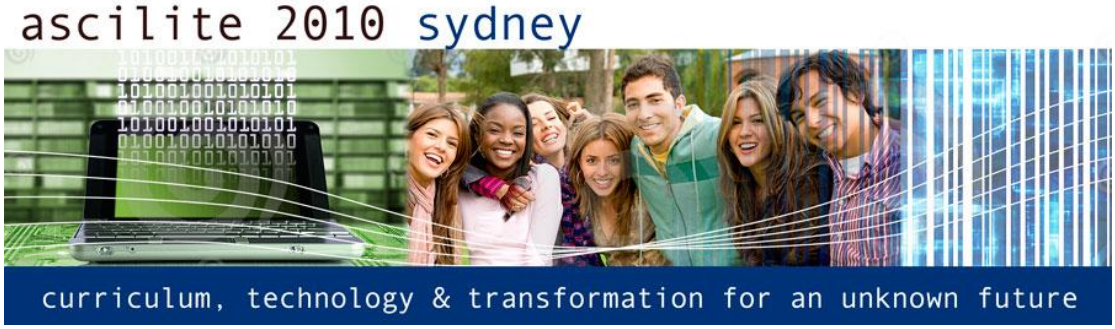

Engaging students through multimodal learning environments: The journey continues

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The innovative use of educational technologies provides higher education institutions valuable opportunities for their staff to design media enhanced, interactive, more inclusive and engaging learning environments. The key motivation for incorporating educational technologies into the curricula is unquestionably the desire to improve the engagement and learning of students. To assist with this the increasing use of multimedia in teaching has provided many opportunities to present multiple representations of content (text, video, audio, images, interactive elements) to cater more effectively to the different learning styles of an increasingly diverse student body. This paper presents the findings of an experiment to measure the impact of multiple representations of content on learning outcomes, including learning performance and engagement. While, in this study, multiple representations of content did not lead to discernable improvements in learning performance, students reported very favourably on multimodal learning elements and perceived that they had assisted their comprehension and retention of the learning material. The implication of this study for educators is to consider carefully the incorporation of selected multiple representations of key concepts, particularly those that use a combination of audio and visual content. The limitations of the experimental methodology and directions for future research are also presented for consideration.

Keywords: multiple representations; multimodal; multimedia; modal preferences; engagement

Introduction

With the rapid move to more online provision of off-campus study, traditional print-based materials are being converted into more multimodal, interactive, technology-mediated e-learning formats. Multimedia enhancements in these environments include, for example, video and audio elements, recorded lecture presentations, interactive audio-enhanced diagrams and simulations, interactive quizzes and graphics. Multimedia can be used to represent the content knowledge in ways that mesh with different learning styles that may appeal to different modal preferences (Birch & Sankey, 2008; Moreno & Mayer, 2007). At the same time, non-traditional learners have grown in prominence and are today a significant consideration when coming to design learning environments. This has caused a significant blurring of the boundaries in relation to how learning resources have traditionally been supplied to students, as against how they should now be supplied (Bradwell 2009). These changes have caused fundamental educational questions to be asked such as "what to teach and how on earth to teach it" (Jochems, van Merrienboer, & Koper, 2004). For many universities this has required new

approaches to the design and delivery of learning materials to be considered across the board (Kellner, 2004). Bradwell states:

> Teachers and lecturers have to deal with a much greater range of information processing styles, cultural backgrounds and styles of learning. As a result, the ideal for teaching in higher education is now recognised to involve much more than lectures as the means of information provision (p. 19).

This situation is further highlighted when we consider the issues associated with the learning styles of these students. Whether we like it or not these may not necessarily be the same as what we would normally associate with traditional higher education students (traditional learners), at least those who have succeeded at higher education and who could comfortably work within a read/write style of teaching (Sarasin, 1999). Barrington (2004) believes this is increasingly becoming an issue because higher educational institutions (in the West at least) still privilege certain ways of knowing and focus on a narrow view of the intellect that 'does not always allow for socio-cultural differences' (p.422). In simple terms:

> "It is undoubtedly the case that a particular student will sometimes benefit from having a particular kind of course content presented in one way verses another. One suspects that educators' attraction to the idea of learning styles partly reflects their (correctly) noticing how often one student may achieve enlightenment from an approach that seems useless to another student." (Pashler, McDaniel, Rohrer & Bjork, 2008, p. 116).

