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Learner perceptions on instructional design of multimedia in learning abstract concepts in science at a distance

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This study was carried out to explore learner perceptions on the instructional design features of interactive multimedia (IMM), which was especially designed to support the open and distance learners studying microbiology as a part of the BSc degree programme of the Open University of Sri Lanka (OUSL). The purpose of developing this IMM was to explain the dynamic abstract concepts and processes of bacterial genetics that are hard to comprehend by referring to print course material, as surfaced from course evaluations. When developing the IMM package, emphasis was placed on the interface design, navigational design and instructional design in particular. Instructional design was mainly based on Gagne's nine events of instructions, and Mayer's Cognitive Theory of Multimedia Learning on verbal and pictorial information. IMM was designed incorporating basic instructional features such as learning outcomes, an introduction, self-assessment questions, glossary, and so forth. Animations with narrations were extensively used to explain abstract processes. These design features were integrated, enabling active learning, visualising the dynamic abstract bacterial processes over time, and testing learners' knowledge with immediate feedback, allowing them to achieve a meaningful learning experience. Learner perceptions on instructional design features were gathered through quantitative and qualitative research methods by means of questionnaires, interviews and observations. Evaluation revealed many positive features and a few negative features to be incorporated into the design of IMM in providing better support for the learners. Findings of this study throw light on designing effective learner-centred multimedia learning material.

Keywords: interactive multimedia; distance learning; Sri Lanka; instructional design; science

Introduction

The Open University of Sri Lanka (OUSL) is the only national single-mode distance teaching university in Sri Lanka. Traditional methods of open and distance learning (ODL), predominantly through print supported with audio-visuals, have been practised at OUSL for a long time. Computer-based multimedia learning materials have revolutionised instructional practice in ODL by enhancing active learning through interactivity and exploration. OUSL also gradually moved into fusing technology with educational content, enabling learners to experience learning through multi-sensory representations; namely, text, sound, still and moving images.

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In general, a few decades ago, teaching science disciplines through ODL methodology was regarded as a challenge. However, OUSL took up this challenge in 1983 and developed course material for its distance learners.

The microbiology course was first offered in 1991 as a pre-requisite course to many other science courses. The original course material in print was prepared in 1989/90. Skills and techniques were taught in face-to-face laboratory sessions. The printed course material lacked the interactivity that was essential for distance learners and exhibited the characteristics of a correspondence course (Jayatilleke, Kulasekara, & Coomaraswamy, 2009). Subsequent to the training received through the 'Material Production and Desktop Publishing' component of the Department for International Development UK project 1995–1998 (Weerasinghe, 1999), this course was extensively refined and transformed in 1997/98, incorporating advance organisers, learning outcomes (LOs), self-assessment activities/review questions, summaries, trilingual glossaries and also supplemented with audio-visual material (Coomaraswamy, 1999).

However, feedback evaluations carried out in 2003 still indicated learners' difficulty in comprehending abstract bacterial genetic processes, which are lengthy explanations in print course material. In addition, these bacterial processes were represented using series of graphics, illustrating the temporal change. These graphics portrayed a more cluttered visual display, with added symbols (arrows, labels, dotted lines, etc.). As such, learners have to read these lengthy texts, and *mentally animate* the static graphic depictions in appropriate fashion (Hegarty, 1992), to understand these processes. In addition to this cognitively demanding task, English being their second language, linguistic demands also become challenging to the learners.

Systematically designed multimedia learning material had greater potential to overcome the limitations of print media in supporting the development of scientific understanding, especially in teaching and learning abstract concepts in science (Garnett, Oliver, & Hackling, 1998). Therefore, with the purpose of explaining dynamic abstract concepts in microbiology, an interactive multimedia (IMM) was developed as a supplement to the print course material, to support undergraduates who are following this course.

Objectives of the study

The objective of this study was to investigate learner perceptions on the instructional design of the IMM in learning dynamic, abstract microbial genetic processes and in developing a more user friendly learning package.

