

Learning to play the guitar at the age of interactive and collaborative Web technologies

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ABSTRACT

Recent advances in online technologies are changing the way we approach instrumental music education. The diversity of online music resources has increased through the availability of digital scores, video tutorials and music applications, creating the need for a cohesive, integrated learning experience. This article will first explore how different technological innovations have shaped music education and how their actual transposition in the digital world is creating new learning paradigms. As a practical illustration of these paradigms, we will present the development of a new online learning environment that allows master-apprentice or self-taught learning, using interactive and collaborative tools.

1. INTRODUCTION

In order to understand how technology can help a self-taught learner, or a learner in between lessons with a master, we must present the specificities of private and group lessons. In this introductory section, we will identify the learning processes in place and determine which are missing when the learner is left alone. We will then review how technology has been used to mitigate these in the past and how new Web technologies can be used today.

1.1 Group Music Classes vs Private Music Lessons

Table 1 describes the master and the learner activities. It identifies the modalities in place and the type of feedback that is possible between them. In the typical context of a private lesson, prior to any lesson, both protagonists will discuss the learner's intrinsic motivations. The master will adapt his teaching according to the learner objectives and prior knowledge. This differentiated teaching will continuously occur throughout the lesson series since the master will adapt his teaching to the learners progress. During a lesson, the learner observes and receives direct instructions from the master, but he also plays with his master. That allows him to regulate his action according to what he observes, ears and feels. The learner also has

the ability to discuss his sensations with his master and to receive feedback on his action. All these interactions are believed to contribute to learning and to help to maintain motivation.

Similar activities can be observed in group lessons. In that context, there might be less emphasis on individual objectives and progression but a gain benefit on interaction with peers. In a group context, the attention of the master is shared between the learners. Learners are able to regulate their action with respect to the master, to the group and among themselves. Learners can discuss their sensations and request feedback from peers, and consequently form a community of practice.

1.2 Informal learning in-between lessons or in the case of self-taught learners

Table 2 presents the tasks of the learner in-between lessons (or in the case of a self-taught learner) and relates these to the learning and teaching activities presented in Table 1. It shows which technologies can be used to mitigate the absence of a master and of peers. For each activity, the table presents different types of technologies and gives a few examples of existing commercial and research solutions.

1.2.1 Search for Material

One of the tasks the learner might want to perform is to search for new material. A typical self-taught learner will want to search for his favourite artists' songs. Websites to share tablatures exist on the Web for a long time. At first, this information was stored in simple text files using ASCII characters to represent strings and fret positions, techniques and chords information. The Ultimate-Guitar Website [16] (see Table 2 for all technologies' references) is one example of this type of sharing platforms. Nowadays, these sharing platforms have evolved and can display the score in standard western notation and advanced tablature notation. They also offer playback functionalities and permit, for example, to modify the playback tempo or to loop sections of the score (Songsterr [15] is one of these). The most elaborate interfaces will even link and play synchronously audio and video recordings of a performance (Soundslice [14], JellyNote [13]).

Music information retrieval algorithms offer new possibilities to extract playing instructions directly from a recording. There already exist some commercial software applications where one can input audio recording and

No.	Teaching activities	Learning activities	Modalities	Feedback
1	Ask the learner(s) about his / their goals and motivation. Perform a formative evaluation to determine group or individual level.	Tell the master about his / their goals and motivation. Perform the request evaluation.	Aural, visual, tactile	Discuss the feasibility of the goals and objectives. Help to establish attainable goals. Determine the necessary learning path and steps for the group or individual.
2	Prepare adapted material.	Receive the master lessons plan.	Aural, visual	Discuss the learning plan. Continuous adaptation to the group and to the individual's progression.
3	Explain a concept, an exercise or a musical excerpt.	Listen to explanation of a concept, an exercise or a musical excerpt.	Aural, visual	The master can give oral or written instructions (annotation on a score or in a lesson book) to the learners. Learner(s) can also take personal notes.
4	Perform a demonstration on the instrument.	Observe the master demonstration.	Aural, visual	The learner(s) can ask the master to repeat all or part of the demonstration. The learner(s) can ask for more information.
5	Ask the learner(s) to perform a musical excerpt or an exercise individually or in groups.	Play a musical excerpt or an exercise individually or in groups.	Aural, visual, tactile	The master can give oral or written instructions (annotation on a score or in a lesson book) to the learner(s). The master can physically correct the position and gesture of the learner(s). Learner(s) can listen and observe to other learners performance. They can regulate according to the other's performance. They can also discuss and comment peers performances.
6	Perform a musical excerpt or an exercise (including improvisation) along with the learner(s) individually or in groups.	Perform a musical excerpt or an exercise along with the master individually or in groups.	Aural, visual, tactile	Realtime regulation: the learner can adjust his performance to what he hears and observes from the master and from the other learners.
7	Ask learners to practice musical excerpts or exercises (including improvisation) in small groups.	Practice musical excerpts or exercises with peers.	Aural, visual, tactile	Realtime regulation: the learner can adjust his performance to what he hears and observes from the other learners. Learners can also discuss, comment and manipulate each other.

