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The ALMS Project - Mobile Technology for the Instruction of Music Technology

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ABSTRACT

This paper details the design and development of new resources for the instruction of Music Technology to tertiary music students, largely made possible by recent developments in mobile technologies. It focuses primarily on interactive and media-rich content delivered in a mobile application, *Audio Literacy for Music Students* (free for iOS and Android OS) augmented with two other media as interactive teaching materials. In addition to the introduction of these resources, the paper details common pedagogical difficulties instructors face when teaching technology to music majors, and how these issues inform the pedagogical design of the teaching media. Design flaws in a previous desktop application conveying the same content are discussed with an emphasis of design elements critical to its pedagogical effectiveness. It is hoped that details of these successful and unsuccessful attempts to convey audio concepts may be useful in developing future interactive teaching resources.

1 Introduction

In recent years, the capability of any musician to produce digital artistic content and disseminate it on online platforms has become increasingly important. Thus, the acquisition of technological competences by music students is becoming, year by year, more essential to the students' growth and professionalism. The *Audio Literacy for Music Students* (ALMS) mobile app has been designed to support undergraduate level instruction of the principles of sound and its manipulation as a basis for understanding current and future music technologies. In such a context, however, many pedagogical challenges lie in the students' lack of a technical background and elementary vocabulary of the discipline. Even familiarity with simple concepts such as frequency and amplitude cannot be taken for granted with this student group.

2 Background

Mobile applications (apps) have the potential to enhance learning modes and teaching approaches globally by providing learning modalities that could not be otherwise achieved [1], [2]. Mobile technologies are proven to be effective in supporting and enhancing student learning by a number of studies across several disciplines [3], [4]. Although it has been stated that in-class teaching is not replaceable entirely by remote means [5], the 2020-21 COVID-19 pandemic has forced institutions all over the world to rely mainly, if not exclusively, on technology for distant learning, and for almost every discipline [6]–[8]. The impact on education has been considerable, accelerating the demand and development of education technologies. Educators would do well to adapt to the increased reliance on ubiquitous learning environments.

"The anytime, anywhere availability of mobile devices also has potential to promote a seamless 360-degree learning experience that breaks down the barriers between formal and informal educational environments" [9] p.28. This ubiquitous learning environment arises from the combination of adaptive environments and the advantages of portable computing: learn any content in any location, not bound by physical restrictions. Additionally, interactive features can be developed to increase the students' involvement. Some studies suggest that ubiquitous learning can also increase student interest and favours the discussion about the course's topics in face-to-face situations [10]–[12].

Ubiquitous learning does, however, present possible challenges that need to be addressed by developers and educators through good design. The variety of hardware configurations of various mobile devices, such as screen aspect ratios, processing power, and other technical specifications all present challenges. Memory storage requirements, if too demanding can dissuade students from installing and using large applications. The screen size is also a design challenge that need be addressed. [13], [14].

More fundamental challenges can be related to the taught subject matter more than to hardware configurations. In the case of ALMS, the app is addressed to the instruction of Music Technology, an essentially multidisciplinary study merging arts and engineering. In general, for multidisciplinary studies, challenges can encompass:

- Vocabulary: students may know key technical terms from one discipline but not the other(s)
- Technical concepts: student might not possess sufficient background to understand key concepts in the different fields. Music students would likely lack the knowledge of engineering concepts for example.

[15]–[17].

From the point of view of experience design, a user - centered approach has become increasingly dominant in the design of educational apps [18], [19]. Along with such an increasing tendency comes more solid frameworks and methods for the quality evaluation of mobile learning applications [20], [21].

2.1 The importance of concepts

Technology changes, but the nature of sound never does. If we can help our students understand the nature of sound, they will more easily understand what a given technology actually does to the sound. "[We] need to avoid, in our understanding of learning, a bifurcation of material technologies and conceptual understanding" (Burn, 2017, p 12). Especially important for multidisciplinary subjects such as Music Technology is the fact that concepts drawn from one discipline might be explicative for another one. E.g., understanding a physical principle will clarify a musical one, and vice-versa [23]. Moreover, understanding the principles behind a given technology will also help in understanding future technologies that share similar behaviours (once a student learns the principles behind a specific reverb algorithm, they will find it easier to learn how to use another one). However, in the development of a curriculum for Music Technology it may be challenging to balance theoretical concepts with sufficient practical experience to reinforce them. [24], [25].