IMM learning package

As a supplement to the print course material, the IMM 'Recombination of Genes in Bacteria' was produced using the Macromedia Director authoring tool.

While designing the IMM, the same content information in the print course material of *BTU2104 Principles of Microbiology* – Lesson 19 was presented with a great amount of interactivity. In order to produce an effective instructional product that promotes meaningful learning, instructional design perspectives based on research foundations were harnessed. Instructional design was mainly based on Gagne's nine events of instructions (Gagne, 1985) and Mayer's Cognitive Theory of Multimedia Learning in designing verbal and pictorial information (Mayer, 2001). Emphasis was also placed on effective visualisation of abstract concepts and learner motivational

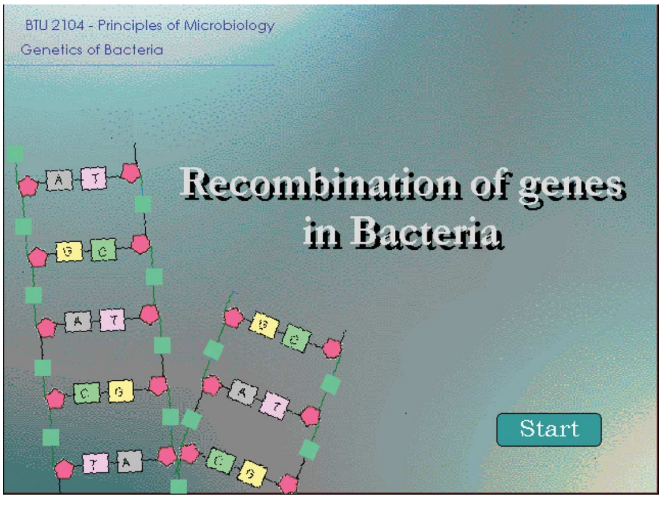

Figure 1. 'Title' screen.

factors. Careful attention was also placed on presenting information in the medium of English, as English is the learners' second language.

Three basic screen structures were used for the 'Title' screen, the 'Contents' screen and for the factual information screens.

The title screen (Figure 1) was made simple and explicit (having the title, a picture showing two strands of DNA molecules, background music and a navigational button to start with) in order to create a receptive attitude, and to provoke learner interest towards the theme of study.

The 'Contents' screen (Figure 2) consists of navigational buttons (1–7) indicating the sections. In addition, this screen consists of three other buttons; namely, Tour Guide, Menu button, and an Exit button.

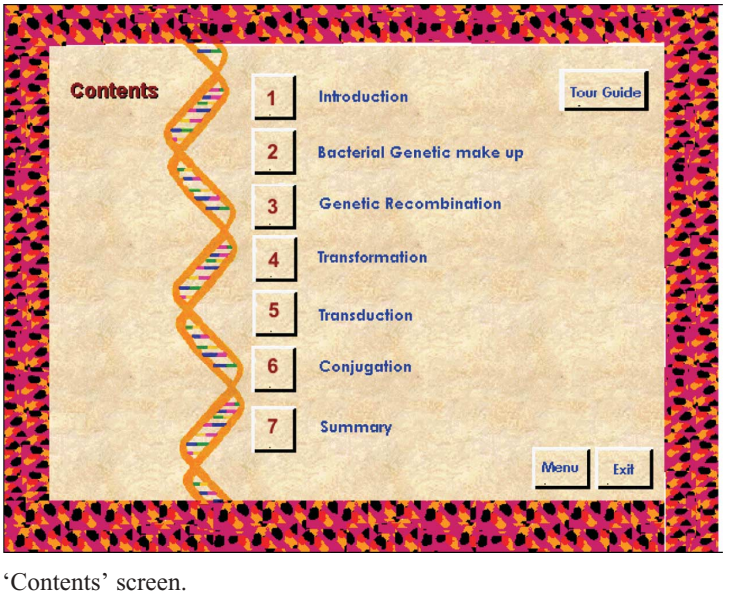

Figure 2. 'Contents' screen.

