

Sonification (audio graphs) pilot on M140

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Executive Summary

Sonifications are audio representations of graphs, and as such are an ‘alternative format’ which could be used to improve accessibility of module materials. This project explored the utility of sonifications to all students enrolled on a module, specifically students on the 17J presentation of M140 *Introducing statistics*. In this case all the graphs corresponded to scatterplots. The first goal of this project was to demonstrate how sonifications can be made available to students via the module website, thus providing a template for any future implementation.

Students were asked to give their feedback on the sonifications via a short questionnaire placed on the module website, and 83 students chose to do so. Amongst these respondents, 37% listened to most or all of the sonifications and 31% listened to no more than 2 of them. Despite being given no training in how to interpret sonifications, 71% felt they could imagine the shape of the scatterplot at least some of the time. However of those who chose to comment, 54% provided generally negative comments about whether the sonifications helped them understand the scatterplots. Also 26% said they would listen to sonifications if they were provided for other units.

The pilot has demonstrated that audio representation of graphs can be implemented on a module and made available to all students on that module. The student response indicates that for a small number of students, whether visually impaired or not, the alternative format is valuable and requires no training to access. However it is also clear that any further rollout would need to clearly explain to students that the materials are alternatives and not additional requirements to study in the module.

Aims and scope of your project

What were the main aims of the project?

Following the success of the previous eSTEEeM project, *Sonification of depictions of numerical data* (<http://www.open.ac.uk/about/teaching-and-learning/esteem/projects/themes/technologies-stem-learning/sonification-depictions-numerical-data>) we aimed to implement sonifications (audio versions of graphs) on a live module, and to gather feedback from students.

What were the more specific goals?

We aimed to evaluate the effectiveness of audio versions of graphs on a live module, M140 *Introducing Statistics* 17J by gathering both qualitative and quantitative data from students. Some of the questions we hoped to answer included: would students appreciate this alternative format? Would sonifications enhance their understanding? Would sonifications detract from their understanding? Would the students enjoy listening to them?

Activities

What was the overall approach?

The overall approach was to implement audio versions of the graphs for Unit 5 of M140 on the Virtual Learning Environment (VLE). We then gathered feedback from the students using a survey. We deliberately described the sonifications as *audio versions* to the students, as we did not wish to burden them with new terminology, as well as new technology.

M140 *Introducing Statistics*, was a natural choice upon which we could explore sonifications with students; the module contains a lot of graphical depictions of numerical data, the module team chair (Carol Calvert) is on the project team, and it was hoped that, because the students would be statistically minded, that they would wish to provide feedback to the survey.

The production method of module materials in the School of Mathematics and Statistics is somewhat different from other modules across the university. Specifically, materials for such modules are generally produced using LaTeX, which has led to a barrier in producing alternative formats; however, during production of M140, the production team explored the creation of structured content in Unit 5. This allowed us to work with Learning and Teaching Innovation (LTI) Translation to implement audio versions of each of the graphs (approximately 75 in total) for Unit 5 on M140.

What were the planned activities of the project?

We planned to invite the students to engage and interact with the sonifications for Unit 5. Following engagement with the sonifications (or even a decision not to engage with them) students were invited to complete a short questionnaire. This questionnaire, although set up to provide anonymous responses, gave students the option of providing their Personal Identifier (PI). We wanted to keep the option open to use these PIs to link responses on the questionnaire to other information about these students such as demographic and attainment data.

We planned to present the sonifications to students via a special HTML version of Unit 5 giving just the graphs; this version was enhanced to contain audio versions of the graphs. Note that in common with most mathematics and statistics modules currently in presentation, an HTML version of the units is not otherwise available to students. A link to the HTML version of Unit 5 was given in the Study Planner, along with a link to the questionnaire. We also planned to let students and tutors know about the audio versions of graphs, and the project in general through forum posts (on student and tutor forums) and online tutorials.

