Paper

Old wine in new skins: Customising Linear Audio Cassettes into an Interactive CDROM Format

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Abstract

An audio cassette from the Educational Techniques Group Trust's 'Chemistry Cassettes' series entitled '*Entropy – the driving force of change*' has been adapted from a linear format into an interactive CDROM format. Details of this process are described together with a student evaluation process of this topic. The results of the evaluation were encouraging in terms of acceptance by the students and their performance for the numerical parts of the topic, though difficulties with the abstract aspects were still encountered. It was encouraging that a large number of students asked that more topics from the 'Chemistry Cassettes' series should be produced in interactive CDROM or on-line format.

Introduction

In recent years, there has been considerable interest and activity in self-, distance- and computer-based learning in scientific education. For example, the Open University[1] has invested heavily in computer-based materials to enhance its programmes, the Chemistry Video Consortium[2] has developed material to promote self-paced learning for practical laboratories and there are many examples[3] of other Universities who have produced on-line courses. The Royal Society of Chemistry now has a significant on-line learning resource[4], and many posters and demonstrations at the 'Variety in Chemistry Education' Annual Conference[5] feature computer-based resources. In all, a considerable amount of time, effort and money is being put into this area of education.

'Chemistry Cassettes'[6] were developed by the Educational Techniques Group Trust (ETGT) of the Royal Society of Chemistry in the 1980s and 1990s. They covered a range of topics (see Appendix I) and took the form of audio cassettes in which a practising teacher, an expert in the field, spoke for about 60 minutes, and these were accompanied by booklets containing diagrams and questions, designed to be studied in parallel with the audio cassettes.

Clearly the cassettes are now dated, particularly in terms of their mode of delivery. However, much of the content is still relevant today, and this makes them a useful potential resource for today's Chemistry courses. Since these cassettes contain a great deal of important chemistry presented by experts in both the subject and in teaching, it would be a pity to lose such a valuable resource.

Three questions arise: *"Would it be a service to convert them into a format that rescues the content and converts it into a form that is a more valuable teaching method, e.g. a computer readable interactive learning package?" "How can the delivery of the audio cassettes be up-dated in practice?"* and *"Will today's students view them as useful learning resources?"*

In this project, an attempt was made to update the mode of delivery of one of the cassettes, to ask a group of students to study the topic and the new interactive software, and to report back on their experiences.

Adapting the audio cassettes

Significantly changing the content was deemed to be an unnecessary task for a number of the cassettes because the subject matter is 'timeless'. With

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others, this is not the case and extensive changes would be needed. Therefore the ETGT has looked at the possibility of improving the delivery of those cassettes where only small changes in content would be required. This would involve

- Digitising the audio file so that it could be played through a PC,
- Re-working the booklets to provide a computer-based format,
- Linking the audio and the contents of the booklet in a computer based package,
- Adding a quiz
- Retaining and enhancing the interactivity of the learning package.

To test the appropriateness of this approach, the ETGT produced a demonstration[7] CDROM covering just one of the cassettes, '*Entropy – the driving force of change*'. Because it is a demonstration CDROM, the links between the spoken commentary and the diagrams and questions were covered in two ways on a single CDROM. Navigation buttons were used to allow students to move between the two pages containing the different approaches. In the first, the student was expected to pause the audio and click on a numbered button to reveal a pop-up diagram or question (answers to questions could be revealed by using a 'right click' on the same button; e.g. Figure 1). In the second, a transcript of the text of the audio accompanied the audio and students were expected to scroll the text as they listened and to click on 'hot' words to reveal the diagrams and questions: e.g. Figure 2. In this project no attempt was made to compare the effectiveness of these two approaches and students were not asked which approach they used.