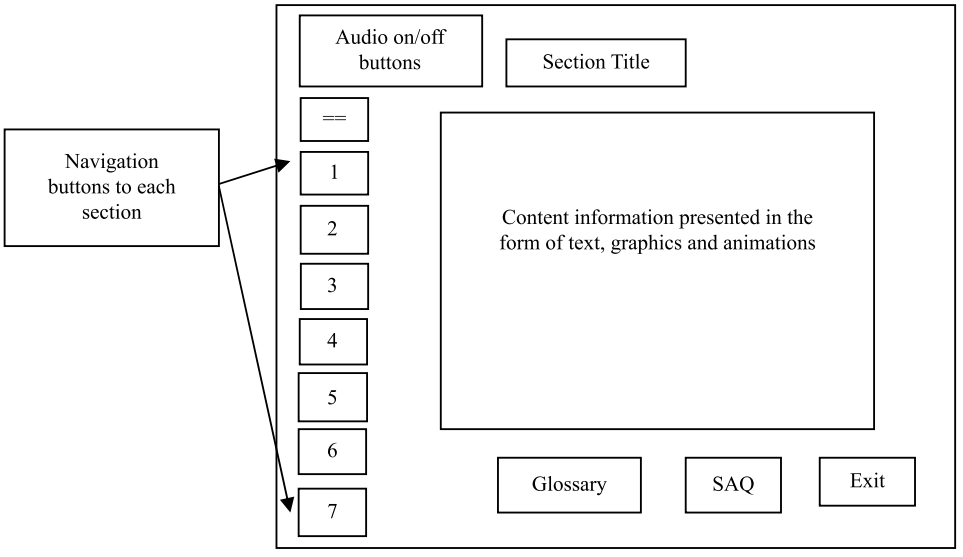

Figure 3. Storyboard showing the structure of factual information screens.
Note: SAQ – Self Assessment Questions.

The 'Contents' screen starts with a background narration instructing learners to view the 'Tour Guide' if they are viewing the package for the first time. The 'Contents' screen was made as simple as possible, in order to gain fullest attention on the organisational structure of content information. As such, 'negative space' (empty background space) was kept to its fullest, to give a better perspective of the positive space (space for text/objects).

Factual information screens were structured as shown in a storyboard (Figure 3).

Each page was supplemented with the following features:

- A simple definition at the beginning.
- Content information placed in the middle portion of the screen, presented in the form of text, graphics and animations.
- An audio on/off button at the top left corner of the screen.
- Navigational buttons placed on the left-hand side and 'Exit' button at the bottom-right corner of each screen.
- A link to 'Self Assessment Questions' (SAQs) with interactive feedback.
- A link to the 'Glossary'.

A sample screen is given in Figure 4.

Animations were extensively used to explain the dynamic bacterial genetic processes. These animations were incorporated with *play*, *stop* and *repeat* buttons, allowing learners to view as they wish. Graphical illustrations of bacteria depicting the nuclear material with different colours were used to emphasise the text explanations. Information was chunked appropriately with short descriptions, taking care not to overload the working memory of the learner. In the case of explaining detailed instructions, windows overlays were used, however, not to exceed more than two or three