What changes did you have to make to your plan (aims, project activities, etc.) and why (e.g. technical problems, difficulties in involving users/stakeholders, etc.)?

There were two related problems that we had during the project, both centred around internal communication between the group members and were around activities “pencilled in “ but then neither cancelled nor confirmed. These caused minimal issues and illustrated the need for a named person to be checking what activities we had planned in the calendar for each month.

We decided not to use the demographic and attainment data as the project team deemed that the number of responses is too small to offer valuable insight.

What data and evidence did you gather and how did you gather it (e.g. survey, interviews, focus groups, user studies, cultural probes)?

We gathered 83 responses from students using a 7-question survey, available here: <https://learn2.open.ac.uk/mod/questionnaire/preview.php?id=1194138>. We designed the questions to help us evaluate the students’ reactions to the sonifications.

Findings

What are your main findings? What evidence supports these findings?

The main findings can be summarised from the results of the 7-question survey, which we describe next. In what follows, any reference to our ‘previous study’ is in reference to our previous eSTEeM project, the results of which are summarised at <http://www.open.ac.uk/about/teaching-and-learning/esteem/projects/themes/technologies-stem-learning/sonification-depictions-numerical-data>.

The first question gave students the option to specify their PI. This question was included so that for students who were happy for us to do so, we could link responses on the questionnaire to other information about these students such as demographic and attainment data. 57% of respondents chose to do so.

2. How many audio versions of graphs did you listen to?

In Unit 5 of M140 there are approximately 75 scatterplots. Audio versions for all of these were created. Students were encouraged to complete the questionnaire regardless of the number of audio versions

they listened to, so this question gives a measure of engagement with the concept. The responses we received from this survey question are shown in Table 1.

Table 1 Responses to Question 2

Response	Percentage	Total
None	16%	13
One or two	10%	8
Between three and ten	33%	27
I am not sure but not many	5%	4
I am not sure but most of them	25%	21
All of them	12%	10
Total	100%	83/83

So generally respondents had listened to some, but not all, of the audio versions.

3. The audio versions use sound to depict the scatterplots. So we wonder if the extent to which music is important to you affect if/how often you listened to audio versions of the scatterplots in Unit 5. Please tell us roughly how important music is to you – tick all boxes that apply.

The previous study had suggested that the extent to which music was important to a participant influenced how easily they engaged with sonifications. So this question was used to assess the importance of music to the respondents. The summary of responses we received from this question is shown in Table 2.

Table 2 Responses to Question 3

Response	Percentage	Total
I regularly play a musical instrument/sing in a group such as a choir	19%	16
I can read music	30%	25
I enjoy listening to music	70%	58
I always prefer to have music on in the background if I am studying	23%	19
I rarely have background music on	39%	32
Total		150/83

4. How often you could imagine the shape of a scatterplot from its audio version?

The previous study indicated that the strength of sonifications is to quickly provide the gist of the graph. As all the graphs in Unit 5 of M140 are scatterplots, the gist of the graph translates to the shape of the scatterplot. So we were interested in the extent to which the audio version was successful in conveying this to students. The responses to this question are summarised in Table 3.

Table 3 Responses to Question 4

Response	Percentage	Total	Percentage of those who listened to at least one audio version
Always	7%	6	9%
Most of the time	24%	20	29%
Sometimes	29%	24	34%

Rarely	14%	12	17%
Not at all	10%	8	11%
Not applicable as I did not listen to any	16%	13	---
Total	100%	83/83	

So out of those who listened to at least one audio version, roughly three-quarters were able to get the gist. However few respondents felt that they always were able to use the audio version to imagine the shape of the scatterplot.

5. Did the audio versions help you understand what the scatterplots in Unit 5 were showing? Please tell us briefly why or why not.

We categorised the students’ responses as positive, neutral, mixed and negative. Each of the project members analysed and categorised the responses, and the summary is shown in Table 5 along with the responses to Question 7. We will discuss the feedback to this question as part of our discussion to Question 7.