The increasing use of multimedia in teaching has provided many opportunities to present multiple representations of content (text, video, audio, images, interactive elements) to cater more effectively to the different learning styles and modal preferences of an increasingly diverse student body. This study investigates how the innovative use of educational technologies can provide valuable opportunities for teaching staff to design more engaging media enhanced learning environments. The key motivation for incorporating these enhancements into the curricula is unquestionably the desire to improve the learning performance of students. This paper presents the findings of an experiment to measure the impact of multiple representations of content on learning outcomes, including modal performance and engagement.

Multimodal learning

In recent years, the use of multimedia in conjunction with hypermedia have been successfully applied to many e-learning environments in order to both enhance these environments and to cater for a wider variety of student learning styles (Birch & Gardiner, 2005; Sankey & St Hill, 2009; Sprague & Dahl 2010). Neuroscience research has also revealed that 'significant increases in learning can be accomplished through the informed use of visual and verbal multimodal learning' (Fadel, 2008, p. 12). In other words, students may feel more comfortable and perform better when learning in environments that cater for their predominant learning style (Cronin, 2009, Omrod, 2008). This is known as the "meshing hypothesis" (Pashler et al. 2008, p. 109). It has also been seen that presenting material in a variety of modes may also encourage students to develop a more versatile approach to their learning (Hazari, 2004); as recent findings in the field of cognitive science suggest:

> Multiple intelligences and mental abilities do not exist as yes-no entities but within a continua which the mind blends into the manner in which it responds to and learns from the external environment and instructional stimuli. Conceptually, this suggests a framework for a multimodal instructional design that relies on a variety of pedagogical techniques, deliveries, and media (Picciano, 2009, p. 11).

Multimodal learning environments allow instructional elements to be presented in more than one sensory mode (visual, aural, written). In turn, materials that are presented in a variety of presentation modes may lead learners to perceive that it is easier to learn and improve attention, thus leading to improved learning performance; in particular for lower-achieving students (Chen & Fu, 2003; Moreno & Mayer, 2007; Zywno 2003). Mayer (2003) contends that students learn more deeply from a combination of words and pictures than from words alone; known as the 'multimedia effect'. Further, Shah and Freedman (2003) discuss a number of benefits of using visualisations in learning environments, including: (1) promoting learning by providing an external representation of the

information; (2) deeper processing of information; and (3) maintaining learner attention by making the information more attractive and motivating, hence making complex information easier to comprehend. Fadel (2008) found that, 'students engaged in learning that incorporates multimodal designs, on average, outperform students who learn using traditional approaches with single modes' (p. 13).

Fundamental to the design of these learning environments are the principles of multimodal design, in which 'information (is) presented in multiple modes such as visual and auditory' (Chen & Fu, 2003, p.350). The major benefit of which, as identified by Picciano (2009), is that it 'allows students to experience learning in ways in which they are most comfortable, while challenging them to experience and learn in other ways as well' (p. 13). Consequently, students may become more self-directed, interacting with the various elements housed in these environments. So, depending upon their predominant learning style, students may self-select the learning object, or representation, that best suits their modal preference (Doolittle, McNeill, Terry & Scheer, 2005). In other words, 'different modes of instruction might be optimal for different people because different modes of presentation exploit the specific perceptual and cognitive strengths of different individuals' (Pashler et al. 2008, p. 109).