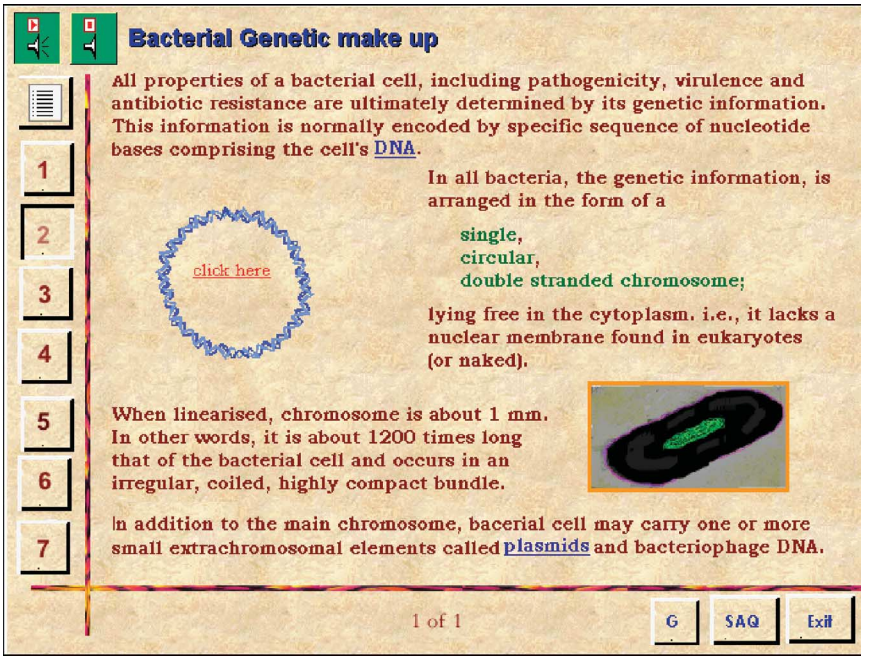

Figure 4. A sample screen showing the format of a section.

levels. Background narrations were used explaining the visuals and animations, and were coupled with the same text explanations with controls. These oral explanations were of simple narrative style with learner paced segments.

It took about 1000 person-hours to complete all animations, and almost 2000 person-hours to complete the whole package.

Methods

For the evaluation of IMM, both qualitative and quantitative methods were used to collect data. Quantitative data collection was carried out with a questionnaire, while interviews and observations were conducted to gather qualitative information.

The *questionnaire* used was a self-completing questionnaire, that was modified and adapted from 'Learner questionnaire' given in Reddi and Mishra (2003). It comprised close-ended questions on navigation, screen design elements, pedagogical components and media components. Responses were gathered on a four-point Likert scale (strongly disagree [1] to strongly agree [4]).

The *interview* schedule consisted of standardised open-ended questions in which the exact words and sequencing of questions were determined in advance (Patton, 1980), and supplemented with some probing questions. The interview schedule also addressed the same themes and, in addition, questions related to their learning experience with the IMM. Each interview was recorded.

The *observational study* was carried out while each learner was studying the IMM, using an observational schedule. This schedule was highly structured, identifying observational categories in advance (Cohen, Manion, & Morrison, 2000). Learners' involvement in navigation, use of interactive components and media components, and

learner performance while answering SAQs and any technical problems in the program were observed. Special remarks/observations were also noted in the same schedule. During observations, researchers adopted a passive non-intrusive role without interfering with their learning, as pointed out by Cohen et al. (2000).

Triangulation of research methods was used to achieve reliable evidence and validate results.

Sample

This study was carried out with learners who were following the *BTU2104 – Principles of Microbiology* course at OUSL. One hundred and sixty-five learners registered for the course, and all were informed of the evaluation of the IMM by post and during face-to-face sessions. They were informed of the necessity of usability and developmental testing of the IMM, for acceptance by the learners and further improvements. Learners were requested to respond whether they wished to participate in this evaluation. Forty-two learners responded and wished to be part of the evaluation and gave their consent in writing. Evaluation was carried out at the main campus. Learners were given the freedom to study the IMM as they wished, without any time restrictions.

All respondents were considered for the quantitative study through the questionnaire. In the qualitative study, the sample size was restricted to first 30 as the data collection achieved a theoretical saturation, as stated by Strauss and Corbin (1998).

Frequencies were computed for quantitative data, and content analysis was carried out for qualitative data.

Results

Use of media components

Use of media components (visual and verbal) in the IMM were highly appreciated by learners. Perceptions received through questionnaire are given in Table 1.