Table 1: Teaching and learning activities in private and group lessons.

retrieve an analysis of the chords and notes played (Chordify [17], Capo [18], GuitarMaster [19]). Non-commercial applications are also developed in the MIR research field to automatically retrieve gestural information from a combination of audio-video or motion capture recordings of a performance and with the use of predictive models [1].

1.2.2 Seeking information, demonstrations and feedback

Two other tasks the learner wants to perform is to search for information and instructions and to find models to observe. These two tasks might be complemented with the will to receive feedback on the comprehension and on the execution on the instrument of what was learnt. Various sources of information for these tasks include text-based questions and answers on forums or social networks, blog posts and dedicated Websites exploiting various types of media. Nowadays, audio and video recordings production is easily available to anyone. Distribution is also facilitated with the use of general platforms for videos (Youtube [28], DailyMotion [30], Vimeo [29]) and audio (Soundcloud [36]). These recordings can then be linked and included in the previously mentioned forums, blogs, and Websites. Waldron [22–27] made an extensive study of different online communities of practice where members are seen as "prosumer", e. i. users that both produce and consume material posted by the community. In these communities, members can, for example, produce instructional audio-video recordings or post advice on techniques they master, and, on the other hand, post their questions or recordings of their performances to request the other members for feedback and comments. The previously mentioned research projects on automatic analysis of performance can also be used for the task of providing automatic feedback to the users. However, to our knowledge, actual commercial products including automatic feedback only use audio analysis for pitch and rhythm detection (Yousician [38], JellyNote [13]).

A special case of applications can include all this

information on a single support. Just as a master would annotate the learner score so that he can go home and practice with that supplemental information, digital scores made possible the concept of augmented score. Augmented scores were first introduced in the VEMUS/IMUTUS project [32, 33] and took the form of annotated scores where the annotations could take various forms: graphical, textual, aural and sonic. VEMUS/IMUTUS also introduced the idea of displaying various analysis curves of the performance in parallel to the score (frequency curves, sonograms, envelope curves, etc.). Nowadays, augmented scores can include data from multimodal recordings of performance and from the analysis of these performances.

1.2.3 Play With Others

Another activity that is frequent in private and group lessons is to play along with the master or with peers. This is a rewarding activity and an important motivational factor. It is often something that a learner would miss when he is alone to practice. As we have seen, nowadays most score editors and score sharing platforms offer playback functionalities. These "virtual players" can use different technologies from MIDI playback to sound synthesis or sampling to synchronization with audio or even audio-video recordings. Some will only play the instrument as others will also include accompaniment by other instruments. Dedicated software like Band-in-a-Box [40] has been long used for that purpose. However, playing along a virtual peer or band is not as rewarding as playing with real peers. For that purpose, projects like I-Maestro [34] introduced the idea of playing over distance. Game platforms like Rocksmith [37] or learning environments like Yousician [38] also use the idea of challenging other users in network performance of a score.