Content of the learning package: *'Entropy – the driving force of change'*

The original cassette[8] was designed for 'A' level/ 1st year undergraduate Chemistry students and is a largely qualitative look at the concepts of probability, entropy and free energy and their role in explaining the direction of change. The topics covered include

- A few observations on the direction of change and the need for a guiding principle
- Gases in containers – chance and the positional distribution of molecules
- Probability and entropy
- Entropy and the direction of change
- Some examples involving entropy increases
- The need to consider the distribution of energy
- Standard entropies – differences between gases, liquids and solids
- Entropy changes in chemical reactions – a qualitative approach
- Entropy changes in chemical reactions – calculating the value
- The importance of both the system and the surroundings
- Calculation of entropy change in the surroundings
- Calculation of the total entropy change and the importance of conditions
- Gibbs free energy
- Free energy and the direction of spontaneous change
- Calculation of free energy changes
- Extraction of metals from their ores – Ellingham diagrams

The student evaluation process

The next stage in the project was to test the CDROM with students. This was achieved by introducing the up-dated learning package to one hundred students on the first year course for honours chemistry and subsidiary chemistry at a leading UK University, who were asked to use it during the first semester of the first year of their course.

Specifically, the students were asked to study the topic using the learning package, to complete the associated course work (see Appendix II), and to complete a questionnaire on the learning experience (see Appendix III). Students were expected to study the topic as a self-paced learning experience. They were given a CDROM and some suggestions about how they should attempt the study (see Appendix IV). The learning experience was not managed in any other way by staff at the University.

Results

Of the one hundred students who took part in the project, fifty-two completed the course work and submitted the questionnaire. Although this topic would be a formal part of the course in the second semester, the remaining students failed to engage with it at the time of the project (see the discussion section below).