Learners rated animations as the most helpful feature in this IMM, in clarifying their doubts about bacterial genetics. They said that animations visualised the microbial processes as live processes, which cannot even be explained in face-to-face situations. Learners also revealed that animations enabled them to grasp the processes quickly, clearly, easily and repeatedly:

> 'Hfr conjugation' and 'specialised transduction' are very difficult to understand. But today I could effectively grasp those processes, with the animations in this learning package. (S22/F)

> I think, animations will reside in my memory longer than the processes I studied from textbooks. This is like remembering a story in a film, and whenever I want, it is easy to recall. (S28/F)

They were satisfied with having adequate number of animations to explain all concepts; however, a few pointed out some movement points to be further improved. Observational studies witnessed learners' thorough engagement with animations with repeated watching. They have perceived this learning as they were studying in a classroom situation, and accepted it as an excellent strategy for self learning.

Table 1. Learner feedback on the use of media components.

Use of media components	Frequency (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
1. Written text on screens are easy to read	0	12	55	33
2. Audio narration helped me to learn effectively	0	0	33	67
3. I prefer a background narration to be included into the Glossary	0	25	45	30
4. Colour graphics stimulate learning	0	0	24	76
5. Animations made me understand the complex processes easily	0	0	19	81
6. Various media used, complement each other	0	0	60	40

All learners highly appreciated the bacterial picture descriptions in colour and said that they could discriminate the structural features more clearly than the black-and-white illustrations in print course material. Questionnaire data also reported a 100% strong support (Table 1).

Information given in the form of text/audio, especially describing the concepts at the very beginning of each section, was highly appreciated by learners. Further they said that this oral/verbal information conveyed the meaning of genetic concepts perfectly. Learners also revealed that they could easily grasp the content information as it was presented in small manageable chunks. Questionnaire data also supported the same fact, having 100% strong support (Table 2).

Table 2. Learner feedback on the use of pedagogical components.

Use of pedagogical components	Frequency (%)			
	Strongly disagree	Disagree	Agree	Strongly agree
1. Introduction is useful to get an overview of the whole lesson	0	0	45	55
2. Learning outcomes are clear to me	0	0	24	76
3. Learning outcomes helped me to focus on what I should achieve by studying this package	0	0	29	71
4. Tour Guide helped me to move within the package	0	0	57	43
5. Content is broken into units that are small enough to be readily learned	0	0	50	50
6. Self Assessment Questions (SAQs) gave me enough practice	0	10	52	38
7. Glossary helped me to understand the unknown/ difficult terms	0	0	33	67
8. Theories and principles are explained well as a whole	0	0	43	55
9. It was easy to navigate within the lesson	0	0	38	57
10. I kept getting lost in the program	35	65	0	0

Learners commented that narrations enhanced the message depicted by the visuals. They highly appreciated the listening component, as it is very much limited in the teaching packages at OUSL. Questionnaire results also supported the same fact (Table 1). Interviews revealed that narrations were simple, clear, at a moderate speed and easy to understand.

Many learners remarked that narrations were helpful especially when learning with computers:

> It is very difficult to keep on reading over and over on computers, so that narration helps us in such occasions. (S18/F)

Some other learners pointed out that narration of the same written text was useful, as it gives them a chance of reading, identifying the difficult terms and their correct pronunciation.

Learners appreciated having audio controls as a helpful feature for repeated listening or to switch off audio to proceed with silent reading. Observational studies also confirmed learners repeated listening and pronouncing certain terms loudly. Individual differences were also observed using the audio component:

- some listened to the audio while studying the graphics/animations,
- some read the text by switching off the audio, and
- some read silently, after listening to the audio once.

All learners preferred not having any narrations for SAQs, as they could concentrate fully on questions without interference. Learners' deep engagement in reading SAQs was also noticed during observations.

Learners were satisfied with the existing male voice used in the narration, but some male learners (6/30) preferred a female voice instead.

