ARTICLE

Effects of multimedia characteristics on novice CAD learners' practice performance

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Abstract

Based on the assumption that providing information using multiple modalities improves learners' performance, the teaching of computer-aided design (CAD) in the built environment is increasingly shifting from printed material to a multimedia approach. Yet, the evidence base suggests that presenting information by using multiple modalities does not always enhance learning. This paper reports on an empirically based study that sought to determine under which conditions architectural engineering students benefit most from multimedia CAD learning. It investigated the effects of multimedia on novice CAD learners' practice performance (time and accuracy). One hundred and one students were randomly assigned to four groups to undertake specific CAD learning tasks, with different treatments; media mode (printed-text vs. audio) and the visual mode (static-illustration vs. animation). The results indicated that the audio mode shortened learning time much more than the text mode. Conversely, the text mode enhanced CAD design accuracy, in comparison with the audio mode with the illustration mode alone. In addition, the animation mode improved design accuracy with text and audio significantly more than with illustration visual mode. The animation mode increased the learning time considerably with the text mode. The implications of the design of CAD instructional materials for architectural engineering education are examined.

■ *Keywords* – 3D computer-aided design; architectural engineering education; multisensory modality; instructional mode; visual mode; multimedia learning

INTRODUCTION

As a result of advances in technology, courseware has increasingly become more elaborate in terms of realistic graphics, audio, colour, animation and complex simulations (Clark & Mayer, 2011). These advances have offered new opportunities for teaching and learning. Indeed, learning is increasingly relying on multimedia technology, which involves learning from words (such as printed or spoken text) and pictures (such as animation, video, illustrations or photographs) (Mayer, 2009). One of the key characteristics of multimedia learning involves perceiving and processing information in different presentation modes and sensory modalities (Brünken, Plass, & Leutner, 2003).

In discussing multimedia learning, Mayer (1997) distinguished between delivery media, presentation modes and sensory modalities. Delivery media refers to the system used to present instruction, such as a paper-based medium versus a computer-based medium. Presentation modes are related to the format used to represent the presented instruction, such as text versus pictures. Sensory modality is concerned with the information processing channel that a learner uses to process the information, such as acoustic versus visual information processing.

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THE PRESENT STUDY

Most instructional materials for teaching computer-aided design (CAD) in built environment courses are increasingly shifting from printed material towards multimedia format, and multisensory modality. Three-dimensional (3D) and computer simulations offered built environment students new ways to study the relationship between the design and construction of buildings. Digital media helped to integrate and expand the content of courses in drafting, construction and design (Clayton, Warden, & Parker, 2000). There is evidence to suggest that effective CAD learning materials could improve learners' abilities (Ahmed, Mahdjoubi, Feng, & Leach, 2004), and their cognitive and affective-motivational performance (A-Rahman & Mahdjoubi, 2009). Consequently, careful attention is needed in the selection of multimedia characteristics to design effective instructional material for CAD learning practice performance. However, the successful learning of CAD does not come without proper training and the use of effective learning tools (Hamade, Jaber, & Sikstrom, 2009). In general, most computer software packages are hard to learn, but little is known about how to help new users (Martin & Mendelsohn, 2000).

This field of study has been characterized by trial and error in the design and development of instructional materials for CAD learners. As early 1990, Reiber (1990) stressed that advances in computer graphics (i.e. combined text, verbal information and visual information) have not been matched by corresponding evidence on how people learn from pictures and words. Hede and Hede (2002) also warned that multimedia and e-learning designers need to be aware of the effects of these elements and their complex interactions for learning. More recently, Mayer (2010, p. 171) reiterated that the 'design of learning environments involving graphics should be consistent with a research-based theory of how people learn and evidence-based principles of how to help people learn'. So far, little is known about the impact of the transition from printed format to audio-visual on CAD learners. There has been little effort to test the effectiveness of these new instructional media and determine their effects on architectural engineering students' practice performance.