2.2 The importance of images in teaching concepts

Knowledge visualization, the use of images, both static, moving or imagined is an essential aspect of understanding concepts. Even Einstein made use of his famous 'thought experiments' to visualize the abstract concepts he was contemplating. The literature shows that images are very effective for transferring knowledge and delivering intuitive representations of advanced concepts [26]–[28]. The use of graphic representations can also be used to enhance students engagement [29], [30]. [31] also suggest that the use of images might be particularly effective on mobile devices.

Conveying abstract concepts primarily through text is fraught with difficulties, even when reading in one's native language. Conversely, images can help learners acquire concepts and new vocabulary regardless of what languages are used [32]. In fact, images can help overcome conceptual barriers between different languages [33] and learning new vocabulary faster [34]. This is particularly important to the authors who teach primarily Hong Kong students whose native language is Chinese, but use English as the primary mode of instruction. Although the teaching materials that follow all contain a glossary with as many Chinese translations as possible, there are not sufficient standardized Chinese translations for many aspects of Music Technology to make a Chinese-language textbook or other materials practical.

2.3 The importance of interactive learning for conceptual understanding

Interactivity, the capability of an app to modify its content according to the user's input, has also proven effective in several educational fields. For example, interactive learning has proven effective in enhancing advanced and abstract knowledge understanding, such as mathematics at an undergraduate level [35], [36]. "Interactivity and visualization are valuable for mathematics instruction as a way of reducing cognitive load and maintaining student motivation to learn […]. The results from this research demonstrated that mathematics learning using interactive visuals was significantly higher than the learning that occurs using static visuals" (Just, 2011, p 2). The capability to provide real-time feedback on some audio or visual representation has also been found to be effective in language and vocabulary teaching, specifically when dealing with non-mother tongue speakers learning a secondary language [37]–[39]. The effectiveness of interactivity has also led numerous researchers to experimenting with gamified learning[40].

3 A first flawed attempt: iWAIL

The first attempt at a comprehensive solution to these problems was the creation of a desktop app called the *Interactive Workshop for Audio Literacy* (iWAIL). These were originally very large Max patches (Cycling74) made as standalone applications for OSX and Windows. The content included 20 chapters of text and images (in HTML format), a glossary, and waterfall, oscilloscope, spectrogram, sonogram, and waveform displays. Most would find its content, developed over many years of experience, generous if not copious.

However, despite not having formal assessment of the desktop application, it did not seem to make any significant difference to student learning on test scores and in class discussions. It was later revealed that the reason for this lack of learning impact was the instructor's natural inclination to focus on *content*, and not giving much thought to *design*.

As in figure 1, all access to content were contained in this one pull-down menu, and thus its content was not immediately clear.

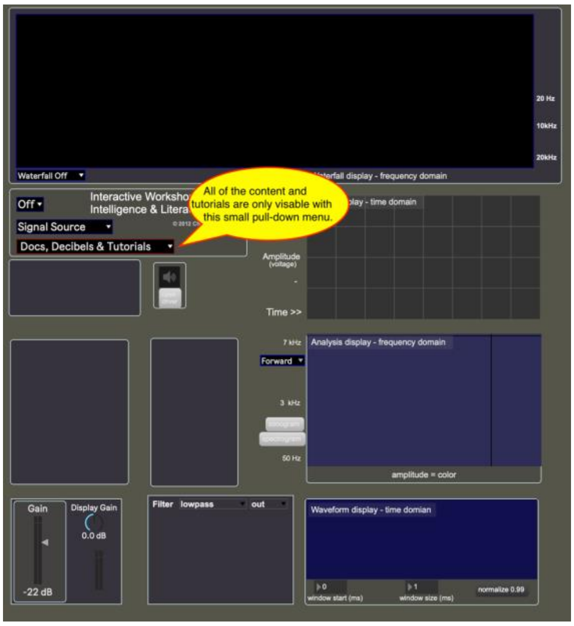

Figure 1. a lone pull-down menu for all content

When opening the documentation window, the rest of the content was also accessed exclusively through a second small pull-down menu, which was also unclear. Also obscure was that the menu contained links to static html pages as well as highly interactive tutorials but did not differentiate these visually. The app had an almost complete lack visual hierarchy of information and use.

The delivery of the app's content as a standalone application also proved problematic. The application did not always work as expected on different operating systems and thus required frequent revisions. In the subsequent teaching materials, the bulk of the content was converted into a PDF book with embedded sound and video files.

