

Visualizing Physics: Good Vibrations

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Abstract. This talk forms part of the author's Masters investigation into perceptions of Physics in school visitors to Unizul Science Centre. Visitors typically fall into three distinct groups with very different needs and responses: those coming from: rural schools, township schools and urban schools. In this study, pupils were exposed to an interactive Science Show: Good Vibrations, presenting the basics of sound and waves through musical instruments. They were then asked to respond to questions requiring both written and graphical answers. From these, conclusions are drawn as to the ability of these pupils to understand sound both visually and conceptually. These conclusions will be used to inform best practice when dealing with different groups of visitors with different needs.

1. Introduction

Good vibrations is a dynamic, highly interactive science show. It covers the science of sound, presenting it through the medium of music and musical instruments. It does this in an integrated, multimedia fashion, using instruments, simulations, graphics and video, volunteers, sounds and practical applications.

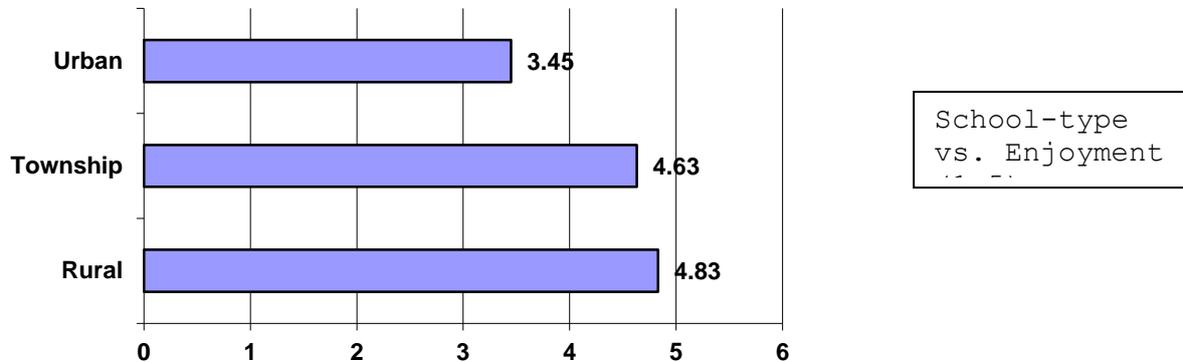
This pilot study was conducted during the "Science Unlimited" festival at the Royal Showgrounds in Pietermaritzburg in October 2010. The 45 minute show was presented to various audiences (both primary and high schools) of about 250 pupils, but for the survey pupils were chosen from high school only, and comprised:

- Urban Boys School (very privileged) – 21 Grade 9 pupils
- Township Co-educational School – 19 Grade 11 pupils
- Rural Co-educational School – 18 Grade 10 pupils

2. Discussion of Survey Results

2.1 Questions dealing with impressions of the show, novelty and links

2.1.1 Question 1: “How much did you enjoy the show on a scale of 1 (awful) to 5 (excellent)?”

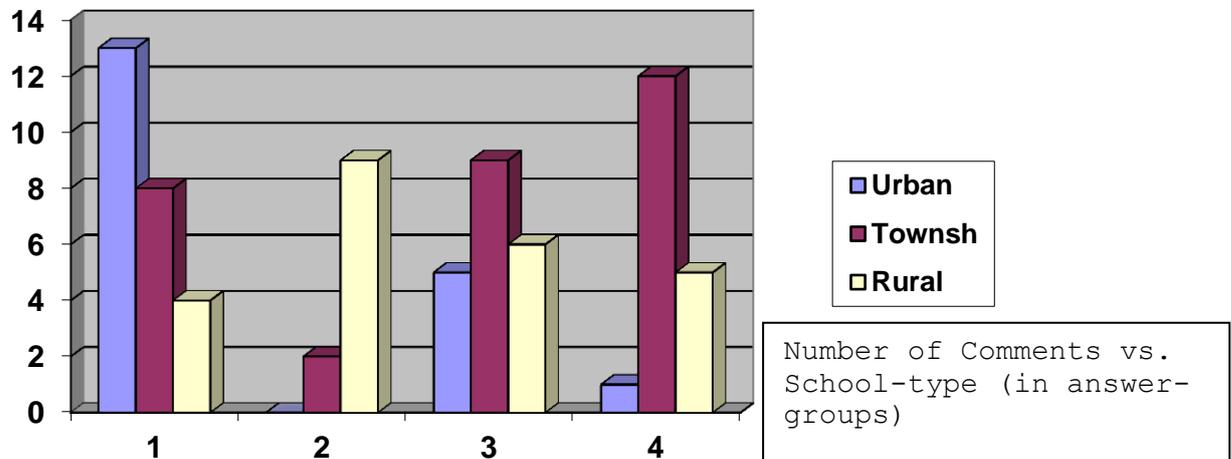


The results bore out what was seen in the presentation. The more privileged urban school had higher expectations of the show and consequently rated it lower. This is also born out in the choice of words for answering question 2 below.