6. If there were audio versions for graphs in other units would you listen to them?

The responses to this question are given in Table 4.

Table 4 Responses to Question 6

Response	Percentage	Total
Yes	26%	17
No	74%	49
Total	80%	66/83

The final question was free response:

7. Do you have any other comments? (2500 characters max length)

As in Question 5, we categorised the students’ responses as *positive, neutral, mixed* and *negative*. Each of the project members analysed and categorised the responses and the summary is shown in Table 5. The analysis of these comments was a subjective exercise; we aimed to remove as much of the subjectivity as possible by individually analysing each response, before collating our overall results per question. The process revealed that there were few instances of substantive disagreement, which were easily resolved by discussion.

Table 5 Summary of responses for Questions 5 and 7

Tone of response	Q5 (helping understanding?)	Q7 (other comments)
Positive	13 (19%)	10 (24%)
Neutral	9 (13%)	3 (7%)
Mixed	10 (14%)	14 (34%)
Negative	37 (54%)	14 (34%)
Total	69	41

Referencing the second column of Table 5, in terms of whether the audio graphs helped understanding (Q5) most of the comments were deemed to be negative. The third column of Table 5 shows the responses to Q7, in which students were invited to give any other comments they had; in contrast to the responses to Q5, the tone of the comments were more evenly balanced.

In order to investigate how the usage of the sonification depended on other factors, the number of sonifications to which a student listened (see Table 1) was grouped in the following way:

- Few: 'None' or 'One or two';
- Some: 'Between three and ten' or 'I am not sure but not many' ;
- Most: 'I am not sure but most of them' or 'All'.

We will refer to these three categories in what follows.

Based on our previous eSTeEM project (<http://www.open.ac.uk/about/teaching-and-learning/esteem/projects/themes/technologies-stem-learning/sonification-depictions-numerical-data>), it was expected that the students who were more musical would respond more positively to the audio graphs; see Table 6.

Table 6 Percentages of the different listening groups who answered positively to the different questions about music (Question 3).

Number of audio graphs listened to	Play music/sing in a choir	Can read music	Enjoy listening to music	Prefer to study with music in the background	Rarely have background music on
Few	24%	24%	76%	24%	38%
Some	6%	19%	55%	16%	48%
Most	29%	45%	81%	29%	29%

One of the most striking features to emerge from the results in Table 6 is in the second column, titled *Play music/sing in a choir*. In particular, note that those students who listened to Few and Most sonifications respectively indicated that 24% and 29% of them did *Play music/sing in a choir* while of those students who listened to Some of the sonifications, only 6% said that they *Play music/sing in a choir*.

We may study the remainder of the row corresponding to students who listened to Some sonifications in Table 6 and note that all of the percentages except for that in the final column are lower than their equivalent percentages in the other rows. In particular, those students in the 'Some' group have a smaller percentage who *Can read music* (19% compared to 24% and 45%), a smaller percentage who *Enjoy listening to music* (55% compared to 76% and 81%), and a smaller percentage who *Prefer to study with music in the background* (16% compared to 24% and 29%). In the final column, we see that of those who listened to Some sonifications 48% of them will *Rarely have background music on*, compared to 38% of the 'Few' group and 29% of the 'Most' group.

In summary of Table 6, the results suggest that those who listened to Some sonifications attach less importance to music than those who listened to Few or Most.

In Table 7 we explore the results from Table 3 with reference to the three categories: Few, Some and Most. We see that those who listened to Few audio graphs were more likely to have felt they 'rarely' or 'not at all' understood them. However the proportion who felt they 'always' or 'most of the time' understood was, about the same regardless of whether they listened to 'few', 'some' or 'all' of the audio graphs.

Table 7 Understanding of audio graphs (percentages of the different listening groups).