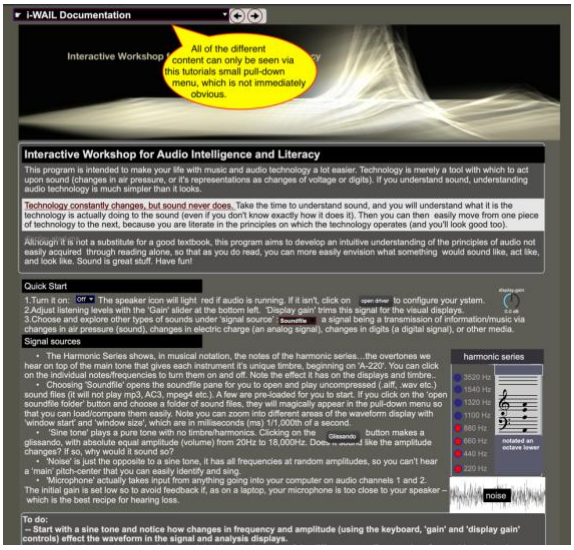

Figure 2. iWAIL content menu

Lastly, along with *how* to access the content and *how* to use the interactive elements, the crucial point of *why* one should access the content was also not explicit. Why is this information important? How relevant and useful will it be for a career in music after graduation? How was it going to be used in the context and assessment of the class it was written for? These were questions left unanswered and thus students did not have the motivation to use the content so laboriously presented to them.

4 Choice of three different media

Different instructional media naturally lend themselves more easily to different forms of content delivery. Textbooks naturally focus on text with some concepts augmented with illustrations and the occasion link to websites. A video documentary will naturally focus on images for the main narrative, augmented and elaborated via spoken and written text. It was found that the optimal instruction media could not be found in a single delivery media but rather in three;

- PDF book
- ALMS Interactive desktop software
- ALMS mobile app

Figure 3. PDF book, mobile and desktop applications

PDF books easily accommodate images and text and may also include imbeded video and audio. This format also lends itself to being formatted and read as a book. During its first semester of use, many students printed it out the entire PDF book, all 100 pages of it, and bound it for easy reading and to make notes in the margins.

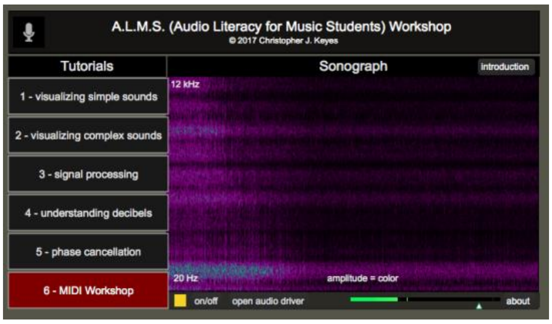

Figure 4. ALMS Interactive Max patch

ALMS Interactive is a MAX patcher (requiring

Cycling 74's MAX to run). As a desktop app it lends itself, as its title suggests, to interactive learning tutorials. Some of these overlap with the ALMS mobile application but have some features difficult to realize in the current version of iOS and not possible on current Android devices; they have thus been rendered into videos, available in the mobile app and PDF versions. One advantage of this desktop format is the added screen space, so that detailed text and the interactive elements can be included in the same page.

One might also note from figure 4 the app has been redesigned so that its six tutorials are clearly seen on the left-hand side of the landing page and easily navigated to. By default, when the app is opened a sonograph of the computer's mic input is automatically analyzed and displayed as a sonograph. This is meant to stimulate the student's curiosity and entice them to further explore. As this is distributed as a MAX Patcher, requiring the student to download and install (but not purchase) MAX. Its authors at Cycling74.com then take up the responsibility to update the software for new operating systems and to make the software backwards compatible.

5 Description of the mobile app

The mobile app is the principle learning media and was developed by the Apps Resource Centre (ARC) of Hong Kong Baptist University (HKBU). As seen in figure 5, the visual hierarchy of the app's landing page is quite clear: 'Content', 'Tutorials', and 'Glossary'. Also in figure 5, choosing the 'Content' page brings you to the second page which (with scrolling) lists all 24 chapters, and crucially, chapter 00, the Introduction. Chapter 00 gives a summary of why the app was made in the first place, why it's content will likely be very important to the students in their careers, and lastly the structure of the app's content and augmentation with the PDF book and ALMS Interactive software. The content of the app relies heavily on images, sound files and videos. As with all of the ARC's apps, media are embedded directly into the app whenever possible. Although they may take up more space on the student's mobile device (at least for the semesters they are using the app) embedding the media has three advantages: they do not require internet connections to run, there is no drain on the student's data usage plans which might be a disincentive for its use, and most importantly, the media play, rewind, fast-forward etc. extremely smoothly. This is very important in that it allows students to easily return to any part of the videos they don't understand multiple times, review, and skip ahead for things they already know easily. Server-based media are often clumsy in scrolling multiple times, and the buffering and delays can easily frustrate students and become a disincentive for further learning.