The use of multiple representations, particularly in computer-based learning environments has now long been recognised as a very powerful way to facilitate understanding (Moreno, 2002). For example, when the written word fails to fully communicate a concept, a visual representation can often remedy the communication problem (Ainsworth & Van Labeke, 2002). Some simple examples of multiple representations include, using audio enhanced PowerPoint slides as mini lectures, usually using point-form text or images (Figure 1), interactive diagrams with accompanying transcripts and voiceovers (Figure 2), video presentations, interactive graphs and forms, audio explanations of concepts, and still images. In these examples, the multimedia elements (visual, aural, and interactive elements) present additional representations of the information also provided in text-based explanations. This approach caters for a range of different modal preferences and provides students with a choice in how they can access key content, and thus may be considered a more inclusive response (and one that potentially stimulates metacognition) to the needs non-traditional learners.

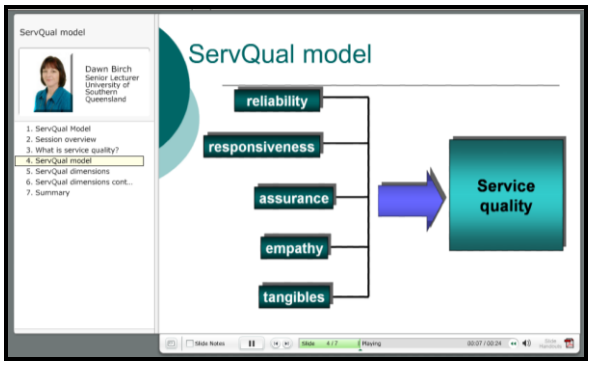

Figure 1: Audio-enhanced PowerPoint presentation

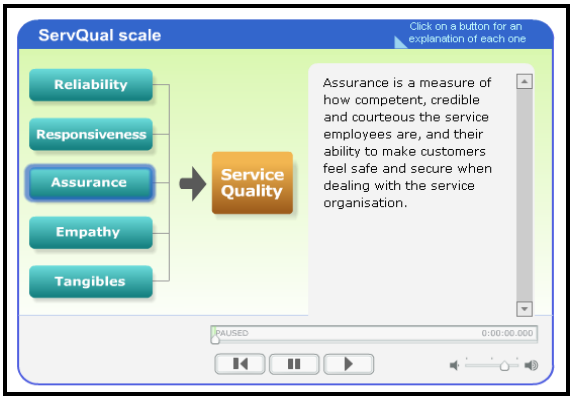

Figure 2: Interactive narrated diagram with a text-based transcript

Facilitating metacognition

On the other hand, there may be cases where educators are trying to design for all the different types of learning styles. Inevitably limitations to this approach arise, as many students 'don't even realise they are favouring one way or the other, because nothing external tells them they're any different from anyone else' (DePorter, 1992, p.114). Consequently, it has been seen that when designing learning environments to cater for a range of different learning styles, an understanding of students' metacognitive needs is equally necessary. This being the case, a further aspect that needs to be considered, is helping individual students become aware of their own preferred approach to learning. For as McLoughlin (1999) emphasises 'teaching students how to learn and how to monitor and manage their own learning styles is crucial to academic success' (p.231).

It has been suggested that when students are aware of their individual strengths and weaknesses (as learners) they can be more motivated to learn (Coffield, Moseley, Hall, & Ecclestone, 2004). The potential of this awareness is that students can then question their long-held beliefs, or behaviours, and can be taught to monitor the range of strategies that can be used to aid their own learning (Sadler-Smith, 2001). This strategy has also been shown to increase the confidence and the grades of students, by helping them to make the most of the learning opportunities that have been designed to match their preferred modality (Coffield, et al., 2004). To help determine their predominant learning style, students typically encouraged to complete some form of learning styles inventory.

The need for evidence of the learning styles hypothesis

Despite the ongoing call for evidence-based practice, difficulties in assessing the impact of educational technologies on learning outcomes have been reported due to the need to provide all students with the same opportunities (Cronin 2009; Forte & Bruckman 2007; Mayer, 2008). This study seeks to address the dearth of experimental studies to test the 'meshing hypothesis'; that is, the claim that instructional resources should mesh with the student's learning style (Pashler et al. 2008, p. 108). The problem investigated in this research was to determine the impact of multiple representations of content on learning outcomes across different learning styles/modal preferences. Four research questions were developed to investigate the research problem:

1. Do multiple representations of content lead to improved learning outcomes and does this vary across learning styles/modal preferences?
2. What types of representations of content (visual/aural/text/kinaesthetic elements) lead to improved learning outcomes and does this vary across learning styles/modal preferences?
3. Do multiple representations of content lead to cognitive overload, thus reducing learning outcomes and does this vary across learning styles/modal preferences?
4. What is the optimal combination of representations of content for improving learning outcomes and does this vary across learning styles/modal preferences?