Number of audio graphs listened to	'Always' or 'Most of the time'	'Sometimes'	'Rarely' or 'not at all'
Few	38%	12%	50%
Some	32%	32%	35%

Most	42%	42%	16%
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Referencing Table 8, the interest in having more audio graphs (see, also, Table 4) provided depended on how many graphs to which the respondent had listened. Although there was little interest from those who only listened to Few or Some of the audio graphs, approximately 40% of those who listened to Most of the graphs did express interest in listening to more sonifications.

Table 8 Interest in listening to further sonifications

Number of audio graphs listened to	Few	Some	Most
Percentage expressing interest in having more	15%	15%	41%

Overall the tone of the free text comments given in response to Q5 and Q7 were interpreted as negative, as detailed in Table 9 and Table 10.

Table 9 Tone of response to Q5 (percentages of the different listening groups).

Number of audio graphs listened to	Positive tone	Neutral tone	Mixed tone	Negative tone
Few	10%	20%	0%	70%
Some	13%	10%	16%	61%
Most	29%	14%	18%	39%

Table 10 Tone of response to Q7 (percentages of the different listening groups).

Number of audio graphs listened to	Positive tone	Neutral tone	Mixed tone	Negative tone
Few	0%	33%	0%	67%
Some	25%	6%	31%	38%
Most	27%	5%	41%	27%

Some of this negative response arose because using the audio graphs did not fit with the way they liked to study.

- *“I prefer it silent to aid my concentration so it is not something I would actively look for to aid my learning.”*
- *“didn't use them, study from the books unless stuck”*

For a few the audio graphs were actively disliked or inappropriate

- *“I'm afraid for me this reminded me too much of the many hearing tests that I endured as a child.”*
- *“Im partially deaf...”*

For others the negativity related to the difficulty that they had interpreting the audio graphs. Although many reported being able to obtain some information about the graph from the sound, the lack of detail and precision was seen a problem. For example

- *“No i did not get it only followed up and down”*

In particular this difficulty was juxtaposed with the ease that many had with interpreting graphs visually. So many of the students did not feel that the audio graphs added anything. For example

- *“am very comfortable with interpreting graphs in the traditional way and did not find this a useful addition”*
- *“They didn't add any insight to the visual”*

It was noted by some respondents that this difficulty could have been ameliorated by training. After all, the skill to interpret graphs visually is something that students have learned and have probably been doing for years. In contrast attempting to interpret audio graphs was something new.

- *“It'd perhaps be a good idea to provide a few examples with explanations as to what the sounds represent to make it clearer what the listener should look out for.”*

However despite a lack of training some did feel that listening to the graph helped them interpret the graphs.

- *“Listening to them required me to think more about the shape of the graph than simply looking at it.”*
- *“They didn't ADD understanding, but corroborated it”*
- *“With the graph next to it to look at I guess it forces you to really look at the points and the line to track what you're listening and perhaps that exercise in examining the points is useful to prompt slightly deeper thoughts/analysis of a graph”*

Furthermore, even when students felt that the audio graphs were not helpful to them personally, some felt that they could be useful for somebody else – primarily visually impaired people.

- *“I think these graphs are great for the visually impaired”*
- *“I think that these may be more useful for some individuals than others, depending on their learning style and development needs.”*

Finally the respondents did highlight a couple of areas in which further technical developments could be helpful. Currently the ‘stitching together’ of the audio graph via a sequence of sound points lead to some crackle in the audio; eliminating or reducing this would be desirable.

The length of each graph (6 seconds) was not always seen as appropriate; it was felt to be too long when there were few points of the graph, but too short when there were many points. Furthermore one respondent suggested linking the audio graph and visual plot in such a way that each point of the visual plot is highlighted as its note was sounded on the audio graph. In particular such a development would help with the training about how to interpret audio graphs.

Conclusions

We have concluded the following:

1. It is possible to include audio graphs on modules website, even for modules where the material is not delivered via structured content.
2. Although only a minority of students appeared to get a benefit from the audio graphs, the instances in which it appeared to detract from the study of others were very rare.
3. Where audio graphs are to be used, guidance about how to interpret them should be offered. In particular reassurance about what is and is not reasonable to pick up from them.
4. Some further technical development of the method by which the audio graphs are produced is desirable.