The ALMS app was designed with a hope that it would be an ideal mobile combination of the ALMS PDF book and the ALMS Interactive desktop software thereby bridging mobility and usability while making sure to not lose the intended pedagogical objectives.

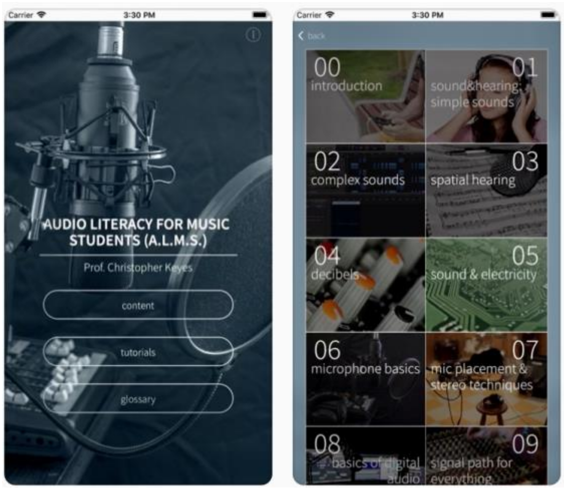

Figure 5. the ALMS landing and content pages.

One of the pedagogical advantages of the app format is that it lends itself in making telescoped hierarchies of information. Figure 6 shows the chapter on mic placement and stereo techniques. The student is first presented with an overview of the most essential information .

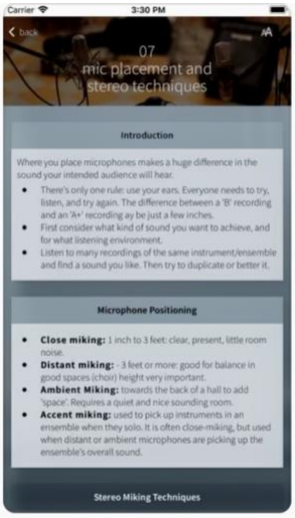

Figure 6. summery of mic placements of chapter 07

Not showed here but at the bottom of this, and all content pages is a link titled 'full pdf version' which brings the content of the PDF book into the app's window. This facilitates an introduction and/or review for the first page, and then a more detailed explanation in the PDF book, which is downsized for use on small devices and thus saves space.

5.1 Tutorials

The tutorials section of the iOS version of the app is the most interactive and includes:

- Visualizing simple sounds
- Visualizing complex sounds
- Signal processing
- MIDI workshop, and a
- Sonogram.

Unfortunately, implementation on the Android OS is not practical at this time. In the Android version the interactive elements are replaced by videos of someone interacting with them. However, all of the interactive elements are also available in the accompanying *ALMS Interactive* desktop application in figure 4.

The first tutorial, 'Visualizing simple sounds' is presented as a keyboard and oscilloscope representation of frequency, amplitude and timbre – the basics. As with all the tutorials there is a '?' icon on the upper right corner that details how to use the tutorial's interface and learning activities.

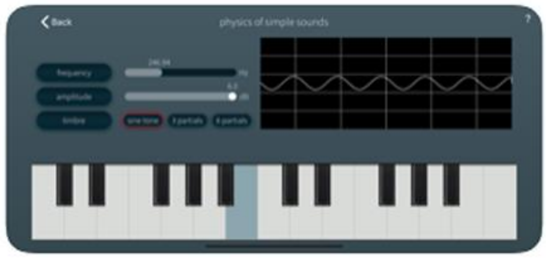

Figure 7. The first tutorial with frequency, amplitude and timbre controls.

As seen in figure 8, the second tutorial gives sonograph analysis of more complex soulds including embedded sound files, the harmonic series, and microphone input for students to interact with.

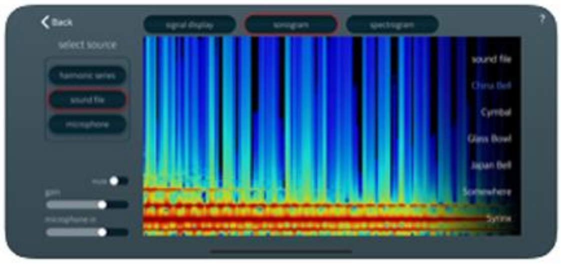

Figure 8. the second tutorial; - harmonic series, sound files, and microphone signals.