Methodology

The main purpose of this research was to establish a cause-and-effect relationship between the way in which content is presented to students and their learning outcomes. Differences across predominant learning styles/modal preferences (visual, aural, read/write, kinaesthetic, multimodal) were also investigated. An experimental design was selected to allow for the manipulation of the different ways instructional content was presented and the measurement of students' learning performance. A post-experiment survey was conducted to investigate which learning elements were considered to be most helpful in assisting learning.

Undergraduate students studying at the University of Southern Queensland (USQ) in Australia were emailed an expression of interest to participate in this multimodal learning experiment (Table 1). Participants were offered an incentive of a $30 University Bookshop voucher available upon completion of the experiment. Initially each students was asked to complete the VARK learning styles inventory online to help determine their learning style (http://www.vark-learn.com/english/index.asp), and then email their results (learning style) to the researchers. Fleming (2001) proposed that learners have a preferred learning style, namely, visual, aural, read/write or kinaesthetic (VARK), with many learners (about 40%) being multimodal (using a combination of these).

Table 1: Process of experiment

Prior to experiment
1. Expression of interest to students, asking them to participate
2. Completion of VARK learning styles inventory by all interested students
3. Selection of participants based on spread of learning styles
4. Allocation of experimental group, date and time for experiment
During experiment
5. Pre-test of concepts (x2), before exposure to each learning scenario
6. Completion of learning scenarios (x2)
7. Completion of post-tests (x2), after exposure to each learning scenario
8. Completion of online survey at conclusion of experiment

The experiment involved the participants being exposed to two different learning scenarios, both drawn from Services Marketing theory (within the Faculty of Business). The first concept was 'Customer Satisfaction' and addressed the 'Disconfirmation Model'. The second concept was the measurement of 'Service Quality' and focussed on the 'ServQual Model'. Both scenarios were reasonably short and not particularly difficult. Students who had previously studied Services Marketing were excluded from the experiment to control for prior learning. The learning material was presented in six different ways, or conditions (Table 2) with an additional multiple representation of the content progressively being added for each subsequent condition, with Condition 6 representing the highest number of multiple representations of content used in this experiment.

Table 2: Learning conditions used in the experiment

Representations of content for both the Disconfirmation Model and ServQual Model					
Condition 1	**Condition 2**	**Condition 3**	**Condition 4**	**Condition 5**	**Condition 6**
• Text • Study guide	• Text • Study guide • Printed PowerPoint	• Text • Study guide • Printed PowerPoint • Recorded PowerPoint with audio	• Text • Study guide • Printed PowerPoint • Recorded PowerPoint with audio • Interactive diagram with script only	• Text • Study guide • Printed PowerPoint • Recorded PowerPoint with audio • Interactive diagram with audio only	• Text • Study guide • Printed PowerPoint • Recorded PowerPoint with audio • Interactive diagram with script and audio
Group C (10)	Group B (10)	Group A (10)	Group D (10)	Group F (10)	Group E (10)
Group D (10)	Group E (10)	Group F (10)	Group C (10)	Group A (10)	Group B (10)

Sixty (60) participants were recruited, allowing for ten to be placed in each of the experimental groups. Each participant was exposed to two learning concepts across two different learning conditions. The aim being to include two participants from each of the five learning styles (visual, aural, read/write, kinaesthetic, and multimodal) in each group. However, only four of the participants who agreed to participate in the experiment had a predominant 'aural' learning style. The most common learning style from those agreeing to participate in the experiment was 'multimodal'. So where a shortage of participants with one of the predominant learning styles existed, a multimodal learner was included to make up the number for each group.