This study seeks to determine the effects of multimedia characteristics on architectural engineering CAD learners, to determine under which conditions architectural engineering students benefit most from multimedia CAD learning materials. The research represents a convergence of two disciplines: architectural engineering and education. It seeks to harness advances in cognitive load theory (Chandler, 2004) and multimedia leaning theory research to shed light on the mediating role of media instruction mode (IM; printed text vs. audio) and the visual mode (VM; static illustration vs. animation) on novice architectural engineering learners' practice performance, measured by more accurate 3D CAD modelling skills, achieved in the shortest time possible. The learning scenario involved the design of a simple 3D model of building using a CAD package. The findings could provide an informed basis for evaluating prevailing assumptions on the effects of multimedia instructional materials on CAD learners. They may also help in the development of evidence-based multimedia learning materials that is more effective in imparting knowledge and understanding on the design and construction of buildings using 3D CAD.

THE EFFECTS OF MULTIMEDIA CHARACTERISTICS ON CAD EDUCATION

In a review of studies concerning whether multimedia instruction is effective, there is consistent evidence for a multimedia learning effect. Mayer (2003, p. 131) argued that the 'multimedia effect refers to the finding that students learn more deeply from a multimedia explanation presented in words and pictures than in words alone'. A growing body of knowledge confirmed that learning is enhanced when instructional materials include illustrations and narration. This phenomenon is referred to the modality effect (Fletcher & Tobias, 2005). The modality principle is the most well-established principle of multimedia design. (Mayer, 2010).

The cognitive learning theory (CLT) helps to account for the modality effect (Chandler, 2004). CLT is a theory of instruction that addresses directly the limitations of working memory. It contends that presenting information in one modality will overload the limited capacity of working memory (Paas, Renkel, & Sweller, 2004). Consequently, the aim of multimedia instructional designers is to decrease cognitive load to achieve better learning. When the working memory is overloaded, meaningful learning is impaired (Sweller, 1988).

It is asserted that the cognitive processing of visually and acoustically audio-visual materials takes place in two separate subsystems of working memory that require separate, independent cognitive resources (Brünken, Plass, & Leutner, 2004). However, presenting information in visual and auditory modalities can increase the amount of information that can be stored and processed in working memory, which in turn can improve learning. The combination of visual presentation with audio explanation delivers information in an easily understood format (Wright, 1993). In addition, Jeung, Chandler, and Sweller (1997) found that students receiving multimedia instructions with audio, spent less time on subsequent problem-solving compared with students receiving visual-only instructions. A number of experiments, with older learners, demonstrated the superiority of audio/visual instructions for enhancing learning (Moreno & Mayer, 2000).

Advances in technology have made it easier to develop multimedia instruction by presenting information in different formats, such as text, pictures and audio (Ozcelik, Arslan-Ari, & Cagiltay, 2010). They made possible a full integration of sound in instructional software. Empirical evidence suggests that people learn better from graphics that are accompanied by spoken text rather than printed text (Schmidt-Weigand, Kohert, & Glowalla, 2010). In addition, learners who receive textual and pictorial materials audiovisually, that is, using visual images and narration of the text, acquired more knowledge than learners who receive the same materials presented only visually, that is, as visual images and on-screen text (Tabbers, 2002). Consequently, the use of audio in multimedia instructions has been strongly advocated (Sweller, 1988). It was reported that in many situations, visual textual explanations may be replaced by equivalent auditory explanations, and thus enhancing learning (Mayer, 2003). According to Paivio's (1991) dual-coding theory, replacing visual text with audio will decrease working memory load and improve learning. Using two modes instead of a single mode for information (visual and variable) representation enhances the performance of working memory, as the processing workload can be distributed across both channels.

Jeung et al. (1997) and Mousavi, Low, and Sweller (1995) confirmed that students receiving multimedia instructions with audio, spent less time on subsequent problem solving compared with students receiving visual-only instructions. Multimedia has consistently resulted in better learning results by providing an instructive environment that best supports the learner (Mayer, 2009). In addition, when essential material is highlighted, learners' attention to relevant information is improved, and their efficiency and effectiveness of finding necessary information are also enhanced (Ozcelik et al., 2010). Students find it easier to complete lessons that use audio extensively to present information (Orr, Golas, & Yao, 1994). In addition, the use of audio can draw and hold the learners' attention to the most important parts of a display, complement the visual information on the screen and support the learner reading the text on the screen (Aarntzen, 1993).