Figure 1: Using a numbered button to produce a pop-up frame

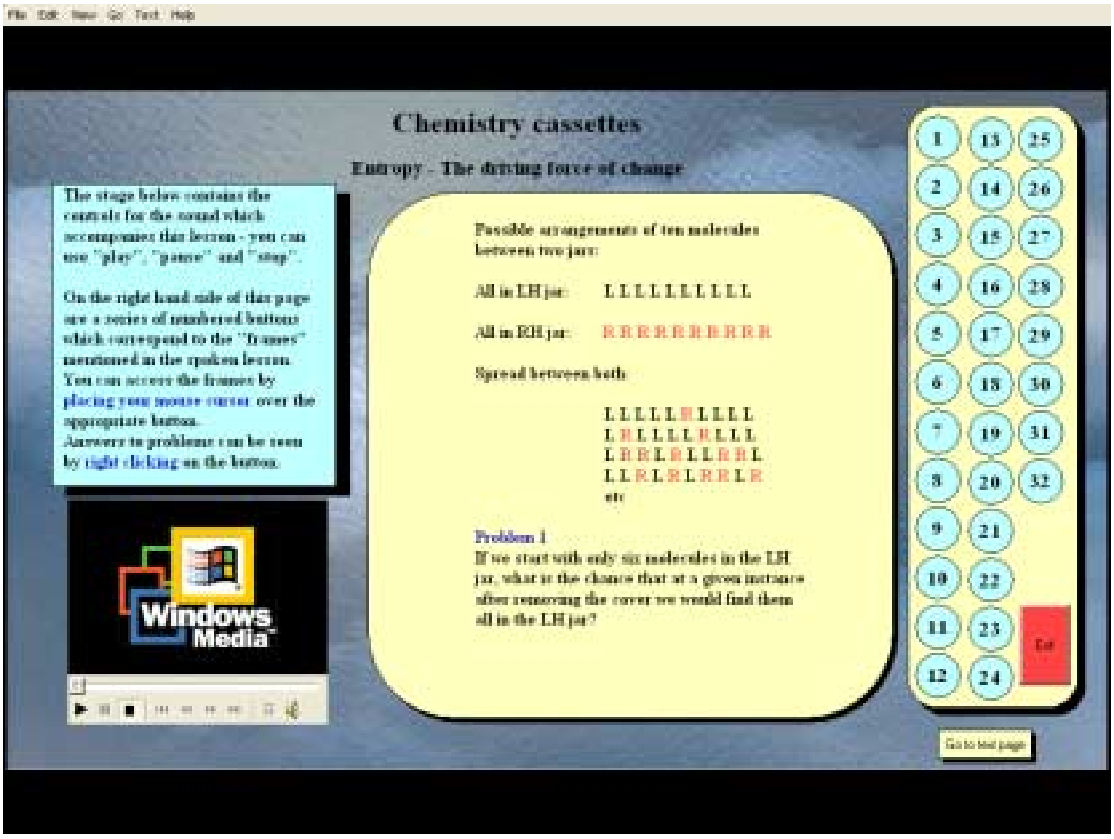

Figure 2: Using a hot-word to produce a pop-up frame

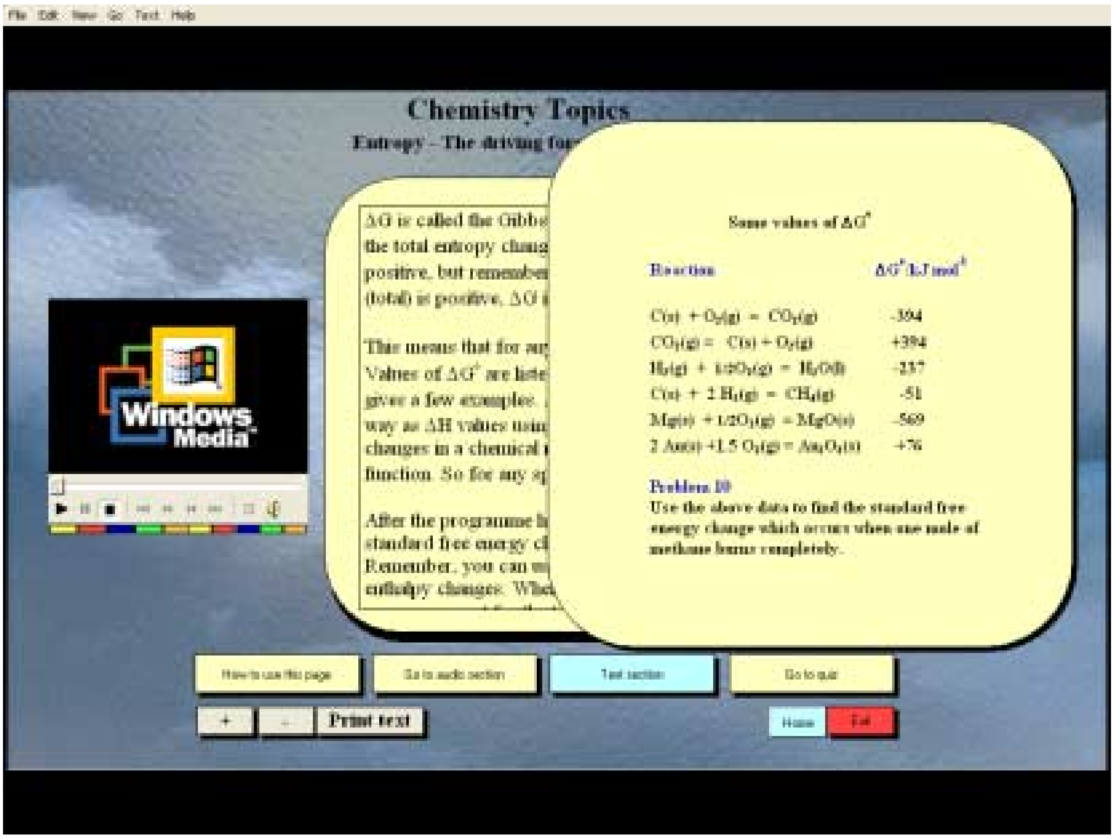

Table 1. Questionnaire

Question			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Responses			48	48	47	45	48	48	47	48	48	48	48	48	48	48
Average			3.6	3.9	3.4	3.53	3.77	3.5	3.91	3.77	4.06	3.3	3.6	2.7	3.33	3.2
Range	Min		1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Max		5	5	5	5	5	5	5	5	5	5	5	5	5	5
Number	5		9	12	6	12	17	10	14	17	17	6	13	5	2	8
Answers	4		21	26	20	15	14	13	18	13	19	16	11	4	24	12
	3		10	6	12	9	9	17	13	11	11	12	16	17	13	17
	2		6	1	5	3	5	7	1	4	0	12	6	16	6	3
	1		2	3	4	6	3	1	1	3	1	2	2	6	3	8
%>3			63	79	55	60	65	48	68	63	75	46	50	19	54	42
%<3			17	8.3	19	20	17	17	4.3	15	2.1	29	17	46	19	23

