relevant. They did not agree that the design and environment of the GBI was clear and adequate or sufficient. At the end of the GBI, they were neutral about design and environment, perhaps because they were able to finish their own guitars.

Table 1. Faculty Perspectives about Content, Design, and MLAs

Measure[1]	Means and Standard Deviation Pre	Post	Paired Sample T-Test (two-tailed)
Content	M = 2.5 SD = 0.27	M = 3.8 SD = 0.36	$t_{(100)}$= 3.81, p< 0.009**
Design and Environment	M = 2.2[1] SD = .47	M = 2.9[1] SD = 0.66	$t_{(100)}$ = 2.86, p< 0.011*
Alignment of MLAs	M = 3.1[1] SD = 0.24	M = 3.9 SD = 0.32	$t_{(100)}$ = 4.06, p=0.003**

[1]Scale: 1 = strongly disagree…5 = strongly agree; significance level: *p<.05; **p<.01

These perspectives were supported by many participants' comments about the adequacy of the time for the sessions, especially for the actual building of the guitar. At the beginning, the faculty were neutral about the alignment of the MLAs to the required state standards and the usefulness of the MLAs. At post-test they had greater agreement that the MLAs were aligned and useful for the subject areas they are teaching. Most of the comments about the Content, Design and Environment, as well as MLAs were generally positive. Some suggestions were offered regarding improving the webinar in preparation for the GBI, the content, pacing, having more tools and materials, and more clarity with the MLAs. Below are examples of faculty comments:

> *The content of Institute was very empowering. Things that I sort of knew how to do I was thrust into and I had to do them. I overcame my fears and trepidations time and time again. This helped me in many ways. Also, the diverse backgrounds of the participating teachers helped me gain insight into what I do in my school from a whole different perspective. I feel that I would now be able to point some "troubled" students into a completely different life path, one that would offer them success and fulfillment that they may otherwise never know.*
>
> *All my negative expectations were defeated. All my positive expectations were vastly exceeded.*
>
> *Outstanding concept and the instruction was fantastic. I see how this can further the educational experience of students everywhere, as well as increase interest in school based activities.*
>
> *The institute was very informative and details of construction were thoroughly given. The opportunities to solve problems and different ways to solve problems that may arise was also very helpful.*
>
> *This institute exceeded my expectations. Not only did I learn about building a guitar, but I learned all of the theory behind how it all works.*
>
> *Before coming, I was apprehensive about how well this could actually be done at a high school setting. I had trouble convincing any other engineering and technology teachers to sign up with me. One person even commented that they thought this program was a gimmick to sell their product to schools without much educational value. I told them to look at the MLAs online. I can't wait to show them all that can be taught within this program. The MLAs were very appealing to me*

and I wanted an electric guitar to apply the MLAs to my content whether I could actually build with my students or not.

The institute was very intensive, it would have been nice to have two weeks to build. Understood that follow up activities are given ample time to complete, developing the MLA could use more direction. However, not giving too much parameters about the learning activities also opens more opportunity for creativity and introduction of different methods of leading a learning activity.

Before coming to the institute, I had no idea what the "implementation" would look like in terms of after attending. It took about 2 days of conversations to be able to understand the after-institute expectations of how implementation would look. I would suggest that the webinar have a bit of information about the variety of ways possible to implement the ideas presented here by the project. Also, I felt that the webinar had a lot of statements like "We're going to tell you more information about certain aspects..." but none of that information was really delivered until attending the institute. I understand the idea that the webinar is important, but it didn't seem as focused or as tight as it could have been for helping me understand the purpose and goals not only of the institute but looking beyond that.

Great instructors. Would really like a checklist for building the guitars and/or a network to communicate with other participants to share information. There were so many great details and reasoning given by the instructors that might be hard to remember by the time this is in progress in my class.

It seemed like we were waiting for tools all the time. We had many demos and then a couple of people would start using the tools and we would be waiting. I would suggest a couple more stations or assigned stations with certain guitar bodies or styles. I feel like we spent more time looking for tools but having assigned groups would be more helpful.

I found that the history and the variety of different guitar types was less valuable for this type of introductory course. If I had more prior knowledge or the institute was longer, I may have been able to apply that information better.