Animation is also commonly used in multimedia-based education, as it is often assumed to increase interest, motivation, direct attention, illustrate procedures and explain how things work (Hegarty, 1992). Others believe that it can help make difficult content easier to understand, particularly if the subject matter is dynamic in nature (Dwyer, 1994; Kaiser, Proffitt, & Anderson, 1985). Some evidence suggests that animation is, in general, more beneficial for learning than still pictures (Marmolin, 1991). Lieu (1999) postulated that changing teaching/learning content from static (i.e. text and illustration) to dynamic computers (i.e. narration and animation) can increase teaching vitality and activate class atmosphere. It can also mobilize students' activity.

Research findings established that simultaneous audio narration and animation are more effective than either alone or non-concurrent audio narration and animation (i.e. audio narration followed by animation or animation followed by audio narration) (Mayer & Anderson, 1991; Mayer & Sims, 1994).

Learners spend more time focusing on specific areas of an animation when they receive animation and narration rather than animation and onscreen text (Schmidt-Weigand et al., 2010). Koroghlanian and Klein (2004) sought to determine the effects of media instructional modes, illustration modes and spatial ability levels in multimedia computer programmes, concerning a scientific process for high-school biology. The instructional modes consisted of two versions, text and audio. In the text version, the instruction was presented as a screen text, whereas in the audio version the instruction was presented as spoken words with limited screen text. The spoken words of the audio version matched the text of the text version and there were two versions of the illustration mode, static and animated. The static version consisted of a graphic depicting the scientific process with no visual movement to show the process in operation. The animated version showed the process with visual movement to demonstrate the process in operation. The overall effects of multimedia characteristics on education are summarized in Table 1.

Conversely, there is evidence suggesting that presenting information by using multiple modalities does not always ensure better learning performance, especially when the limitations of the human cognitive system are not fully considered (Ginns, 2005). For instance, Koroghlanian and Klein (2004) found no benefits of animation over static illustration. During a constrained time period, there was evidence of limited learners' ability to select visual information in diagram that corresponds to auditory information (Jamet, Gavota, & Quaireau, 2008). When learners' receive animation and narration rather than animation and onscreen text, Schmidt-Weigand et al. (2010) did not find strong effects on retention or transfer scores. In seeking to measure animation's effect on immediate recall and problem-solving skills, Childress (1995) concluded that there were no differences in the achievement.

At present, no research exists to support the notion that adding multimedia features to CAD instruction improves architectural engineering students' learning and performance. There is limited experimental evidence to demonstrate how architectural engineering learners respond to specific CAD-based design of built environment tasks, using different types of instructional materials, incorporating variations in multimedia features. This research predicts that variations of media IM (text vs. audio) and the VM (static illustration vs. animation) will have a significant effect on the novice CAD learner's practice performance (time and accuracy).

TABLE 1 Multimedia characteristics for varying educational purposes

EDUCATIONAL PURPOSE	MULTIMEDIA CHARACTERISTICS	EVIDENCE BASE
Learning about things that are dynamic in nature/explanation of dynamic processes and how things work/ supports visualization and mental representation processes; explores phenomena	Animation	Dwyer (1994), Kaiser et al. (1985), Hegarty (1992), Mayer and Anderson (1991), Mayer and Anderson (1992), Reiber (1990), Mohler (2001)
Shortens the learning time for subsequent problem solving	Audio	Jeung et al. (1997)
Explains and visualizes technical equipment or support scientific instruction	Animation and video	Mayer and Anderson (1991), Mayer and Anderson (1992)
Provides a meaning to space and dimensions	Text and graphics	Peeck (1987)

RESEARCH METHOD

This study adopted an empirical research method. This methodology, according to Brünken, Plass, and Leutner (2003) allows the validation of cognitive load effects found with indirect measures, and to analyse cognitive load effects in channels other than the visual modality. This approach allows validating empirically the theoretical predications of multimedia learning and CLT theories. The research method allows the direct measurement of the effectiveness of multimedia learning on architectural engineering students' performance, which overcomes the limitations of other indirect or subjective methods, such as the use of observations or questionnaires to gauge learners' responses to multimedia features.