1.2.4 Structure the Learning Path

Finally, as we have seen the availability of online music resources for learning is vast and disparate. Learners often

Tasks	Activities	Technologies	Examples
Search for material	2	digital score editor	Finale [2], Sibelius [3], MuseScore [4], Guitar Pro [5], TuxGuitar [6], PowerTab [7]
		collaborative score editor	JamShake [8], LeadSheetJS [9]
		score / tablature sharing platform	General: NoteFlight [10], Scorio [11], flat.io [12], JellyNote [13], Soundslice [14] Tablature: Songsterr [15], Ultimate Guitar [16]
		automatic audio analysis	Chordify [17], Capo [18], GuitarMaster [19], Songs2See [20]
		automatic multimodal analysis	see [1] for a review
Seek for information and explanation	3	Blog / Forum / Website	Hooktheory [21], specialized Websites (look Waldron [22–27] for references)
		Instructional videos	General purpose video-sharing platforms (Youtube [28], Vimeo [29], DailyMotion [30]), PRAISE [31], TELMI
		augmented score	IMUTUS / VEMUS [32,33], I-Maestro [34], PRAISE (LeadSheetJS) [9]
		Instructional videos	see previous
		3D motion capture and synthesis	I-Maestro [34]
Observe demonstrations	4	Forum, Website	see previous
		social network	general purpose social networks, PRAISE [31]
		video-sharing platform	General purpose video-sharing platforms, specialized Websites
		audio sharing platform	Music Circle (PRAISE) [35], SoundCloud [36]
		collaborative score editor / augmented score	see previous
Ask for feedback / evaluation	5	automatic audio analysis	JellyNote [13], Soundslice [14], Rocksmith [37], Yousician [38], IMUTUS / VEMUS [32, 33], I-Maestro [34], PRAISE [31], Songs2See [20], Magna Quest [39]
		automatic multimodal analysis	see previous
		motion capture / sensors	I-Maestro [34]
		Midi / synthesis / sample playback	score editors, score sharing platforms, IMUTUS / VEMUS [32, 33], I-Maestro [34], PRAISE [31]
		accompaniment software	Band-in-a-Box [40]
Play with others	6, 7	audio recording	IMUTUS / VEMUS [32,33], I-Maestro [34], PRAISE [31], JellyNote [13]
		serious game	Rocksmith [37]
		play over a distance / online competition	I-Maestro [34], Yousician [38]
		serious game	Rocksmith [37], Magna Quest [39]
		learning management system (LMS)	Yousician [38], IMUTUS / VEMUS [32,33], I-Maestro [34], PRAISE [31], Songs2See [20]

Table 2: Technologies used to assist learning and teaching activities.

have to search among many different sources to find resources that fit their needs. This in itself can be a source of motivation lost. However, there exist platforms that try to solve that problem by providing a complete environment dividing the learning in achievable and significant steps that can quantitatively and qualitatively be evaluated. These platforms are of two kinds: serious game and learning management system (LMS). There is no absolute definition of serious games, but what is generally agreed upon is that they are a category of games that uses entertainment and multimedia to convey an experience to the user [41]. In the case of music education, that experience will take the form of a musical skill. Serious games for music are derived from electronic rhythm games that appeared in the 1990s. They have the specificity of using real instruments as game controllers. Rocksmith [37] from Ubisoft is a well-know example for the guitar. Magna Quest [39] is another example emerging from research and applied to the violin.

On the counter part, LMS dedicated to instrumental learning or said otherwise computer-assisted music pedagogy for instrumental learning are derived from the digital form of a pedagogy named programmed learning. Actual LMS use game design elements to keep the learner motivation, this is what is called gamification [42].

In LMS, learning can be organized in levels where the learner can progress on different paths. The learners can compare themselves with others throughout the use of leaderboards. They can follow their progress with progression bars and dashboards. They can unlock new learning paths by taking tests and receiving badges. These badges can be shared on social networks. Learning analytics tools can also be used to inform the learners of their progress and recommend them activities to go further. All these tools are at the disposition of

pedagogical content developers to help them create motivating learning environments. The research projects we review all include an LMS. I-Maestro [34] also includes the idea of collaborative work. While PRAISE [31] introduce social network tools with the Music Circle where learners and masters can share their performances and annotate other learners performance recordings.

2. THE NOVAXE PROJECT

This project will offer a new gesture rich guitar notation as well as an augmented score, allowing learners to access different dimensions of the performance and to create links between the gestural instructions found in a score and the one captured during real performances using a set of sensors. It implies the creation of analysis tools to extract score and gestural parameters from a performance. These parameters are useful to align the score and the performance, to complement the score with performance instructions, to transcribe a score from a performance and to provide feedback to a learner on his performance of a score. The project aims to explore the hypothesis that interaction and collaboration throughout peer reviews and emulation combined with observational learning from a master but also from self-observation can be beneficial for musical instruments learning.