As the participants needed to access the multimodal presentations via computer, the experiment was conducted in two student computer labs at USQ. The learning conditions and the post-experiment survey were housed in two separate online spaces. Before commencing the experiment, participants were provided information about the experiment and asked to sign a consent form. They were also informed that the purpose of the experiment was to measure the impact of two learning scenarios (conditions) on their learning to see if these varied across learning style compared to condition. They were further instructed to carefully work through each learning scenario, ensuring they did all of the required reading, listening and interacted with each element within each condition. They were then allowed access to the experiment website where they selected their assigned group and followed the instructions, working through each learning condition. To measure prior knowledge and learning, each participant was asked to complete a pre-test comprising multiple choice questions for each concept and

then to complete a post-test (identical to pre-test) after being exposed to each learning scenario. To control for confounding factors, a standardised set of instructions, format and setting were used for each group.

Demographic data was gathered from university records including gender, age, program and grade point average. A post-experimental survey was developed to gather students' perceptions of the learning elements they were exposed to during the experiment. Each was asked which of the two learning scenarios they had found to be: (a) easiest; and (b) most enjoyable to learn. Six open-ended questions provided each participant with an opportunity to express what they felt had been the most helpful resource/s they had been exposed to during their interactions with the two allocated learning conditions. These qualitative measures were administered to provide students with the opportunity to give a more in-depth account of their encounter with the learning environments.

Findings and discussion

Of the sixty participants approximately two thirds (68%) were females and 32% were males. A broad age range was represented, with the youngest participant being 17 years and the eldest being 60 years. The majority of participants were under 30 years of age (70%). The spread of participant learning styles are seen in Table 3. The majority of participants had a predominant multimodal learning style (35%), with equal numbers of kinaesthetic (21.7%) and read/write (21.7%) learners. Visual (16.7%) and aural (6.7%) learners were under represented in the sample. There were also differences across gender. The males in the sample predominantly had a multimodal (52.6%) learning style with no visual learners, while females were more evenly distributed across multimodal (26.8%), visual (24.4%), kinaesthetic (22%) read/write (19.5%) learning styles. There were very few aural learners in the sample with only 7.3% of females having an aural learning style and only 5.3% of males.

Table 3: Learning styles of participants

Predominant learning style	Female	Male	Total
Visual	10 (24.4%)	0 (0%)	10 (16.7%)
Aural	3 (7.3%)	1 (5.3%)	4 (6.7%)
Read/write	8 (19.5%)	4 (21.1%)	12 (20.0%)
Kinaesthetic	9 (22.0%)	4 (21.1%)	13 (21.7%)
Multimodal	11 (26.8%)	10 (52.6%)	21 (35.0%)
TOTAL	41 (68.4%)	19 (31.6%)	60 (100.0%)

The majority of the participants in the sample (60%) had a grade point average of 5.0 or above (out of 7.0) with only 8% of students with a grade point average of less than 4.0, indicating that very few lower-achieving students elected to undertake the experiment. There were no significant differences found across the six experimental groups with respect to gender, age or grade point average.

In addition to the experimental data, a thematic analysis of the qualitative data was conducted on the responses to the six open-ended questions. An initial scan of the total 333 comments was performed using the qualitative analysis tool, Leximancer, to provide an initial feel for the themes contained within these data. The Leximancer scan revealed a considerable cluster of concepts around the key words of; information; reading; learning; audio; concept; diagram; learn; helpful and easier. From this investigation, the analyses of these qualitative data continued using the NVivo (v8) software to explore four main themes:

- The usefulness of having a combination of resources (139 comments)
- The usefulness of audio (50 comments)
- The place of reading within online environments (59 comments)
- The right amount of choice (14 comments).

Each of these four themes will now be explored in relation to the four research questions, in turn.