One hundred and one built environment students, from built environment courses at the University of the West of England, Bristol, participated in the research. Participants were selected from those who had little or no CAD experience. They were randomly assigned to four groups, each was designed to evaluate the effect of four different multimedia presentations: text and illustration (26 students), text and animation (23 students), audio and illustration (27 students), audio and animation (25 students). As stressed by Mayer (2010), the purpose of exposing architectural engineering students to four multimedia presentations modes is to be consistent with a research-based theory of how people learn.

Ramon, Javier, Ramon, and Pedro (2007) proposed a method of assessing the learner's knowledge of CAD whereby students are assessed by means of practical exercises. For this study, the educational multimedia learning scenario consisted of an introduction to the principles of 3D building design. It required the generation of a 3D model of a community centre using a set of instructions. The tutorial consisted of a fully dimensioned 2D plan and a 3D model, as displayed in Figures 1 and 2. The multimedia learning scenario was created using AutoCAD Architecture and presented in four different multimedia instructional materials. The static presentation of text and illustration was presented as printed material. The dynamic presentation was displayed on a computer, as audio and animation. The process of design was recorded using Camtasia screen recorder software.

Several criteria were deemed important in the selection of the experimental material, including

- the selected sample is representative of typical learning scenarios used in teaching building design using 3D CAD (i.e. community centre);
- the number and content of the multimedia characteristics should be manageable and suitable for the purpose of the intended instructional tasks (i.e. IM and VM);
- the type of projects is familiar to the participants (i.e. built environment content);
- the experimental material is available in a form which allows experimental manipulation, that is the independent variables (media IM and the VM could be manipulated to determine their impact on the dependent variables (learner's practice performance);
- tests are conducted in the same way and under the same conditions to improve the reliability of the investigation (i.e. the experiment takes place in the same room, using the same equipment (computers and display) to minimize the interference of confounding variables;
- precautions are taken to minimize inter-treatment interactions, which include conducting the tests

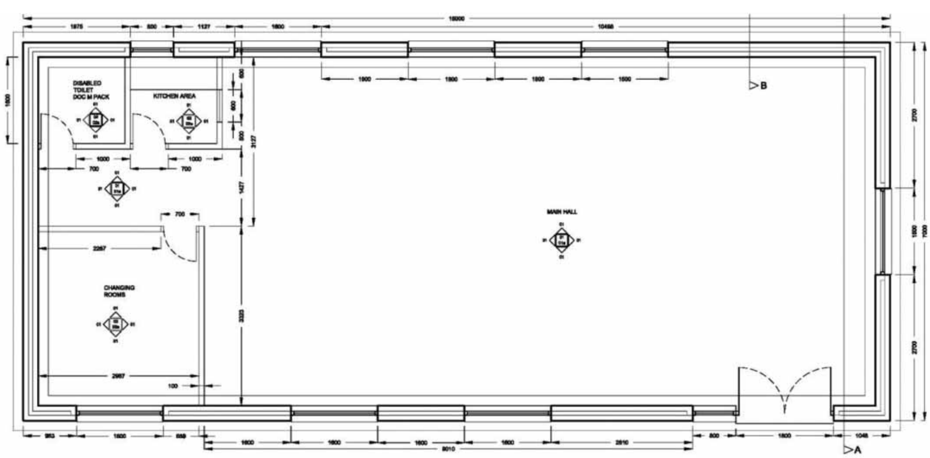

FIGURE 1 Plan view of the community centre

FIGURE 2 3D view of the community centre

with each group of participants on a separate days, and the use of matched subjects. A matched subject design involves assigning different experimental groups for each particular treatment;

- instructional tasks are carefully selected to suit novice learners, so that they could be solved with few operations and within a reasonable time; and
- participants are selected from those, who had no prior CAD experience.

Students were able to control the pace and sequences of the tutorial. The individuals assigned to the audio-illustration and audio-animation groups wore the same headphones, while working through the instructional materials. The semi-static/dynamic (i.e. text and animation or audio and illustration) were shown using both printed and digital presentations. In the experimental assessment, each student was asked to sit in front of a computer and a code was allocated for him/her. Subsequently, the purpose of the research, and the tasks that needed to be undertaken, was explained. Once the assessment task was completed, the time taken to finish the CAD exercise was measured for each student using a stopwatch. Each CAD drawing was then saved on a separate file, using a personally allocated code.