The results of the students completing the work are summarised in Tables 1 and 2**.**

Table 2 Course work

Number submitted	52
Average mark	60.2
Range of marks	27 to 90

The majority of students made no comments for question 15, but when comments were made, the main responses were

- Animate the diagrams
- Automatically scroll the text with the audio
- Annotate the diagrams
- Break up the text into smaller sections
- Do more topics in this way

Discussion

The main aim of this work was to answer the questions of whether it would be a service to the community to rescue the contents of the chemistry cassettes and convert them into a form that is a more valuable teaching method, and whether today's students would view them as a useful learning resource.

The authors' view is that the cassettes contain a great deal of important chemistry presented by experts both in the subject and in teaching, and this project has shown that it is possible to overcome the main shortcomings – the datedness of their presentation. The project has shown that it is possible to produce a computer based learning package with greater interactivity, including a self-assessment quiz, from one of the cassettes. Further, the project has shown that the computer based learning package works as a learning resource, with a significant number of students endorsing the package. However, the project has raised further questions, which point the way to further studies in this subject.

Firstly, the question of why such a large number of students failed to complete the course work needs answering. Did the students see this entropy course-work as an optional extra to their course, and should staff have played a more active role in managing the learning experience? Coupled with this comment is the question of exactly how such a resource could be best used in a University course – as an integral part of the course; as an add-on extra for revision or support to the main teaching or as a diagnostic tool for staff? The current project has already revealed student strengths (skill at numerical calculations) and weaknesses (understanding of the concepts of probability) in this area of chemistry.

Secondly, the question of whether a student questionnaire was the most appropriate way to judge the usefulness of the learning package needs addressing. Is there a better way of judging the effectiveness of the package as a learning tool? It is now clear that there should have been an attempt to compare the students' performances on this part of the course with those on other parts and this will be a feature of any further work.

Thirdly, what of the other chemistry cassettes? Should this work be repeated using one of the other topics? If the conversion is deemed to be of value, how will the other cassettes be converted? The task is not small and the ETGT may need to ask for volunteers to help with the work

Conclusions

It has to be assumed that those students who did not return course work and questionnaires did not complete the study of this learning package, and it was disappointing to see that forty-eight out of the one hundred students fell into this category. It is suggested that this situation would have been improved if staff had taken a much more active role in managing the learning experience, perhaps meeting with students to assess progress regularly, and perhaps introducing tutorials at appropriate parts of the course. To put the situation into context, lectures were not delivered on the topic during the coursework period; these come on stream during the following term together with appropriate tutorials. It is also possible, therefore, that the project was tried at too early a stage in the students' course, and the students may not have been aware of the help this exercise would give them in mastering an important topic later.

However, the results for the students who did complete the project were encouraging. For example, even though course-work was undertaken as part of this project and before the lectures and tutorials in term 2, the marks fell in the range 27 to 90% with an average of 60, showing a very good spread, indicating that the course work was discriminating, and a good average mark showing that the learning experience was effective. Student responses to the learning experience were also encouraging with most questions in the questionnaire receiving the majority of replies in the '3, 4 and 5 categories', and it was also encouraging to see the large number of students who would like to see more topics developed in this way. Some students had taken the time and trouble to identify such topics: e.g. Ionic crystals; Ions in solution; Some organic reaction pathways; Some reaction pathways of double bonds; Aromaticity; Symmetry in chemistry; Quantisation; The architecture of matter; pH and its measurement; The periodic law; An introduction to NMR spectroscopy; Radicals and their reaction pathways.