Effects of GBI on Faculty Attitudes and Instructional Processes

Faculty Confidence in Teaching STEM. Table 2 shows paired pre-post sample t-test results for faculty reporting their confidence in teaching STEM. Eight questions rated on a five-point scale (1=poor, 2=below average, 3=average, 4=very good, 5=excellent) were loaded on one factor labeled, "Confidence in Teaching STEM." The faculty entered the GBI rating themselves *average* in terms of their confidence in teaching STEM. They later reported *very good* levels of confidence in teaching STEM. This particular survey result is supported by several faculty comments immediately following the GBI that shows their confidence and how GBI has affected their teaching processes:

I am completely confident in this program's ability to engage students and to allow them to learn STEM skills in ways they may not think possible. I say this as I myself experienced just this.

I was inspired to dream about how I can use this engaging practice to show students that the STEM subjects are useful and fun!

How 'bout it! Usually this time of year, I try hard not to think about school at all, but I'm finding myself kind of excited about the fall and what I can bring to my students! Thanks!

The Institute truly blew me away. Every aspect of the workshop was amazing. There has not been a workshop, project or content area that has fueled my desire to teach like the guitar building workshop has done for me this week.

The Institute was fast-paced and challenging, and each day I left wishing I could have a bit more time in the lab to build, test, and refine!

Table 2. Faculty Confidence in Teaching STEM

Measure	Paired Sample Means and Standard Deviation: Pre	Paired Sample Means and Standard Deviation: Post	Paired Sample T-Test (two-tailed)
Confidence about Teaching STEM	M = 3.0[2] SD = 0.40	M = 3.8[2] SD = 0.48	$t_{(100)} = 6.63$, p<0.001**

[2]Scale: 1 = poor…5 = excellent; significance level: ***p<.001

Effects on Faculty Instructional Process. Faculty attending the 2106 GBIs were very positive above their adoption and adaptation in their classrooms of the concepts they learned during the GBIs. Faculty comments after the GBI showed much promise, not only in terms of changes in their instructional process, but in possibly influencing their institutions and colleagues in adopting/adapting this concept. This is supported by the following representative comments:

I will use everything from immediately (in the fall) implementing the MLAs into currently existing course and developing an entire course based on this week.

This project has the possibility to revolutionize how we teach. It is truly an interdisciplinary project that pulls in every discipline.

I have so many ideas on how to incorporate this into my classes and they have not stopped coming.

I always put my students first and this institute shows me that I am teaching for the right reasons...my students!!

I am going to create learning activities to help my students learn key mathematical and science concepts that I would otherwise not cover. This institute has provided me the tools and resources to teach the skills to help my students better achieve their goals in my classroom.

I will be implementing this program into my classroom to try and give the kids a hands on way to experience the science and math that they are learning. I also hope to get some kids actually building and using the CAD technology that they have never really used before. This will increase *their experience in engineering which I find is the part of STEM that my students tend to be lacking.*

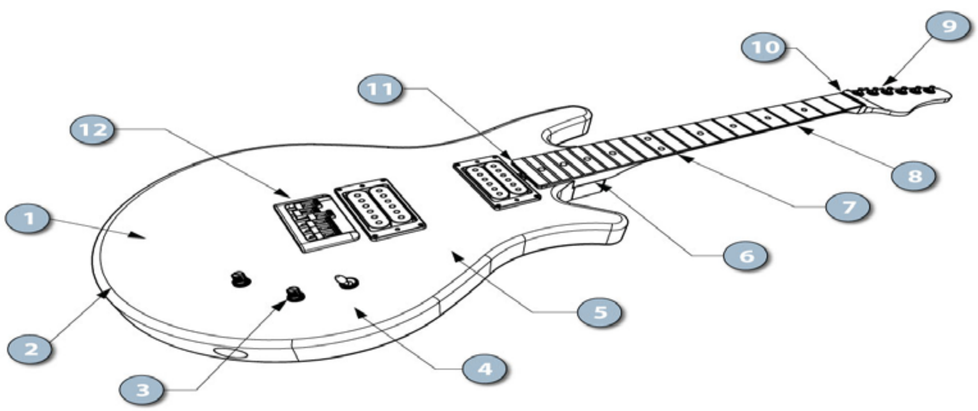
I found the most valuable learning form this institute to be the way in which I can teach a variety of different STEM concepts within the content that I teach. The institute has provided me personal feedback and recommendations on how my particular classroom can benefit from the implementation of the guitars.