The accuracy of the CAD drawing was determined by an 18-point scale, which was related to issues, such as building shape, dimensions and position. Each 3D construction such as walls, doors and windows were allocated an item number, a position and a dimension ($W \times H \times L$). Accurate items were allocated a point, whereas those which were imprecise were not given a score. The instructional modes consisted of two versions, text and audio. In the text version, the instruction was presented as a screen text, whereas in the audio version the instruction was presented as spoken words with limited screen text. The spoken words of the audio version matched the text of the text version. There were two versions of the illustration mode, static and animated. The static version consisted of a graphic depicting the scientific process with no visual movement to show the process in operation, whereas the animated version showed the process with visual movement to demonstrate the process in operation.

Two criterion measures were employed in this study, a practice achievement and time. Practice achievement was measured by practice item scores and a post-test. Practice performance is measured by the drawing accuracy and the time it takes to accomplish a specific CAD task. The time was measured per minute while the accuracy was measured out of 18 points. The CAD drawing model consisted of 18 items of walls, doors, windows, roof and 3D views. Each point of accuracy was measured by a correct drawing item in terms of the dimension and position in reference to a model drawing as shown in Figure 1. The time spent on instruction and practice items, as well as the total time spent on the programme, was measured and recorded for each participant.

DATA ANALYSIS

Factorial two and analysis of variance (ANOVA) were conducted to analyse the data (Oliver & Mahon, 2005). To compare more than two groups, a 2×2 ANOVA was selected for practice scores. A significance level of 0.05 was set for all statistical tests. The time was measured in minutes, and the average time for each group of participants was calculated. Accuracy was measured using an 18-point scale, which was related to issues such as building shape, dimensions and position. When a statistically significant difference between three or more groups was identified, a post hoc analysis was conducted. The post hoc multiple comparisons were required to determine which specific pairs of means were significantly different from other pairs (Morgan, Griego, & Gloeckner, 2001).

RESULTS

The mean scores of time and accuracy were recorded for each participant. On average, 'text and illustration' group took 34.3 min and scored 12.5/18 on design accuracy. The 'text and animation' group took the longest to complete the task (41.26 min, on average), but their designs were relatively more accurate, scoring 14.3/18. Conversely, the 'audio and illustration' group completed the task in a relatively shorter time (on average 28.77 min), but their designs were the least accurate, and scored only 10.56/18. In comparison, the 'audio and animation's group took longer to perform the same task (an average of 32.08 min), but their designs were relatively the most accurate (15.28/18). The null hypotheses of no difference in means of the learning time and the design accuracy between groups and within groups were tested using an ANOVA.

Table 2 shows that there was a statistically significant main effect for the instructional modes on the learning time (F (1, 97) = 105.424, MSE (mean square error) = 12.912, $P < 0.001$). There was also a statistically significant main effect for the VMs on the learning time (F (1, 97) = 105.424, MSE 12.912, $P < 0.001$) as well as a statistically significant difference in the learning time in the interaction between the instructional modes and the VMs (F (1, 97) = 6.494, MSE 12.912, $P = 0.012$). As a result of the interaction between these groups, a post hoc multiple comparisons test was required to establish which specific pairs of means are significantly different from the other ones. The post hoc test confirmed that 'text and animation' presentation had a statistically significant longer learning time than other three presentations ($P < 0.001$) (Table 3).

Conversely, the 'audio and illustration' presentation had a statistically significant shorter learning time than the other three presentations ($P <$ 0.001). However, there was no significant difference in learning time between static presentation of 'text and illustration' and dynamic presentation of 'audio and animation' where $P = 0.127$.