Use of pedagogical components

Introduction

Questionnaire data revealed a 100% strong agreement (Table 2) on having an 'Introduction' at the beginning. Observational studies too witnessed all learners watching this section before going into the content sections.

Self Assessment Questions

Learners rated SAQs as the most helpful pedagogical feature in this IMM, and were excited over the prompt feedback. One learner expressed her views:

> SAQs are also remarkable, and it is helpful to evaluate myself. In one section out of the SAQs, I got all correct answers, I was just like flying, and I felt like I know everything. And when I got a wrong answer, there I stopped to think where I went wrong. I think this is really wonderful. (S30/F)

Learners highly valued the instant feedback in SAQs compared with the limited feedback in course books. They also revealed that SAQs gave them a chance of assessing their own performance immediately, clarifying their uncertainties and thereby developing their self-confidence.

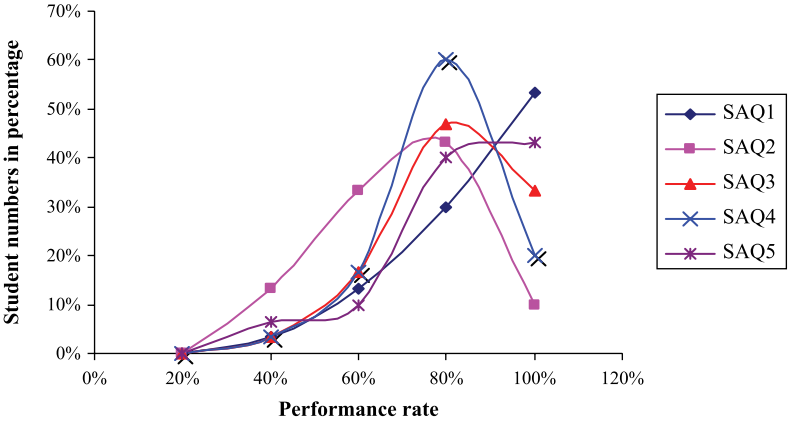

Figure 5. Trend of learners' performance to each SAQ at their first attempt.

Observational studies also witnessed learners' eagerness to study the SAQs in each section, sometimes even before proceeding with the relevant content sections. Most of the learners tend to go back to the relevant section when they got wrong answers, to verify their understanding, without merely clicking answers to get the correct answer. It was also witnessed that the majority of learners obtained more than 80% marks at their first attempt, except for SAQ2, and none of the learners obtained less than 40% marks (Figure 5). Learners requested to include more SAQs in each section at the interviews.

Glossary

Learners highly appreciated the interactive 'Glossary' and revealed that they could check the Glossary repeatedly as it was interactive and directly linked with each section, unlike in textbooks. Observational studies also witnessed repeated usage of the 'Glossary' even while attempting SAQs. Assistance provide by the 'Glossary' to understand the difficult terms was well supported through the questionnaire (100% agreement). The questionnaire also revealed a 75% agreement to include a background narration to the 'Glossary' (Table 2), something that was also revealed during interviews.

Access to prior knowledge

All learners valued the opportunity to refresh their knowledge on 'bacterial genetic make up' at the very beginning of the lesson. Furthermore, they requested to incorporate '*lytic*' and '*lysogenic*' cycles of viruses in the form of animations as they are essential in comprehending the 'Transduction' process.

Summary

None of the learners skipped the summary section, and four learners (4/30) viewed it for the second time. The value of the 'Summary' in the form of visual representations recapitulating the content was clear from the interviews.

Learning outcomes

Researchers noted that some learners (16/30) missed viewing learning outcomes (LOs). The reasons highlighted by them were on the placement of LOs within the 'Menu' option, and the audio instructions asking them to view LOs were not stressed at the specific point in the 'Tour Guide'. As a suggestion, learners (15/16) suggested keeping the LOs in the 'Contents' page, either below the 'Introduction' link or after the 'Summary'. One learner suggested incorporating LOs along with each section.