The third tutorial (figure 9) allows for the same input sources as the second but adds a white noise generator as inputs to a filter. The app allows the learner to choose from five different filter types along with changing center-frequency and Q factor. The visualizations and sonic transformations give learners a clear understanding of the concept intended, especially for the white noise and harmonic series input.

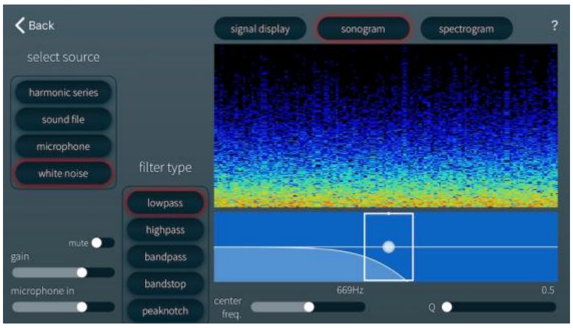

Figure 9. third tutorial analyzes and applies filters to the harmonic series, sound files, white noise and incoming microphone signals.

6 Evaluation

The evaluation process was based on data gathered in two instruments:

- Year-2 undergraduate music majors who have used or are already using the ALMS app were asked to fill a questionnaire,
- Year-1 music students who never used the app and had no background in Music Technology were asked to take part in an evaluation test.

The questionnaire for Year-2 students was designed in order to gather quantitative data (hours spent using the app, perceived usefulness etc.) and qualitative data (comments and suggestions).

The test for Year-1 students was designed as follows: participants were asked to fill a pre-test questionnaire, testing their knowledge of the content of the first two chapters of ALMS. The questions reported in the questionnaire were related to some basic concepts of physics of sound, such as: “What is a partial and how is it related to timbre?” or “What is a sound’s amplitude?”. Two questions were also requesting to match the image of a sonogram with an instrument or with a filter. After completing the pre-test survey, they were asked to use the app for twenty minutes, completing the following tasks:

- Open and read the first two sections in the *content* menu of the app (*sound & hearing* and *complex sounds*);
- Use the first three interactive tutorials in order to attain a more direct experience of the concepts presented in the *content* menu
- Look back to the already considered concepts/content or explore new content not previously visualized.

After these tasks were completed, the students were assigned a post-test survey including the same questions of the pre-test, in a different order. This would allow us to check whether there had been an improvement in their knowledge after using the app. The post-test also included some questions about the app design and usability.

7 Evaluation results

7.1 Year-2 students’ questionnaire

The questionnaire for Year-2 students was completed by 19 respondents. It was found that on average each student used the ALMS app 12 times during the first 9 weeks of the semester and the ALMS PDF book 11 times (it should be noted that the questionnaire asked for a rough estimation). In spite of the slightly higher usage, students found the PDF book to be slightly more useful, with an average score of 8.15 against 7.95 for the app (on a scale of 1 to 10). Furthermore, students indicated that ALMS Interactive looked sensibly less informative, with 5 times of average usage and 6.58 as an average score. However, its content pertained only to the content covered in the first four weeks of their Music Technology course. In addition, 63% of the students (12) found the ALMS app to be very intuitive to use, with a score 8 or above, against the 38% (7) for ALMS Interactive. The questionnaire also included two open-ended questions asking for comments/feedback and possible suggestions for improvement. Many students left those spaces blank. Among the students who replied to the last two questions, half of them expressed satisfaction (“Good learning material”, “Perfect”, “It’s very good”). Some other students remarked minor discomforts (“A dark background is hard to read”, “Use more point form”, “typos”). In general, according to those replies, the experience did not show major flaws and was sometimes highly appreciated.

7.2 Year-1 students' evaluation test

6 Year-1 students [1] took part in the evaluation experiment. In general, the number of given answers increased considerably between pre and post-test, as shown in Figure 10.

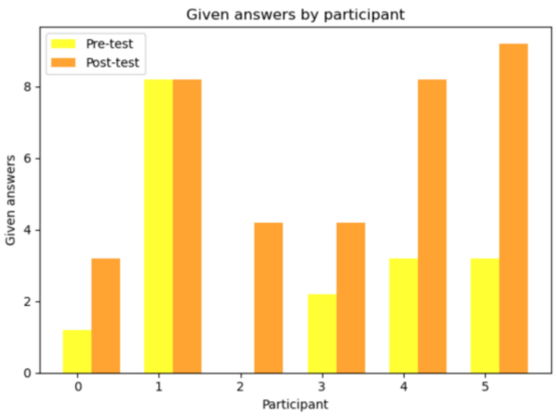

Figure 10. Number of answers given by participants (out of 10). Participant number 3 did not submit the pre-test.