The results also indicated that there was no statistically significant main effect of instructional modes on design accuracy (F (1, 97) = 0.510, MSE = 4.783, $P = 0.477$), but there was a statistically significant main effect of the VMs on design accuracy (F (1, 97) = 62.158, MSE = 4.783, $P <$

TABLE 2 Between-subjects effects: IM*VM on CAD learning time[a]

SOURCE	TYPE III SUM OF SQUARES	df	MEAN SQUARE	F	SIG.
IM	1361.250	1	1361.250	105.424	0.000
VM	661.563	1	661.563	51.236	0.000
IM*VM	83.845	1	83.845	6.494	0.012
Error	1252.480	97	12.912		
Corrected total	3294.059	100			

Note: $R^2 = 0.620$ (adjusted $R^2 = 0.608$).
[a]Dependent variable: Time (minutes).

TABLE 3 Multiple comparisons of mean differences in learning time between groups IM*VM[a]

(I) GROUPS	(J) GROUPS	MEAN DIFFERENCE (I−J)	STANDARD ERROR	SIG.	95% CONFIDENCE INTERVAL	
					LOWER BOUND	UPPER BOUND
Text and illustration	Text and animation	−6.953[b]	1.029	0.000	−9.64	−4.26
	Audio and illustration	5.530[b]	0.987	0.000	2.95	8.11
	Audio and animation	2.228	1.007	0.127	−0.40	4.86
Text and animation	Text and illustration	6.953[b]	1.029	0.000	4.26	9.64
	Audio and illustration	12.483[b]	1.020	0.000	9.82	15.15
	Audio and animation	9.181[b]	1.038	0.000	6.47	11.89
Audio and illustration	Text and illustration	−5.530[b]	0.987	0.000	−8.11	−2.95
	Text and animation	−12.483[b]	1.020	0.000	−15.15	−9.82
	Audio and animation	−3.302[b]	0.997	0.007	−5.91	−0.70
Audio and animation	Text and illustration	−2.228	1.007	0.127	−4.86	0.40
	Text and animation	−9.181[b]	1.038	0.000	−11.89	−6.47
	Audio and illustration	3.302[b]	0.997	0.007	0.70	5.91

[a]Dependent variable: Time (minutes). Tukey HSD.

[b]The mean difference is significant at the 0.05 level.

0.001). In addition, there was a statistically significant difference in the design accuracy among the interaction of between the instructional modes and VMs (F (1, 97) = 8.713, MSE = 4.783, $P = 0.004$) as shown in Table 4.

The post hoc test confirmed that there was no statistically significant difference in design accuracy between 'audio and animation' and 'text and animation' ($P = 0.416$). However, there was a statistically significant difference between 'audio and illustration' and 'text and illustration' ($P = 0.045$) (Table 5).

These results suggest that participants with the 'audio and animation', and the 'text and animation' presentations, had scored significantly higher in design accuracy ($P < 0.001$ and $P = 0.005$, respectively) in comparison with the 'audio and illustration' and the 'text and illustration' groups.

TABLE 4 Between-subjects effects: IM*VM on CAD drawing accuracy[a]

SOURCE	TYPE III SUM OF SQUARES	df	MEAN SQUARE	F	SIG.
IM	2.439	1	2.439	0.510	0.477
VM	297.307	1	297.307	62.158	0.000
IM*VM	41.674	1	41.674	8.713	0.004
Error	463.961	97	4.783		
Corrected total	812.990	100			

Note: $R^2 = 0.430$ (adjusted $R^2 = 0.412$).

[a]Dependent variable: Accuracy (out of 18 points).

DISCUSSION

A summary of the key findings and their implications on CAD learning performance is illustrated in Figure 3. The findings confirmed that the audio instructional mode shortened the learning time much more than text with both VMs, that is illustration and animation. However, it had no significant impact on design accuracy. This result is in agreement with findings of previous studies, which found that students who received multimedia instructions with audio spent less time on subsequent problem solving compared with students received visual-only instructions (Jeung et al., 1997; Mousavi et al., 1995).