This project was created to address some of the fundamental problems in modern music education. It consists of three main facets; advanced notation, Web-based pedagogical technology, and a highly structured educational system. The main focus of the project is to enhance the musical education experience by making it more intuitive, rewarding, and efficient for both the casual student and the serious apprentice. The project

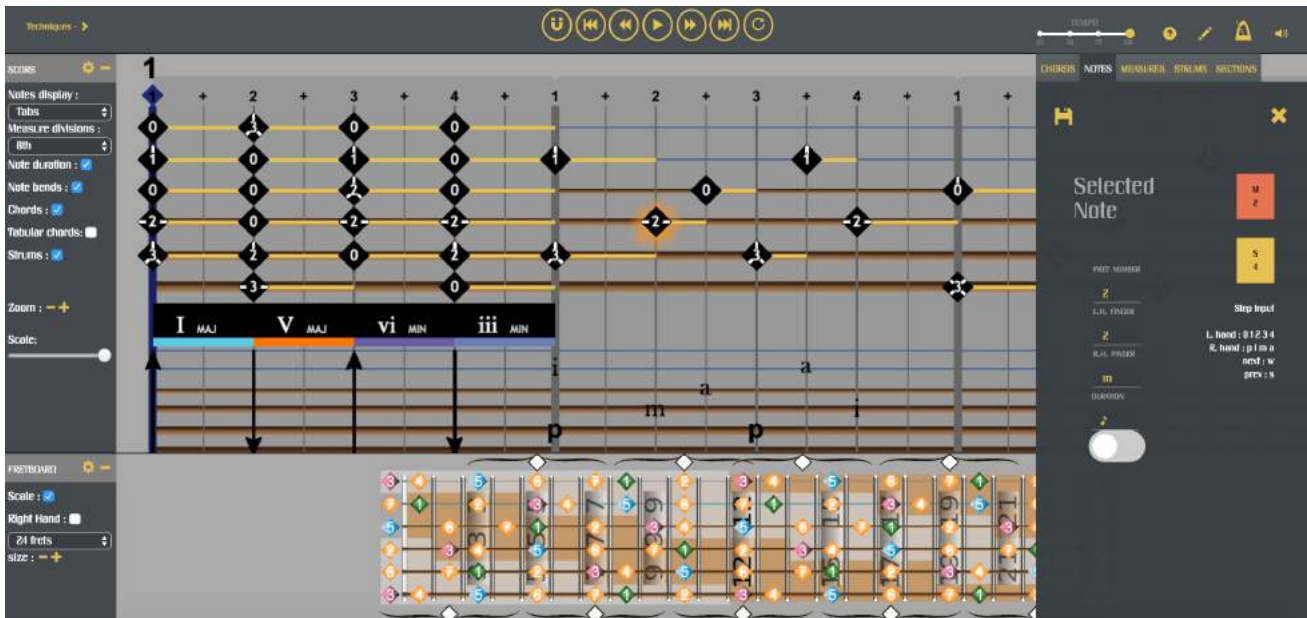


Figure 1: A Novaxe score in the Web platform player with all editions and properties panels open.

is designed to answer three main challenges currently faced by guitar teachers.

First, the majority of guitar students use various notations: standard notation, standard arranged notation, basic tablature, advanced tablature, lead sheets, and the chord and lyric style. Each of these systems has strengths and weaknesses, often increasing workload, while compromising learning efficiency. The project alternate notation alleviates the core challenges faced by many music students.

Second, social networks and cloud computing has changed the way we socialize, collaborate and learn. Internet services and software are more connected than ever. With the propagation of Web applications, driven by recent technological advances, we can access complex data-driven applications from personal computers as well as from a myriad of smart devices. As we have seen in the first part of this article, music learning and production has not escaped these new paradigms. As Martín et al. notes: "with the rise of online music communities using performance or pedagogical applications, there is an increasing need for tools for manipulating music scores. There is also a need for Web-based tools for visualizing, playing, and editing [scores] collaboratively [9]."