Almost every student answered two more questions in the post-test with an average increment of 3 answers, 33% (in calculating the average and the number of right answers, student 3 was not considered).
Figure 11 shows a substantial increase in right answers.

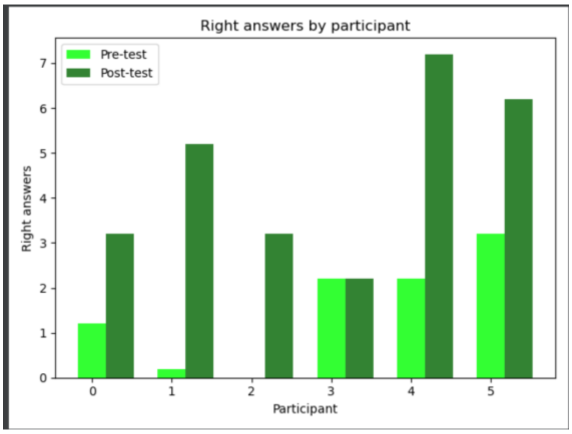

Figure 11. Number of right answers given by participants (out of 10)

In the case of right answers, there was a general tendency towards better scores in the post-test. The increase in right answers was 3 per student on average, 33%. The following histogram shows the distribution of right answers between pre-test and post-test (Figure 12). While in the pre-test students could only get up to 3 right answers, in the post-test they would score between 2 and 7 right answers with a fairly high probability.

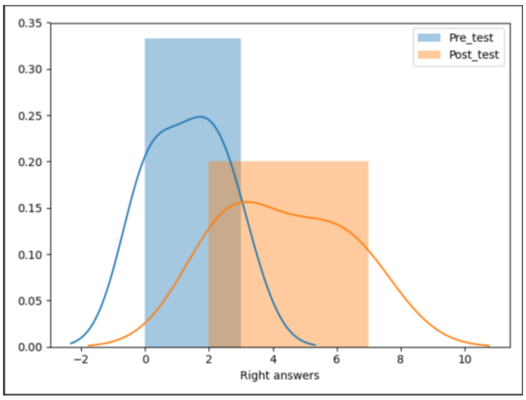

Figure 12. Graph showing the distribution of right answers (number/probability axes).

[1] The pre-test of student 3 was not submitted and therefore data for student 3 are partial.

Looking at the previous graphs it is clear that there was an enhancement in both number of answers and right answers.
The question where students performed better was number 4 (as ordered in the pre-test): “In physics, what exactly is a sound?” (expected answer: “Vibration” or any answers more detailed than that), which got a correct answer by 5 out of 6 students. Most of other questions received 3 or 4 right answers. The most difficult questions were slightly less intuitive (“What is the difference between harmonic and inharmonic partials in a sound?” and “What are attack transients and why are they important?”). However, also the question: “What is sound amplitude?” scored only two right answers. Likely, students seemed to confuse frequency and amplitude.

8 Conclusions

This paper describes a mobile application for Music Technology education, also supplemented with a PDF book and an interactive desktop app. After discussing the design of the ALMS app and giving description of the supplementary material, we presented preliminary evaluation data about the effectiveness of the ALMS app in terms of teaching and engagement. We evaluated the app in two ways: (1) through a survey and (2) through an experimental testing. Data show considerably encouraging results on both tests.
In (1), students rated the ALMS app 7.95 on average and the PDF book accompanying it 8.15 out of 10, with an average use of more than once per week on average. In general, they also found the app very intuitive to use (68%) and gave enthusiastic feedback, while also outlining some suggestions for improvement (mostly details about the interface design). On the contrary, the ALMS Interactive desktop app was much less used (around once every two weeks) and appreciated (6.58/10).
In (2), almost all participants had a better score in the post-test survey compared to the pre-test one, both in terms of given answers and right answers. Both values increased, on average, by 33% after using the ALMS app for approximately half an hour.
In conclusion, the evaluation tests showed a general appreciation of the ALMS app as well as some noticeable improvements in student’s performance. Readers are encouraged to download the app on their mobile devices, note the design elements first-hand, and are welcome to use it and recommend students make use of this new learning recourse.

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