Do you have you any particular successes to report?

There were many successes on the project; the team worked well together, and the collaboration with LTI-Translation was excellent. Special thanks should be given to Lucinda Simpson, who worked very hard to implement the sonifications on the VLE.

In the free response questions (Q5 and Q7) some students were extremely positive; for example:

- *“They audio was helpful if i had a pen and paper in hand. Listening to them required me to think more about the shape of the graph than simply looking at it. It helped me pay more attention to the spread and “timing” of the data entries.”*
- *“This was great! I've never 'looked' at data this way. You can really hear the shape of some of the graphs, and hear their positive or negative slope. This was fascinating, loved it! :)”*

Impact

a) Student experience

In what ways has your project impacted on student learning?

Students have been exposed to important concepts in accessibility as they have seen graphs of data points represented in an alternative format: audio. For example, the following feedback was among the responses we received from Question 7:

- *I can see benefits for students with specialised learning requirements.*
- *I have some minor eyesight issues also, so this would make the files accessible to many students.*
- *There is far more detail and many nuances than can be perceived in audio versions*

Furthermore, we returned an anonymised version of the data from the survey to the students via the forum (<https://learn2.open.ac.uk/mod/forumng/discuss.php?d=2521589>) so that, if they wished to, they would be able to analyse the data for themselves.

How is your project contributing to increasing student success (i.e. retention, employability, etc.)?

It is difficult to measure the impact of this particular M140-based project on the 17J presentation. There are several initiatives running concurrently on M140; the “flexible start programme” and a project involving reallocation of tutorial time to strengthen the initial contact between student and tutor. It is not possible, therefore, to attribute any changes in student satisfaction, in module retention, or future module choices to this sonification project.

Have there been or will there be any benefits to students not directly involved in your project?

The working relationships that we have developed across the university, particularly with LTI, may well be fruitful in future projects that require innovative approaches to customising module content, particularly on the VLE. This has the potential to have positive impacts for students requiring alternative formats of our module materials in the future.

b) Teaching

How have you affected the practice of both yourself and others within the OU?

We have demonstrated that implementations of new technology on a module is possible; this was, in large part, due to the efforts of Lucinda Simpson (LTI-Translation). Assuming that a structured content version of the module materials is available, and that the audio files for each graph exist, we now have a method to implement them within the Virtual Learning Environment.

We developed our 7-question survey which has served its purpose in helping us to evaluate the effectiveness of our implementation of the sonifications. The survey was short, but focused, and did not overload the students.

What has been the impact of your project outside the OU?

As yet, we do not believe that this phase of the project has had any impact outside of the OU as we have not disseminated the results from the project. We do intend to do so, which might lead to external impact in the future.

c) Strategic change and learning design

What impact has your work had on your Unit's or the University's policies and practices?

There has not been any impact so far, but we believe that the project has generated evidence that may feed into decision making surrounding accessibility practices in the future, particularly in terms of alternative formats for mathematical and scientific content.

List of deliverables

Please provide a list of any deliverables that will be of value beyond the life of the project such as websites/wikis (URL), publications (pdf), papers (pdf), etc. Please reference papers and publications in full. Relevant files should be sent separately for inclusion on the eSTEE M website and Scholarship Exchange.

Figures and tables

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References

Vines, K., Hughes, C., Holmes, H., Pearson, V., Kotecki, C., Alexander, L., Colwell, C. and Parks, K. (2016) Sonification of depictions of numerical data. eSTEE M Final Report. <http://www.open.ac.uk/about/teaching-and-learning/esteem/projects/themes/technologies-stem-learning/sonification-depictions-numerical-data>

Please email your a) written report; b) executive summary; c) deliverables each as separate files (clearly listed in the written report); and d) confidential commentary to esteem@open.ac.uk no later than 2 months post-completion.