Having completed viewing of the whole program, these learners were asked to view the LOs before they answer the questionnaire. All learners agreed that LOs are clear, and the incorporation of LOs helped them to focus on what they should achieve by studying the IMM (Table 2).

Navigation

There were no major navigational difficulties observed and all learners followed the instructions stated in the 'Tour Guide' readily. Questionnaire results too indicated the easiness of navigation (Figure 6). During interviews, learners expressed that the 'Tour Guide' was a very helpful component, which made them familiar with moving through the lesson. This was strongly supported by the questionnaire data, having a 100% agreement (Table 2).

Discussion

This study brought to light how easy it was for the learners to comprehend complex dynamic bacterial genetic processes using well-designed IMM compared with lengthy explanations in print course material.

Learning with multimedia

Findings revealed that animations were the main elements that helped learners to comprehend bacterial genetic processes. Animations clearly visualised the flow of dynamic processes and learners have perceived animations as a 'cognitive tool',

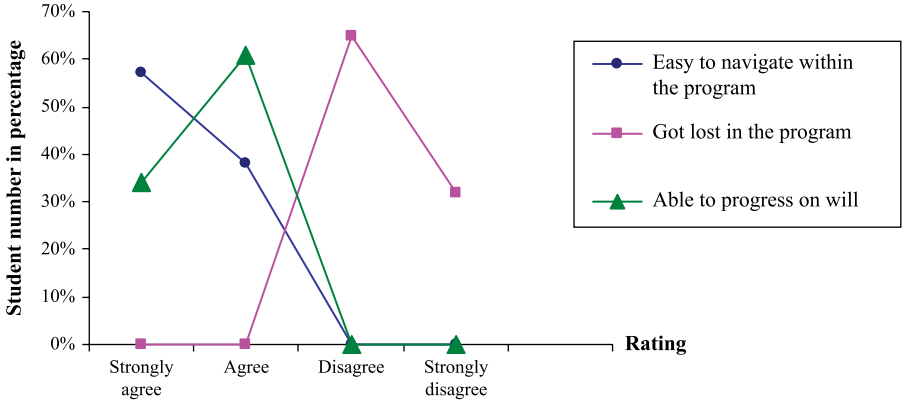

Figure 6. Learners' feedback related to navigation within the program.

scaffolding agent, individual problem-solver, which reduces complexity of self-learning. Lam and McNaught (2006) have also used animations to compensate for the complicated static illustrations that were used to represent dynamics in course books.

Learners' repeated engagement with animations is another encouraging feature that fosters learner autonomy (Oswald, 2004). Explanatory narrations of animations have created 'immediacy' that enhances social presence, and teacher 'immediacy' is regarded as a strong affective consideration especially in e-learning situations (Gunawardana, 2004).

Colour graphics have helped learners remember spatial distribution of components within bacterial cells better than the black-and-white illustrations and explanations in course textbooks. Superiority of pictures over text to communicate spatial distribution was well supported by earlier studies (Mayer, 2001; Paivio, 1986), and pictures help access information more clearly and completely than do words, having more features available for processing (Najjar, 1998).

Use of narrations in this IMM has also become effective in providing a 'listening' component. It has become an alternative mode to learning with computers when learners find it difficult to read text on computers. Narrations have become useful to emphasise the message in visual format and it is highly recommended in multimedia instructional material (Kalyuga, Chandler, and Sweller, 2000; Mayer, 2001). This is because from the point of cognitive load theory (Sweller, 1999), working memory can be effectively expanded by the use of more than one sensory modality.

Inclusion of other pedagogical components such as the Introduction, LOs, prior knowledge, SAQs, Glossary, Summary, have also become very useful in learning the subject content. SAQs with prompt feedback, in particular, have become more responsive to individual learners and have provided them a chance to determine achieving some LOs. Learners' reflections showed their intrinsic feeling of success and enjoyment in return for their learning effort without any external rewards. Achieving high scores for SAQs indicated learners' success in comprehending abstract concepts. Abas and Osman (2007) have also found similar results on feedback responses to questions given in a multimedia courseware.