Research question 1

The first research question concerned whether multiple representations of the content lead to improved learning outcomes and whether this varied across learning styles. The majority of participants (93.4%)

improved from the pre-test to the post-test after being exposed to the learning materials for Learning Concept 1, with the average change in performance from pre-test to post test being 41.4%. Likewise, the majority of participants (91.8%) improved from the pre-test to the post-test after being exposed to the learning materials for Learning Concept 2 with the average change in performance from pre-test to post test being 48.3%. Learning Concept 1 was perceived to be easier to learn than Learning Concept 2 by the majority of participants (58%). However, the majority of participants enjoyed Learning Concept 2 (57.4%) more than Learning Concept 1. While participants were asked not to guess the answers and to select 'don't know' where they did not know the answer, many participants did select both correct and incorrect answers in the pre-test, indicating some use of logic and/or guessing. The learning concepts used in the experiment were not difficult, and thus it may have been possible to make a logical assumption, or an intelligent guess in response.

The experimental data did not reveal any differences in learning performance across the six groups and the six different conditions for either of the two concepts. This lack of support for the learning style "meshing" hypothesis is consistent with the findings of other experiments conducted by Massa and Mayer (2006) and Constantinidou and Baker (2002). However, it should be emphasized that the sample sizes (ten per condition) is too small to make any statistical inferences. Moreover, some methodological limitations are evident, including the lack of participants with aural and visual learning styles, the possibility that the concepts were too simple, or common sense, the unnatural research setting, possible testing effects, and self-selection of participants with higher average grade point averages. Given the literature indicates that multimodal learning may be of greater benefit to lower-achieving students, while higher achieving students perform well regardless of how the content is presented, this could provide some explanation for the lack of impact of multiple representations of content on learning performance within this experiment (Zwyno, 2003).

Research question 2

The second research question sought to determine which types of representations (visual/aural/text/kinaesthetic elements) lead to improved learning outcomes, and whether this varied across learning styles. While there were no differences across learning performance, most participants indicated that all of the learning resources were helpful, with the more enhanced multimodal learning resources considered to be the most helpful. Using the Friedman test, a ranking of the treatments was possible as indicated in Table 4. This finding indicates that the audio enhanced PowerPoint and interactive diagrams with audio and transcript were significantly different to the other learning resources, with these two resources considered to be the most helpful to the learning experience. These two elements (included in condition 6) comprise greater representations of content and include visual, aural, text-based and kinaesthetic elements, aimed at appealing to a variety of learning styles.

Table 4: Perceived helpfulness of learning resources (7 point scale)

Learning resource	Mean	Ranking
PowerPoint with audio	5.62	1
Interactive diagram with script and audio	5.42	1
PowerPoint handout	4.22	2
Study guide	4.16	2
Interactive diagram with script only	4.20	2
Textbook reading	3.98	2
Interactive diagram with audio only	3.66	2

While the sample is too small to draw any statistical inferences, the data indicates (Table 5) that kinaesthetic learners, in particular, found the audio enhanced PowerPoint's to be very helpful, while aural learners found the interactive diagram with transcript and audio to be very helpful. It is also interesting to note that the visual and kinaesthetic learners rated the textbook reading as being the least helpful, while aural and read/write learners rated the interactive diagram with audio only as being the least helpful. This could indicate that visual and kinaesthetic learners may be at some disadvantage when the learning resources are primarily text-based.

Table 5: Perceived helpfulness of learning resources across learning style (7 point scale)

Learning resource	V	A	R	K	MM	Ave
PowerPoint with audio	5.7	5.7	5.1	6.5	5.1	5.62
Interactive diagram with script and audio	5.7	6.5	4.3	5.3	5.3	5.42
Study guide	4.1	3.3	5.2	4.6	3.9	4.22
Interactive diagram with script only	3.5	4.7	4.0	4.2	4.4	4.16
PowerPoint handout	3.3	3.0	3.8	5.1	4.7	3.98
Textbook reading	2.3	5.5	4.7	2.6	3.2	3.66
Interactive diagram with audio only	3.5	2.5	2.4	4.4	3.2	3.20

Participants were also asked open-ended questions concerning the various learning resources. Responses, in many cases, were in keeping with their predominant learning style of the participant. Many participants commented on how the various learning resources assisted them to understand and retain the content, while others commented on which learning resources were easiest, more interactive or more enjoyable to use.