I will be replacing certain examples or class project with ones from the institute (MLAs) and us my own guitar as an example. Hopefully, I will be bringing builds to our campus in a couple of years.

I want to bring this institute to my university as a faculty development opportunity, as well as integrating into a class I teach.

The faculty reported that the GBI influenced their instructional processes as guided by the GBI-inspired guitar build and curricular integration. Figure 10 shows different guitar parts with corresponding curricular lessons as included in the MLAs. Faculty reported generating more ideas for curricular integration. This visual, as presented on the website, is interactive and made available to the faculty and everyone accessing the website to give ideas of how the guitar build parts could be related to interdisciplinary STEM lessons.

Figure 10. Curricular Activities Related to Guitar Parts



Seventy-seven faculty reported using at least one MLA in the classroom. The most popular MLA, based on the number of teachers implementing it (n=77), was Threaded Fasteners with 292 students. Based on the highest number of number of students involved, Guitar Anatomy and Cost was reported by 30 faculty with 456 students involved. The least popular MLA was Guitar Neck & Truss Rod, with six faculty implementing it and 37 students involved (Table 3).

Table 3. Number of Faculty and Students Involved with MLAs

MLA Quizzes	Number of Faculty (n)	Number of Students (n)
Threaded Fasteners	77	292
Fret Spacing	51	324
Guitar Anatomy & Cost	30	456
Set-up	30	58
CAD & CAM	25	96
Scale Length	19	86
Electronics	16	260
Intonation	16	93
Wood for Guitars	15	118
Guitar Body Geometry	14	156
Tolerances in Engineering	9	84
Guitar Neck & Truss Rod	6	37

Faculty Implementation Feedback

Faculty feedback regarding excitement over the curriculum and guitar building, and the effects of these on students has been encouraging. They noted the relevance of the project for enhancing their classes and integrating the concepts into different subject areas. The following faculty comments indicated different ways they integrated and extended the curriculum:

I think it is a wonderful experience for students to do as it incorporates the math and science.

It is a cool way to teach physics and electronic applications.

The creation of an electric guitar can be the core of an entire STEM curriculum. Quite from class:" you could build an entire school around this".

The course is a fantastic way to learn the STEM as well as basic woodworking skills.

Guitar building has changed the way I teach.

I am currently working on a ukulele project with some students. We can teach STEM concepts with the Ukulele, not only with the guitar, and the project costs less than $ 50.00.

We think we are going to go with a class making cigar box guitars next year.

Results based on the faculty follow-up interview survey reflected competing demands on faculty time, lukewarm or no administrative support, budget limitations to buy tools and equipment, and not having enough clarity regarding the integration of MLAs into their classes. These aspects impeded their ability to fully implement the STEM guitar curriculum. These results are based on reports from about 9% of the faculty; 91% of the sampled faculty interviewed were implementing the project with adaptations but not necessarily using Quia and/or completing follow-up data collection efforts.

Students' Guitar Building Skills and Related STEM Content Knowledge

Content Knowledge

Table 4 shows results of the students' pre-post Quia assessments administered by faculty who implemented the MLAs along with their guitar build activities. All of the 12 MLA quizzes administered showed significant improvements in students' related content knowledge as indicated by the post-test percentage results of correct answers. The range of percentage scores on the pre-test was 30% to 70%; on the post-test it was 70% to 95%. The three MLAs implemented with the most significant pre-post assessment differences were Electronics (50%), Guitar Anatomy and Cost (difference of 35%), and Fret Spacing (difference of 34%).