Finally, learning to play a musical instrument is a long process as musical gesture enters a category of gestures referred to as expert gesture. This type of gesture requires years of deliberate practice and hours of repetitive exercises in order to achieve a high level of proficiency. These high-level skills are commonly transmitted from a master to an apprentice throughout hours of guided observations. However, this teaching method has always faced some issues. The periods of contact between the master and the apprentice are often short and punctual. In between these periods, the apprentice is left all alone for self-learning. In the case of pure online learning, the master-to-student link is even compromised by the lack of

physical proximity. Sensors, sound and video analysis are used to mitigate this indirection, and provide the learner with valuable feedback. This helps to maintain the learner motivation and reduces the risk of developing wrong technique that would then take even more practice time to correct.

2.1 The Online Learning Environment

This project is therefore an attempt to answer these challenges faced by music and guitar teaching at the age of interactive and collaborative Web technology. The pedagogy and the innovative musical notation used in the project were developed by Vandendool over more than ten years of personal experience as a private guitar teacher [43, 44]. The pedagogy includes concepts from music theory such as scale degrees, chord tones, harmonic function of chords, rhythm necklace and technical information for both hands. The alternative notation system of the project has the capacity to display this extra information, giving the student a very high level of technical and musical insight. This information is leveraged to create relationships between scores according to the learners skill set, using characteristics such as the progression of chord degrees, fret position, technical information and difficulty.

These pedagogical tools are ported to the digital world. The platform in development includes a score editor and player entirely based on the most recent Web technologies (HTML5, CSS3, and several Javascript libraries). It permits to import scores from other digital formats like Guitar Pro [5] and MusicXML [45] and to convert them into the project notation format. It is also possible to create scores from scratch or to complement these with the editor. The editor let the user add technical and theoretical information to the score including right-hand technique, left hand fingering, notes function in a chord

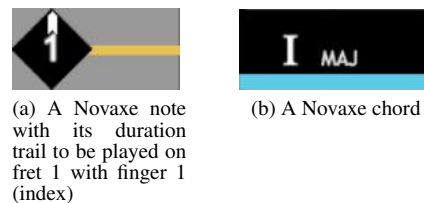
and chord function in a chord progression. This information is organized in visual layers that can be displayed or not depending on a student's level. The player presents several useful options to the user, for example the ability to loop sections of the score or to modify the playback speed.

2.2 Augmented Score

The project is currently at the stage of being populated with scores and guitar lesson material. For that purpose, a set of sensors is in development to capture and analyse information directly from the performance. The usage of these sensors responds to three objectives of the project: automated score transcription, real-time feedback, and collection of data related to musical technique. It will also permit the creation of augmented scores. Augmented scores use a combination of the notation system with multimedia data from the performance of the piece. The multimedia data is comprised of sound and sound analysis curves, multi-point-of-view videos and motion capture data. Scores can be played at various speeds and navigated with synchronized data. This permits the user to explore the score in the usual fashion (notes plotted over a time axis), but also using a data-mining dimension, unveiling multiple layers of information about the performance. Similar ideas were explored for musical education in the IMUTUS / VEMUS [46] and iMaestro [47] project with promising results.

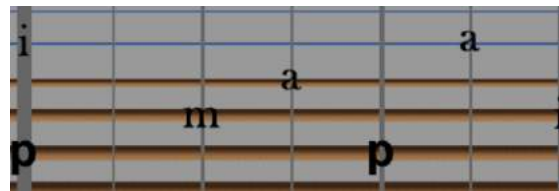
A musical score is a symbolic representation giving instructions to a musician for the performance of a musical piece. In this project, information in a score (figure 1 and 2) is displayed on a grid where the horizontal axis is divided into fractions of beats similar to the piano roll representation used in MIDI sequencers. As it is the case with tablature, the vertical axis represents the strings of the guitar and indicates with a diamond which note is played on a given string at a given beat. The number inside the diamond indicates the fret position and the white stripes around the diamond indicate the finger to use. The duration of the notes is indicated with a yellow trail that starts from the beat division where the note should be played and stops at the beat division where it should be released. In that notation, silences are simply represented by the absence of notes. This notation is a transcription of play instructions, therefore, only the notes that are sounded are indicated. Consequently, notes that would be indicated with a slur in the western notation can have their duration spread between measure.