The thematic analysis of these qualitative data revealed two major themes related to research question 2. The first relates to the usefulness of audio (50 comments), and the second relates to the place of reading within online environments (59 comments). The use of audio in online learning environments has long been purported to provide advantages for student learning (Clark & Mayer, 2003; Fahy, 2005; Hazari, 2004). This finding was certainly confirmed and reinforced in this study. More importantly, it is when audio is used in conjunction with other resources, such as images or text, that the advantage is most prominent. In the learning environments used for this study, audio was provided in two main resources; audio-enhanced PowerPoint presentations and in interactive diagrams (with or without a transcript). The audio component was mentioned some fifty (50) times in the comments, and on nineteen (19) of these occasions the audio was perceived to be a necessary component. This combination of resources was not only seen to provide information, but also led to a greater perceived understanding of the materials being presented and made learning more enjoyable. Previous studies have established that using a combination of verbal and non-verbal approaches that stimulate both visuals and audio modalities, can increase working memory, known as 'Dual Coding Theory', and have a significant impact on how students retain information, consequently make learning more enjoyable (Calandra, Barron & Thompson-Sellers 2008; Clark & Mayer, 2003; Pavio, 1991). The following comments exemplify these attributes:

- I enjoyed reading materials for both concepts, but hearing a real person's voice as part of Concept Two added a personal element that made learning more enjoyable. (Read/write learner)
- Hearing the information spoken and maybe put into different words than the text book helps me to get a fuller understanding. (Kinaesthetic learner)
- I think hearing the information helps my recall. The diagrams I can "picture" in my mind when recalling information. (Kinaesthetic learner)

The second theme arising from the thematic analysis related to research question 2, concerned the place of reading in online learning environments. The fifty nine (59) comments about the reading materials provided (electronic and hardcopy) fell into three main categories; the lack of interest in using reading materials or the boring nature of the reading (40); the perceived sufficiency of the written materials provided (17); and two requests for less reading. In relation to the lack of interest in using reading materials or the boring nature of the reading, some participants commented:

- Even though I always do my textbook readings I find them long and boring and I get distracted easily when reading them. (Read/Write learner)
- I lose my concentration when I'm simply reading, especially if it's new information. It's more interesting to hear someone speaking about something, as it's more personal. (Kinaesthetic learner)
- Simply reading a text book doesn't engage me and I tend to become disinterested and start skimming through the text, identifying only what I believe I may be assessed on and not take in a lot of what is in the text. (Kinaesthetic learner)

- I found the text book reading the least helpful because I found it to be less fun and sort of boring. It was overwhelming with all of the text and I found that I couldn't understand it as well as I could with the interactive diagram. (Multimodal learner)

These comments should not be judged in isolation, rather they should be considered in conjunction with the finding concerning the usefulness of providing a combination of resources. To illustrate this connection:

- It was much more interesting to listen and interact, as I find that when I'm just reading I have to read over and over again for the concept to sink in. It is helpful to have things explained several times and in several different ways. It was helpful to listen at the same time as reading, as extra information was added on in the sound. (Kinaesthetic learner)
- Having an aural aid [for Concept 2] made the concept more enjoyable, compared to Concept 1 where just reading it on my own was less enjoyable. (Multimodal learner)

Research question 3

The third research question sought to investigate whether multiple representations of content lead to cognitive overload, thus reducing learning outcomes and whether this varied across learning styles. The experimental data did not indicate that multiple representations led to cognitive overload, thus did not reduce the learning outcomes. No differences were found across the six conditions for either concept. However, the thematic analysis revealed comments concerning the perceived potential for cognitive overload and the perceived right amount of materials to be provided. Some participants commented on being given too much choice (15 comments) with statements such as:

- Having the audio made concepts more confusing - like it 'clouded' over what was supposed to be a simple concept. (Kinaesthetic learner)
- The first Concept for me was information overkill, it appeared that there was so much for me to absorb with the diagram as well as the reading. (Visual learner)
- More repetition of what was already learned, just another visual of what I had read. (Read/Write learner)

Indeed, some participants found it sufficient to simply read their materials. For example:

- The readings gave me what I needed to know without fluffing around with extras that may well have confused me, the information got straight to the point.(Visual learner)
- I find the reading the most useful and I tend to get distracted with listening and I tend to understand more with reading. (Read/Write learner)

Having seen that there can be some concerns around having too much choice, albeit that these comments are very much in the minority, there is sufficient evidence to suggest that a scaffolded approach, utilising a combination of learning materials (a multimodal approach) to the provision of key information may be optimal.