Table 4. Pre-Post Tests Results Using Wilcoxon Signed Test

MLA Quizzes	Pre-test Median Percentage	Post-test Median Percentage	Z-Statistics
Guitar Anatomy & Cost (n=456)	60%	95%	Z= 4.39; <.001***
Threaded Fasteners (n=292)	69%	92%	Z=-6.2 ; p<.001***
Scale Length (n=86)	60%	90%	Z=3.12; p=.002*
Set-up (n=58)	70%	80%	Z= 3.39; p=.001**
Tolerances in Engineering (n=84)	60%	80%	Z=-2.68; p=.007**
Electronics (n=260)	30%	80%	Z= 3.34; p=.001**
Fret Spacing (n=324)	42%	76%	Z= 5.74; p<.001***
CAD & CAM (n=96)	68%	70%	Z = 2.96; p= .003**
Guitar Neck & Truss Rod (n=37)	55%	70%	Z=2.07; p=.039*
Intonation (n=93)	55%	70%	Z=2.07; p=.039*
Wood for Guitars (n=118)	54%	70%	Z=-2.47 ; p=.013*
Guitar Body Geometry (n=156)	50%	70%	Z= 2.42 ; p=.016*

Significance Level: *p<.05; **p<.01; ***p<.001

Student Guitar Building and Other Skills

The faculty members were quick to point out the skills their students learned as they implemented the guitar building concepts. One faculty member said, "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." Another faculty member noted, "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." Student comments about their experiences with the guitar building project show the different skills they learned from the project:

> *I liked getting to use and become familiar with all the different tools and machines that are used in the process of guitar building.*

> *I loved the detailed instruction, and the teacher's details when they are explaining what we are doing and why we are doing it. It also helps that they have a fix for any problem that might arise. Getting hands on and working with power tools was pretty awesome.*

I learned that the physics equations that we've learned in classes were used in determining the design of the guitar.

Each step in the guitar building process takes a lot of attention to create a professional product. It's easier to fix mistakes made later when attention and detail is put in on earlier steps.

I learned how to cut out a scratch guard, the names of guitar parts, and how to tune a guitar.

I learned how to make, paint, and repair guitars.

I can stay focused on how to solder, how to finish a project.

I learned how to wire a guitar, string a guitar, and do a tap test to see if the pots worked.

The three most important things that I learn were how to do soldering, drilling holes, and sculpturing.

Student Attitudes toward STEM and Persistence

Table 5 shows the paired sample t-test results of the retrospective post-survey of student responses regarding attitudes toward STEM and persistence as a result of the actual guitar building experience and exposure to related STEM curricular experiences. Eight grit questions were asked and average scores were loaded to three factors that provide three different aspects of grit (Grit: Concentration, Grit: Motivation, and Grit: Tenacity). The average scores for these factors were based on a four-point scale (1 = not at all like me, 2=not much like me, 3=somewhat like me, 4= mostly like me). Results indicate that students had not changed their concentration and motivation before and after the guitar building experiences, but their tenacity significantly increased.

Twenty questions about student interest about STEM, its importance, usefulness, and application yielded an average score that loaded to "Attitudes towards STEM." The average score for this factor was based on a five-point scale (1= strongly disagree, 2=disagree, 3=neither, 4=agree, 5=strongly agree). The results shown in Table 5 indicate significant changes in student attitudes towards STEM. Before their guitar building experiences, they were neutral about their interest in STEM, and its importance, usefulness, and application. After their academic and hands-on guitar build experiences, they reported greater interest in STEM and recognized its importance, usefulness, and applications to their lives. Student comments illustrate these perspectives.

I enjoyed the project very much and I liked mostly the fact that I got a chance to build something new for the first time. Words cannot describe the feeling that I have.

I liked getting hands on and learning about what goes into creating a final product. After learning about the materials and tools, gaining the confidence in being able to troubleshoot, shape and design a guitar.

I learned that any thing you do u will most of the time use math.

I learned that patience is one of the most important things an engineer needs to have. Must not be afraid to fail and try until you succeed because every problem in your life has a solution. Finally, not be afraid to ask questions once stuck in a problem.

Time, dedication, and hard work pays off.

Table 5. Student Grit & Attitudes toward STEM

Measure	Sample Means and Standard Deviation: Pre	Post	Paired Sample T-Test (two-tailed)
Grit: Concentration[1]	M = 2.8 SD = 0.04	M = 2.8 SD = 0.16	$t_{(65)}$= 111, p< 0.930
Grit: Motivation[1]	M = 2.8 SD = .29	M = 3.0 SD = 0.15	$t_{(65)}$ = 1.6, p< 0.356*
Grit:Tenacity[1]	M = 3.2 SD = 0.26	M = 3.5 SD = 0.17	$t_{(65)}$ = 3.78, p=0.032*
Attitudes Towards STEM[2]	M = 3.9 SD = 0.27	M = 4.2 SD = 0.29	$t_{(65)}$ =-12.91, p=<.001**