The 'Tour Guide' has helped learners to get an overview of the navigational design, and has provided *learning guidance* as stated by Gagne (1985). Hence they have not found major navigational difficulties. In ODL situations, navigational guidance is essential for the learners to use the IMM, as they are learning in isolation. Others have also used navigational help in their packages (Andrewartha & Wilmot, 2001; Harsasi, Muzammil, & Riana, 2008), thereby helping learners in organising the content and orienting them in a proper learning path (Niederhauser, 2008).

A major drawback in the instructional design of IMM was the placement of LOs, as many learners have missed viewing LOs. The relocation of LOs in the 'Contents' page to display explicitly along with main topics was suggested.

Learning styles

Observational studies surfaced various learning styles similar to the categories identified by Miller (2000). Accordingly, *visual–non-verbal learners* were well apparent from this study, as they show eagerness to study with graphics and animations. A similar study carried out at OUSL also supports OUSL learners' preference to visual learning (Jayatilleke, 2002). These learners visualise pictures of what they have learnt in their mind in order to remember the concepts and ideas (Miller, 2000), and the

provisions provided in the IMM may have provided them an excellent opportunity to comprehend the concepts.

Visual–verbal learners were observed reading text on screen only and switching off the audio component. They were further facilitated by having limited information per screen and by including audio controls to skip audio.

Auditory learners were the other group identified during the study. While listening to narrations, certain terms were spoken out loud by these learners. Miller (2000) states that these learners recall information the way they hear, or by repeating what they heard. In this study, auditory learners were gifted by using narrations to explain graphics and visuals, in all sections of this package.

As a whole, inclusion of various media components have provided opportunities for diverse learners to study in a productive manner, adhering to their unique learning styles. Thus, this IMM has provided learners a personalised learning milieu.

Learning in a second language

Instructional design of the IMM has also facilitated the linguistic demands of the OUSL learners for whom English is their second language. OUSL learners show limited proficiency in English (Raheem & Ratwatte, 1997), and incorporation of glossaries, summaries, recasts, visuals and narrations are important to overcome this difficulty (Ratwatte, 2005).

The support rendered by the interactive 'Glossary' was well evident in this study. It has allowed repeated access to difficult terms 'just in time', facilitating the learners to understand the terms in English at the right time, without allowing them to guess incorrectly. This is especially important for second-language learners as some of the words have multiple meanings in English. Research related to computer-mediated text glossaries are in agreement with these findings, having observed learners attending higher level processing (Abraham, 2008; Chun, 2006). The glossary has provided a scaffolding function by helping them to find difficult and unfamiliar terms. Learners' engagement with the summary also proved beneficial to them as frequent repetition of information is needed for integration of new knowledge in second-language context (Ratwatte, 2005).

Learning with visuals was clearly evident from this study. Visuals (graphics and animations) show explicit information that could be directly mapped into mental representations, so that learners are able to easily grasp information without any language barrier. In particular, animations used in the package allow the learners to portray the dynamics directly from the display. This allows the learners to concentrate only on the central function of understanding the context (Lowe, 2004), rather than diverting the attention to linguistic demands.

Narration of the same text has also proven beneficial, especially for the learners studying in their second language, and has helped learners with correct pronunciation of scientific terms in English. In addition, by providing user controls, they were facilitated to learn with alternative modes according to their preferences. This is especially beneficial in ODL as limited listening components are available.

Conclusion

Instructional design features used in the IMM were well perceived by learners in constructing knowledge in dynamic abstract process by the use of multi-sensory

representations, especially with animations. Interactivity built into various design features has allowed learners to actively participate in learning, providing an individualised learning experience. The findings of this study also throw light on designing effective learner-centred multimedia learning material, especially to learn abstract scientific concepts.

Acknowledgements

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