2.1.2: Question 2: “At home tonight, what will you tell your friends/ family about from the show?”

These answers were classified into four groups:

1. Positive comments about the show (although the language used here differed significantly)
2. Comments of what was learnt, gratitude
3. Intention to pass on some information or learning (or teach) to family
4. Information/ excitement about the different instruments seen



Again it is fascinating to see the different expectations of the show born out in the responses.

- Urban pupils mostly (62%) reported that they would tell family/ friends that the show had been good (1), but none said they would report how much they had learnt (2)! Only 5 expressed an intention to teach something of what they had learned to people at home, or pass on the knowledge (3). And only 1 wanted to share his excitement at all the different instruments seen (4), indicating that this was probably not a new or novel experience. (“..that it was interesting and filled with interesting facts that I learned”)
- Township pupils to a lesser extent (42%) reported that they would tell family/ friends that the show had been good (1), and only 2 said they would report how much they had learnt (2)! But here almost half expressed an intention to teach something of what they had learned to people at home, or pass on the knowledge (3). The most common response was that 12 of them (63%)

wanted to share their excitement at all the different instruments seen (4), indicating that this was definitely a new or novel experience, and had made a big impact. (“I will teach them that different musical instruments have different pitch and their wavelength is not the same”)

- Rural pupils: very few (22 %) reported that they would tell family/ friends that the show had been good (1), but half of them (50 %) said they would report how much they had learnt (2)! One third of them expressed an intention to teach something of what they had learned to people at home, or pass on the knowledge (3). And 5 (28%) wanted to share their excitement at all the different instruments seen (4). (“I will tell them that I have learned about kinds of flute and learned types of guitars”)

It is also interesting to break down group 1 further, and look at the different language used in expressing positive comments about the show:

- Urban: interesting (x10), good, cool, OK
- Township: awesome, fantastic, nice, fun, amazing, new
- Rural: wonderful, surprising, important, practical

The words were peculiar to each school group with almost no overlap! Urban pupils focused on the show being interesting (10 responses) but this word was not used even once by either of the other groups. Township pupils focussed on fun, cool words. Rural pupils seemed to see the whole experience in a far more serious light, mentioning that the presentation was important and practical. These different expectations should definitely be kept in mind when presenting shows to these different groups.

2.1.3 Question 3: “What surprised you most about the show?”: There was a fair bit of overlap between the next three questions (3, 4 and 5), indicating that they probably need to be more clearly stated to get more useful answers. It is interesting to note that Urban schools mentioned being surprised by more technological aspects (the data studio software and ultrasound) while rural schools were surprised at the notion of making musical instruments from waste or simple things – something one could expect them to be more used to! Both urban and township pupils mentioned instruments by name (or description) in response, whereas not one rural pupil did! The notion that one needs vibrations for sound was surprising to township and rural schools, but not to urban pupils. This would suggest a presentation focusing more on the technology for urban schools, and on instruments – especially simple, recycled ones, for township and rural schools, in order to get the greatest novelty or surprise effect. Some sample comments:

- U: “That music is scientific”
“The way a flute bends waves of sound”
- T: “Is that noise and sound are too different things”
“Is that before the sound come out the vibration comes first”
- R: “... to see different types of instruments and how they work”
“... that if the [] is long the sound is low”

2.1.4 Question 4: “What new thing did you learn today?”: Again comparisons are very interesting: T and R schools noted learning the *new* fact that vibration is needed to make music or sound, whereas no U pupil mentioned it. Both groups also equally reported learning anew that different instruments produce different sounds and the key concept: “long is low, short is high”, neither of which was new to the U group. These are fairly basic or lower level points, perhaps indicating that one should adopt a lower entry level for these groups (especially considering that the average age of these groups is higher than the U group). The R group echoed the Q3 results in highlighting different or new instruments. It is always debatable how many instruments to use in the show. Probably there are too many at present, but the R group especially seemed to be very excited at this opportunity to see them (possibly once in a lifetime). Once again (as in Q3) the R group did not mention range of hearing (ultrasonic sound) as being new (or surprising in Q3), possibly because they did not fully grasp the

concept. The same goes for the ultrasonic cellphone ring. This could be further probed through appropriate content questions. Comments were very similar to Q3.