Staff marking the course-work were able to identify particular student problems with their understanding of 'Entropy'. For example, students generally did well on the numerical parts of the topic, and much less well on the more abstract idea of the meaning of probability and entropy. In particular, many students were unable to relate their ideas of probability and entropy to available energy levels. This should lead to more effective teaching in the forthcoming year.

The project reported here is a preliminary study but it has encouraged us to continue with the development and updating of these materials.

Acknowledgements

We thank Miss Fiona Walker and the Royal Society of Chemistry for making available a full set of files for "Chemistry Cassettes" via the www (see www.rsc.org/chemistrytopics), the ETGT for supporting the adaptation, and the students for their participation in the evaluation process.

References

1. The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK. (Examples include '*The molecular world*'; '*Metals and chemical changes*'; '*The third dimension*'; '*Separation, purification and identification*'.)
2. The Chemistry Video Consortium, c/o Dr A.J. Rest, School of Chemistry, University of Southampton, SO17 1 BJ, UK. (Examples of computer-based work include 'Physical Chemistry Experiments'; 'Practical Laboratory Chemistry'; 'Le Bon Geste Practique en Chimie')
3. Universities employing significant computer-based learning in science include College of Charleston, Penn State University, University of Illinois, University of California, Imperial College, and Leeds University.
4. The Royal Society of Chemistry, Burlington House, Piccadilly, London, UK, W1J 0BA whose contributions include its Library and Information Centre Knovel databases (www.rsc.org/library)
5. Variety in Chemistry Education (Teaching) is an annual conference for staff in Higher education run by the LTSN Centre, Department of Chemistry, University of Hull, Hull, HU6 7RX, UK (www.physsci.ltsn.ac.uk)
6. ETGT commissioned and published a series of audio tapes and booklets by leading experts from 1975 to 1990
7. Details of the demo CDROM are available from Dr A. J. Rest, School of Chemistry, University of Southampton, SO17 1BJ, UK, or from Dr D. Brattan, dbrattan@hotmail.com.
8. '*Entropy – The driving force of change*' by Dr Graham Hill who was deputy Head Master at Dr Challenor's Grammar School, Amersham and John Holman, who was Head of Science at Watford Grammar School

Appendix I
Some aspects of the Electrochemistry of solutions
by Graham Hills
Ion Selective Electrodes
by Arthur Covington
pH and its measurement
by Arthur Covington
Ionic Crystals
by R B Heslop
Solving Inorganic Spectroscopic problems
by Alan Vincent
Ions in solution
by John Burgess
The periodic law
by David Johnson
Some organic reaction pathways
by Peter Sykes
Some reaction pathways of double bonds
by Peter Sykes
Radicals and their reaction pathways
by Peter Sykes
Aromaticity
by Peter Sykes
Linear free energy relationships
by Peter Sykes
Symmetry in chemistry
by Sid Kettle
The theory of transition metal compounds
by Sid Kettle
Coordination chemistry
by Sid Kettle (two cassettes)
An introduction to NMR spectroscopy
by Bruce Gilbert and Richard Norman
Quantization
by Peter Atkins
X-ray crystallography I
by Stephen Wallwork
X-ray crystallography II
by Stephen Wallwork
The chemistry of biological nitrogen fixation
by Raymond L Richards
Heavy metals as contaminants of the human environment
by Derek Bryce-Smith
Using chemical abstracts
by an ETGT/RSC editorial team
The architecture of matter
by Graham Hill and John Holman
Competition processes
by Graham Hill and John Holman
Entropy- the driving force of change
by Graham Hill and John Holman

Appendix II: Entropy demonstration CDROM – some questions

1. 20 gas molecules are placed inside a container that has two identical sections. What is the chance of finding all 20 molecules in one of the sections?

2. Use the ideas of probability to explain why the entropy of the system increases when
b) a solid melts

c) the temperature of a gas increases
d) two gases are mixed

Your answers should not exceed more than 100 words for each section of this question.