Research question 4

The fourth research question sought to determine whether there is an optimal combination of representations of content for improving learning outcomes and whether this varied across learning styles. The experimental data did not reveal any statistical differences across learning conditions or learning styles with respect to learning performance. However, the qualitative data indicated that there may not be any optimal combination, with learners both within and across different learning styles expressing different preferences with respect to the learning resources. The thematic analysis revealed that a combination of resources was considered to be particularly useful (139 comments). Providing more than one representation of a particular concept was found to be the most valuable attribute of the materials. The following comments typify the sentiments being expressed:

- I was able to access various types of learning materials which helped in the understanding of the material. After listening to the resources, I found it easier to take in what the material was trying to teach me, it reinforced it in my head. (Kinaesthetic learner)

- There was a variety of different approaches to learning the material and I could utilise all of them if I wanted.
- The combination of reading and listening was good. I do not find it easy to learn when I am just reading. By having the two resources I was seeing and hearing the information twice which helped. (Multimodal learner)
- It combines two powerful teaching styles; visual and audio. When you can integrate two or more teaching styles together, there is greater potential for learning. (Multimodal learner)

Hence, a choice of resources and the reinforcement that choice allowed were fundamental to the participants' appreciation of the learning environments. The main finding here may be that participants like to have options and will gain benefits from those learning styles most suited to their learning style.

Implications, limitations and directions for future research

Although there was an improvement in the scores students received between the pre- and post-test (and this should to be expected) the quantitative data for this study did not necessarily indicate that participants performed better because of the presence of multiple representations. However, the qualitative data clearly indicates that students perceive learning resources with additional representations of content to assist their comprehension, understanding and retention of content, and to be more interesting and enjoyable to use. In particular, students expressed a strong preference for a combination of learning resources and options. Given these findings, the importance of improving student progression and retention, and engendering a joy of learning, leading to life-long learning, educators should be encouraged to continue to explore the use of educational technology and multimedia for developing multiple representations of content. Audio enhanced PowerPoint presentations and interactive diagrams with transcripts and audio, in particular, were valued by participants in this study.

A number of limitations should be considered before drawing conclusions from this exploratory experimental study. First, it is difficult to make any inferences from the quantitative data regarding the impact of providing multiple representations of content on learning performance due to small sample and limitations of the experimental methodology. In addition, there was a predominance of: (1) higher-achieving students; (2) multimodal learners who typically learn across a range of conditions; and (3) a lack of aural and visual learners in the sample. Given the literature indicates that multimodal learning may be of greater benefit to lower-achieving students, while higher achieving students perform well regardless of how the content is presented, this may be one factor that explains the lack of impact of multiple representations of content on learning performance within this experiment (Zwyno, 2003).

Future research should involve a larger sample, with a higher representation of lower-achieving students, and a more even representation of learning styles. This could also involve more complex concepts to allow for a stronger measure of improvements in learning performance across pre- and post-tests. A larger sample would also allow for exploring differences across learning styles, gender, age groups, English Second Language (ESL) versus English First Language students (EFL), and on-campus versus off-campus learners. Ideally, future research would also involve investigating learning performance under more natural study conditions to reduce possible testing effects. Under experimental conditions, students may be more actively involved in processing the learning content and pay greater attention to the content than they would in real life. The difficulties experienced with the experimental methodology in this study may provide some explanation for the dearth of empirical data on the impact of multimodal presentations of content on learning styles, despite calls from educators for evidence that technology-enhanced learning leads to improved learning outcomes.

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