2.1.5 Question 5: “What thing you saw today reminded you of something you already knew?” : It is always good to tie a presentation to pupils’ prior experiences, and this music show is ideally suited for that, as everyone has some experience of music and musical instruments. The guitar and piano were clearly the best known, and should be kept in the show no matter how mundane they may seem as they provide a common reference point across all three school groups. I was very interested that the R school seemed more familiar with the piano, and the U school with the vuvuzela – quite the opposite of what I would have expected. Again the majority of the R school’s responses had to do with musical instruments, showing that this is a clear contact point for them.

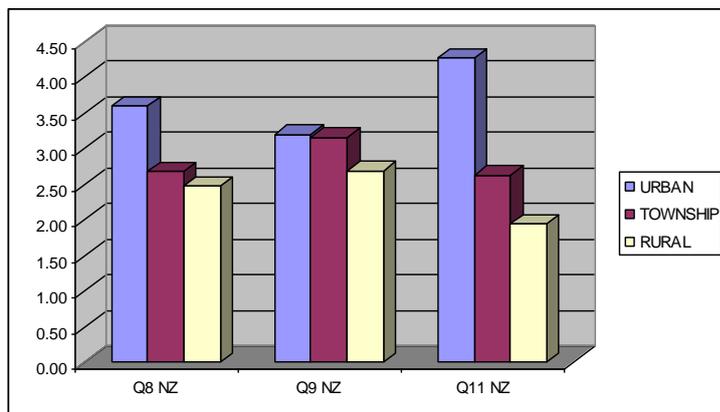
I was interested that the T and R schools mentioned the show reminding them of graphs, even specifying trig graphs from Maths. It is very pleasing to see this link being made, but this may have been obscured by other pupils just mentioning an easier answer like a familiar musical instrument. A dedicated probe would reveal interesting answers here. Perhaps: “Did the show remind you of something you have covered in another class at school?”

2.2: Conceptual Questions testing understanding of sound and waves

Answers for these three questions (8, 9 and 11) were tested against model answers (provided by myself as subject expert, and reflected in red text in the attached survey) and classified according to a 6 point scale – see table below. This scale is based on a *four* point scale suggest in Falk and Gillespie (2009) [1]. I felt the need to widen the scale more as these questions essentially had an answer (yes or no) *and* an explanation.

SCORE	ANSWER
0	Did not answer
1	Gave an incorrect answer
2	Gave correct answer but not explained (or incorrect reason)
3	Gave correct answer, used correct words but without understanding
4	Gave correct answer with good but incomplete explanation
5	Gave correct answer with correct explanation (but not necessarily perfect!)

Answers varied greatly and were generally not very good. In many cases pupils used correct technical terms but not as part of coherent explanations: “It is because of vibrations”. Language is clearly a huge problem for the rural and (to a lesser extent) township schools, and it was clear that they were struggling both to understand the question and to state their answers. In many cases rural pupils simply restated the question in their answer, ie: Why are men’s voices deeper?” was answered “It is because they are deeper!” The results of all three groups for all three questions are graphed below:



Answer-score (0-5) vs.
School-type (in
question-groups)
Excluding zeroes

From these graphs there is a clear decrease in answering ability from U, through T to R. This is most marked in Question 11, which surprised me, as this question was explicitly dealt with in the show! There are many questions which arise from this result. Are the R schools learning much (as they expressed in Q2), but simply unable to relate it in a foreign language, exam scenario? Clearly three questions to 58 pupils is not nearly enough to answer these questions fully, and different types of questions should be used to exclude language and other effects.

It must also be born in mind though that the best results came from the youngest students in the lowest grade, as we had:

- Urban Grade 9 Average age 15.0 3 question average (excl 0's) 3.69
- Township Gr 11 Average age 17.1 3 question average (excl 0's) 2.82
- Rural Grade 10 Average Age: 15.9 3 question average (excl 0's) 2.37

In addition these U pupils would probably NOT have covered sound yet in class (as it is taught in Grade 10), while the other two groups should have covered it. There was little variation of any importance in the answering of the specific questions, and where a school group did seem to “get it” (the U school with Q11), they seemed to “get it” pretty much right across the group.