In this representation, every note is a discrete event. The same score can be played at various tempos. A single score can have multiple performances associated with it. These performances will be of different time length and depending on the interpretation, every single event of the continuous time space of the performance will slightly vary from the reference beat at which it should have been played. In order to synchronize the recording of a performance with its symbolic score representation, the multimodal data streams need to be aligned and quantized. This can be done in real time by recording the

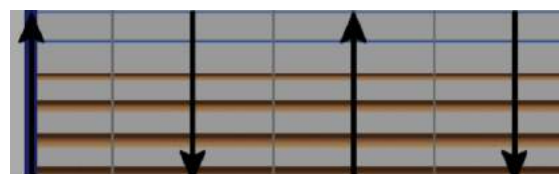


(a) A Novaxe note with its duration trail to be played on fret 1 with finger 1 (index)

(b) A Novaxe chord



(c) A Novaxe picking pattern



(d) A Novaxe strumming pattern

Figure 2: Novaxe score elements

performance while providing the musician with a reference tempo or by post-processing the recorded performance. In this project, both real time processing and post-processing will be used to respond to different situations. Real-time will be used for immediate display of information to the player. Post-processing will be used for the batch treatment of multiple performances and for deeper analysis of performances.

2.3 Future Work

The aim behind the Novaxe project is to build an environment that will permit the learners to perform all the tasks identified in Table 2 in a single Web application. Our hope is that creating such a cohesive and integrated learning experience will contribute in maintaining the learner's motivation in the critical period in-between lessons or in a self-taught situation. Once the environment is online, our next research questions will be to observe the creation of communities of practice and the interaction between learners and peers, learners and masters, and learners and virtual peers and masters.

The project is developed using the Agile methodology. That means that features are integrated in an incremental manner. That permits every step to be validated by groups of testers. The first iteration of the project is actually available online¹ with a basic set of features. In that alpha version, visitors can access public scores and visualize these in the score player. Users can register and log in to access their private score. Private scores are scores that a user has imported using the Novaxe uploader. Users can share scores with other users of the system. That is the first step of the social network and learning

¹ <http://www.novaxe.com>

environment (for example, teachers can use that feature to share exercises with their students). The alpha version of the player offers different playback functionalities. The users can modify the tempo and loop throughout sections of the score. The notes to be played can be visualized using the Novaxe notation system or on a fretboard representation. An online editor is already partially developed and will become available in subsequent versions. A search engine based on musical information of the score (ex.: chord progressions, techniques, etc.) is also in development. We believe that such a basic set of features based on an individual guitar master experience was necessary to "start a discussion" with potential users of the project. The Agile development methodology will subsequently help us to develop a platform that will become closer to the user needs at each iteration.

3. CONCLUSIONS

The ideal master-to-learner musical instrument learning situation involves different modalities from reading a symbolic representation of a musical excerpt to regulating one's action by visual and aural comparison with an expert musician or with peers. This complex feedback loop is lost in periods in between lessons or in the case of self-taught learning. But technological innovations can be used to regain access to some of these modalities, for example, with sound and video recordings. However, even with recordings, what is still missing is the possibility to interact and receive feedback from a master or from peers. This has been partially alleviated with the use of social networks and automatic feedback tools.

Nowadays, the diversity of online music resources is creating the need for a cohesive and integrated learning experience. We have seen how the computer games industry has influenced the way we approach the development of virtual learning environments in every education field but also in music. We have seen how game elements can be used to maintain the learner motivation even in the case of repetitive exercises. We have seen how these LMS can be coupled with social networks to create communities of practice around a learning platform.

The use of the digital and Web technologies in instrumental learning opens new perspectives. For example, as Waldron notes, the proximity with a master or other players is no longer a constraint to belong to a community of practice of a particular instrument or style [23, 25, 26]. It also relates the symbolic musical notation more closely to the performance with the uses of augmented score giving the user access to more dimensions of a musical excerpt. However, it also raises new questions. It is not yet clear what uses the learner is able to make of all the extra information he is receiving in the form of graphical representations of his performance and how he is able to use the diverse types of feedback. Does that really provide him with different perspectives on the matter to learn and will that teach him about the subject matter but also about himself as a learner [48]? Or does that make him dependent on the learning environment? Is the learner still able to develop his own

proprioception or is he always relying on the system? The usage of artificial intelligence agent to take care of the user preferences and learning style might seem appealing, but might it be at the risk of limiting the learner to what is naturally attractive to him? Answering these questions is probably a required step to develop the necessary critical thought to give these technologies their proper place in the musical learning tools arsenal.

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