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

Sustainability

Sustainability has always been a part of the ongoing project activities. Among the different activities the project pursues to ensure sustainability in the schools implementing the program have been promoting full buy-in at those schools and within their community as well as helping them find ways to fund the program in their area. The project team continues to add more business/industry partners as possible suppliers, employers, and advisory experts. Constant contact and renewal of connections through the Advisory Board, whose members mostly come from existing partners, is underway. The partnership with Boeing to further develop competency skills that match guitar building and curricular program skills with industry needs is in its final stage. Project team members are aware that promulgation of a solid supply chain and business/industry partnerships will have a strong impact on project sustainability.

Challenges and Lessons Learned

The following challenges and lessons learned are based on the data presented and analyzed during Year 3.

- Although Guitar Building Institute (GBI) participants were vetted before selection, selection was based on completed application status. Actual participants did not adequately represent underrepresented populations, although current participants are diverse in terms of demographic information.

- The current location of the Institute sites and faculty who are implementing the STEM Guitar curriculum across 44 states is a great success; six states have yet to be included.
- Faculty and students often do not appreciate the importance of data collection to document program implementation and skills development, as evidenced by survey non-completion.
- Although written administrative support is required for the GBI application, faculty still experience administrative challenges, including making adjustments when there are administrative changes in their schools.
- Not all faculty participants attended the webinar or took advantage of the webinar video recording. Thus, the GBIs had different levels of participant orientation, making it more challenging for Institute instructors during on-site sessions.
- Some faculty (albeit a small percentage) indicated issues around unclear integration of MLAs into their subject areas. This must be addressed in the next GBI.
- Providing incentives has not been enough to get participating faculty to fully implement the guitar building program in its entirety, including requirements for actual build, curricular content, and providing data to support the results of the implementation.
- Despite anticipating barriers with faculty in pursuit of full program implementation, the project team has to work hard to find ways to enhance and support full implementation of the part of all participating faculty.
- Although cheat sheets and guidelines are provided to participants for use in dissemination and to increase media exposure, information from schools is provided in differing formats, making it challenging to compile and showcase media exposure in project reports.
- There have been many dissemination efforts and successes on the part of the project team and participating faculty, but this information has not been gathered systematically, thus making information retrieval challenging.
- The project intended to identify “champions” who implement the project fully, including data collection, but this has not been done systematically.

Recommendations

- Increase targeted recruitment of 1) underrepresented faculty and/or faculty who 2) serve underrepresented students. Distribute GBI applications via groups and associations where there is a greater likelihood of receiving applications from underrepresented populations.
- Six states are not yet included. Ensure that faculty are invited to GBIs who are from these six states and/or choose the next GBI host venues in areas where attendance will be easier for faculty from these six states.
- Keep up-to-date with administrative support of faculty and help facilitate information campaigns and/or orientation of administrative staff and leadership. Perhaps plan a GBI or a webinar geared toward administrators to help obtain their buy-in.
- Ensure better communication about the availability of the webinar video recording, since accommodation of all schedules are not possible when scheduling webinars.
- Plan the webinar program so that it is focused on more relevant information that is addressed in an optimal amount of time.
- Continue to solicit faculty perspectives on how MLAs can be integrated in their classes. Additionally, obtain their perspectives about their use of social media to help them with their school work in order to have a better understanding of how the project can facilitate guitar building related curricular development and understand how the use of website resources could help improve learning within the professional community.
- Conduct follow-up webinars on Quia for any participants who may need them, and ensure more frequent check-ins with participants trying to implement the STEM Guitar curriculum to support them with their challenges with Quia assessments and faculty and student surveys to ensure good data.
- Review the information included in the Quia pre-post assessments to ensure accurate pairing of pre- and post-tests and to collect relevant information to facilitate data triangulation with the qualitative data.
- Review "cheat sheets" and guidelines developed to help faculty with their dissemination annually. Include this as a webinar agenda item to ensure that information from faculty flows in smoothly and that reporting formats aid in easier tracking and reporting.
- Ensure that **all** dissemination efforts, especially by the project team, are catalogued and/or annotated and written so that they can be easily cited.
- Use STEM Guitar champions to take turns initiating meaningful conversations using different social media forums and/or on the guitarbuilding.org website itself to initiate

the formation of learning communities. Follow up with the efforts of these champions to provide good data as models for the rest of the faculty.