3. Plots of free energy against temperature for the following reactions are linear, described by the equations given.

$2\ C(s) + O_2(g) = 2\ CO\ (g)$ $\Delta G = (-224 - 0.187T)\ kJ\ mol^{-1}$

$C(s) + 2\ O_2(g) = 2\ CO_2\ (g)$ $\Delta G = (-394 - 0.00008T)\ kJ\ mol^{-1}$

Explain why the two plots have such different gradients.

4. Use the data given below for the reaction

$C_3H_8(g) + 5\ O_2(g) = 3\ CO_2(g) + 4H_2O(g)$

to calculate
a) the standard enthalpy change at 298 K
b) the standard free energy change at 298 K
c) the standard entropy change at 298 K
The standard entropy change in the surroundings and the total entropy change that would accompany the reaction at 298 K

Comment on your results.

	$C_3H_8(g)$	$O_2(g)$	$CO_2(g)$	$H_2O(g)$
ΔG_f (298)/kJ mol^{-1}	-23.4	0	-394.4	-228.6
ΔH_f (298)/kJ mol^{-1}	-103.8	0	-393.5	-241.8
S(298)/ J mol^{-1} K^{-1}	270.0	205.1	213.7	188.8

Appendix III: Questionnaire

Please answer the following questions by circling one of the numbers; **5** indicates a positive response and **1** a negative response to a question.*

[* A referee commented that this was a rather vague instruction and the wording may have weighted the numbers of 1 and 5 responses gained. It would have been better to say that 4 and 5 represent positive responses, 1 and 2 negative responses and 3 represents a neutral response. With hindsight we agree with this comment but this questionnaire was the actual one used.]

a) **The format of this package**.

1. The learning package was easy to use

1 2 3 4 5

2. The instructions for using the package were simple to understand

1 2 3 4 5

3. The links between the audio text and the pictures/frames was easy to control

1 2 3 4 5

4. Using ‘right click’ to obtain answers to the questions was satisfactory

1 2 3 4 5

5. Being able to read the text and listen to the audio at the same time was useful

1 2 3 4 5

6. The ability to vary the size of the text on the screen was helpful

1 2 3 4 5

7. The quiz at the end of the learning programme was a useful revision exercise

1 2 3 4 5

8. Being able to print out the text and/or the frames was useful

1 2 3 4 5

9. It would have been helpful to have had section headings/numbers and page numbers for the text

1 2 3 4 5

10. This was a useful way of studying a topic, e.g. entropy and free energy

1 2 3 4 5

11. I would rather have studied this topic in a lecture/tutorial situation

1 2 3 4 5

12. I would rather have studied this topic by reading a book or written handouts

1 2 3 4 5

13. This learning package has helped my understanding of the subject

1 2 3 4 5

14. I would like to see other topics developed in this way

1 2 3 4 5

15. Please feel free to write any other comments about this package (either positive or negative views would be welcome).
Additionally, it would be particularly helpful to know whether you think scrolling the text files alongside the commentary is a good idea and which other titles from Appendix 1 you would like to see customised into CDROM format (question 14).

Appendix IV: Suggestions about how to study of the learning package

Although the audio part of this learning package lasts for just over **40 minutes** in length, the overall package should be considered as involving from **five to six hours of study time** because it will be necessary to study the diagrams and frames which accompany the audio tape and attempt the problems. It is therefore suggested that you study the package in **five roughly equal, parts** and take about one hour on each part. Make some summary notes on each part and, before you start another part, quickly **revise the previous part** by using your notes or listening to that part of the audiotape again.

A possible breakdown of the package could be:

- A few observations on the direction of change and the need for a guiding principle; gases in containers – chance and the positional distribution of molecules; probability and entropy; entropy and the direction of change; some examples involving entropy increases.

- The need to consider the distribution of energy; standard entropies – differences between gases, liquids and solids; entropy changes in chemical reactions; a qualitative approach; entropy changes in chemical reactions; calculating the value

- The importance of both the system and the surroundings; calculation of entropy change in the surroundings; calculation of the total entropy change and the importance of conditions

- Gibbs free energy; free energy and the direction of spontaneous change; calculation of free energy changes

- Extraction of metals from their ores – "Ellingham diagrams"