In terms of starting where pupils are to their knowledge and cognitive grasp of sound, it is clear that allowances will have to be made for rural groups. The presentation for them should probably contain more repetition and less depth to ensure that key concepts are grasped. With U schools one can safely assume a higher starting point, and can safely delve into topics in more depth, further stimulating the interest which they expressed in Q2.

2.3 Conceptual questions: detailed explanation and drawing or visualization (6, 7, 10)

2.3.1 Question 6: This was a complete failure, and pupils did not answer the question in the way I wanted at all. Admittedly this survey was very rushed and they simply didn't have time to give a complete answer here. I took this question from Falk and Gillespie (2009) and I still feel it is a very useful question to see in how much detail they remember the show and what went on in it. But we shall clearly have to ensure that the pupils have sufficient, unrushed time to answer this one properly.

2.3.2 Question 7: This asked pupils to complete a drawing showing how one man hears another man shouting. The results were fascinating, with not a single pupil producing a correct picture of sound waves (along the lines of ripples in a pond). Many chose not to answer this question, and those who did drew a representation (sine wave) of a wave rather than the reality. By far the majority of pupils chose a basic sine wave representation (26 out of 58 – almost half). 12 pupils didn't answer the question – coming especially from the township school. I was intrigued at how many of them drew loops, with the wave doubling back on itself. Pictures resembling bouncing were also interesting,

perhaps representing a picture they have seen before of a ball bouncing along the ground. A few also drew multiple waves together. Two pupils drew sound waves which arrived at the ear but travelled only half or less of the distance, not emanating from the shouter! At this stage one can only speculate at the reason for these drawings, but it would be good to have the opportunity in a follow up interview to explore further the reasons for these visualizations.

3. Conclusions

Despite having performed this show for over 10 years to many thousands of pupils, this brief study has made me rethink many of the assumptions I had been making. Science pupils in South Africa are at a very low level of knowledge and understanding (TIMSS) and one must assume very little prior knowledge when presenting a show to them.

Urban pupils have very high expectations of a science show and are consequently harder to please. There is less which is novel to them, and they seem to be most enticed by what especially interests them. They expressed no particular intention to pass on the knowledge or experience to family or friends, perhaps because they came from educated families. Surprise or novelty seemed to come mostly from the technological aspects of the show. Urban schools clearly started from a better conceptual base, so one could present at a higher level, and possibly extend the show into greater detail (i.e. tackling harmonics). The Urban schools also benefited from good English language capability, which obviously aids understanding.

Township pupils had lower expectations of the show and were consequently easier to please! They seemed to like the aspects of the show which they thought were “awesome or amazing”. They seemed to be intrigued by the instruments and expressed a strong intention to share this excitement with family and friends. Township pupils differed from urban pupils in expressing surprise or novelty at the link between sound and vibrations. Their conceptual understanding was much weaker than urban schools, and not much different from rural! A large number of township pupils did not make drawings when requested to do so. It would be interesting to probe further if this is lack of ability to draw, or a feeling that it is childish or beneath them?

Rural pupils rated the show very highly and clearly saw the occasion as very serious and important (judging by their choice of descriptive words. They clearly saw the show as a profound learning experience and expressed the intention to tell friends and family about this and to pass on some of their knowledge. This has positive implications for our HIV/Aids show where we plan to use pupils as ambassadors into their communities. The rural pupils definitely related better to the instruments than to the computer simulations and it would appear that concrete practical equipment will be more effective with these groups. Rural pupils were very weak conceptually and shows should focus on reinforcing basic concepts and not focussing too much on counter-intuitive or surprising facts, as suggested by Lee (2003) [2] Language also makes understanding more of a problem.

These brief insights make a strong case for science show presenters to be regularly involved in action research on the impact of their shows, and best practice for different school groups. Sadler [3] has shown that this retrospection leads to improvement in both practice and impact.

4. References

- [1] Falk JH and Gillespie KL 2009 *Visitor Studies*, 12(2), 112-132
- [2] Lee O 2003 *Teachers College Record* Vol 105 No. 3 pp 465-489
- [3] Sadler W 2004 *Masters Thesis*