- Ensure that the information shared by faculty champions in the STEM Guitar Summit serves as a model for collecting and sharing data for the project.
- If the project intends to expand across all 50 states, champions from non-implementing states should be solicited to spearhead Institutes in their areas.

Conclusion

The **LEAD with GUITARS in STEM** project met and surpassed the targeted number of participants (122) trained in its Guitar Building Institutes. The project continues to experience challenging yet positive experiences in its project implementation during its first two years of STEM Guitar curriculum integration in classrooms. Project processes and supports are in place. Incentives, however, have not been enough to overcome other demands on faculty time, such as faculty evaluation processes, state and district/school demands for alignment to Common Core and Next Generation Science Standards or other standards, standardized state testing for students, funding issues, and challenges in integrating MLAs into their classes. These competing demands on faculties' time and the resultant challenges will remain as barriers even during the extension year if these issues cannot be addressed or resolved. Data issues cannot be taken for granted, since poor data threatens the intention to make data-driven decisions. It is clear for those who persevered through the implementation requirements and data sharing regarding their STEM guitar experiences that this project is very useful and relevant for both faculty and students. The project has the potential to change students' lives as they learn more STEM-related skills and improve their attitudes towards STEM and STEM careers. The project reached 44 states in Year 3. It has the potential to reach across all 50 states if concerted efforts are made to find potential champions in states currently without STEM Guitar programs. The project sustainability effort is ongoing, increasing industry and business partners and creating more robust supply chains, and thus will be of great help in continuing the program even without federal funding.

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Appendix. Project Evaluation Questions

For the process/formative project evaluation:

1. To what extent has the recruitment process for the project:

    a. ensured the involvement of the underrepresented groups?

    b. facilitated the commitment of the school administration in supporting the curricular integration of the LEAD GUITARS lessons into their district/school curriculum?

    c. met the targeted core team of STEM faculty(s) in terms of reach, targeted number, diversity in demographics, and span of STEM subject areas?

2. How well did the project team implement the professional development Institutes planned in this project in terms of stakeholder involvement in the planning process, seamless Institute hosting partnerships with the NSF ATE national and regional centers, positive reactions to the Institutes, number of modules developed, plans for developing and implementing more modules?

3. How effective were the coaching and support provided faculty(s) in developing their LEAD GUITARS modules?

4. To what extent did the faculty(s) adhere to the implementation requisites of the LEAD GUITARS modules developed through the course of the project?

5. What different activities were handled by the project team in order to:

    a. support faculty(s) implementation of the use of guitar building concepts,

    b. identify the project Champions,

    c. enhance the supply chain system,

    d. ensure that students have an environment conducive to the workforce, and

    e. facilitate the development of long-term relationships with the administrators, industry, and community partners?

6. How effective were the implementation support activities provided by the project team to the faculty(s) involved in the project?

For the outcomes/summative project evaluation:

1. In what ways has the project enhanced the utility of the LEAD with GUITARS in STEM developed modules during the Institutes and the course of the project in terms of sharing and dissemination through the national conferences and web portal?

2. To what extent were the faculty(s) attitude and self-efficacy in teaching STEM content improved as a result of the project?

3. To what extent were faculty(s) instructional practices improved as a result of implementing the LEAD with GUITARS in STEM modules?

4. To what extent did the project participants' students:

    a. improve their motivation and engagement (cognitive engagement in terms of short cycle assessments and manifested applied learning; behavioral engagement in terms of social awareness, relationship skills/team building skills; and emotional engagement in terms of their self-efficacy) in class,

    b. improve their attitude toward and aspirations for science careers, and

    c. manifest teamwork, project management skills, problem-solving skills, knowledge of manufacturing processes and materials, and sense of quality, and awareness of entrepreneurial techniques?

5. In what ways could the project be sustained based on:

    a. the project team's efforts in expanding and enhancing the supply chain,

    b. the development of structures and systems for LEAD GUITARS' curricular development and implementation, and

    c. the developed relationships with school administrators, business, and community partners?