Conversely, text instructional mode enhanced design accuracy much more than the audio mode with the illustration VM-only. This result is in agreement with James and Michael's (2002) findings that reported the treatment of screen-capture presentations has little effect on improving student comprehension of software, as compared with the textbook tutorial. On the basis of this finding, it seems that adding screen-capture from software to text instruction enhanced design accuracy. It may be that adding screen-capture can help learners to understand how to use CAD functionality. In short,

TABLE 5 Multiple comparisons of mean difference in drawing accuracy between groups IM*VM[a]

(I) GROUPS	(J) GROUPS	MEAN DIFFERENCE (I − J)	STANDARD ERROR	SIG.	95% CONFIDENCE INTERVAL	
					LOWER BOUND	UPPER BOUND
Text and illustration	Text and animation	−2.151[b]	0.626	0.005	−3.79	−0.51
	Audio and illustration	1.598[b]	0.601	0.045	0.03	3.17
	Audio and animation	−3.126[b]	0.613	0.000	−4.73	−1.52
Text and animation	Text and illustration	2.151[b]	0.626	0.005	0.51	3.79
	Audio and illustration	3.749[b]	0.621	0.000	2.13	5.37
	Audio and animation	−0.976	0.632	0.416	−2.63	0.68
Audio and illustration	Text and illustration	−1.598[b]	0.601	0.045	−3.17	−0.03
	Text and animation	−3.749[b]	0.621	0.000	−5.37	−2.13
	Audio and animation	−4.724[b]	0.607	0.000	−6.31	−3.14
Audio and animation	Text and illustration	3.126[b]	0.613	0.000	1.52	4.73
	Text and animation	0.976	0.632	0.416	−0.68	2.63
	Audio and illustration	4.724[b]	0.607	0.000	3.14	6.31

[a]Dependent variable: Accuracy (out of 18 points). Tukey HSD.

[b]The mean difference is significant at the 0.05 level.

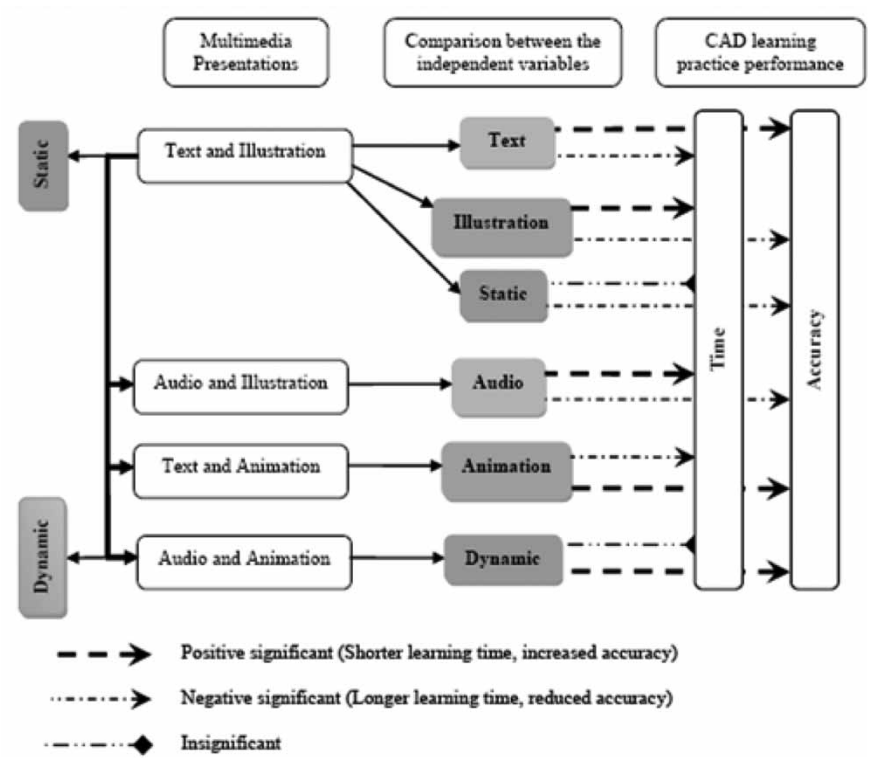

FIGURE 3 The effects of multimedia characteristics (IM; text vs. audio and VM; illustration vs. animation) on CAD learning performance

text instructional mode improved design accuracy more than the audio mode, when using the illustration VM only.

The results also revealed that animation enhanced design accuracy with instructional modes of text and audio significantly more than with illustrations. Participants in the 'text and animation' group had a higher statistically significant score for design accuracy than those in the 'text and illustration' group. From this, it can be concluded that the animation VM had enhanced the design accuracy more than the illustration VM, with both instructional modes (text and audio). This may be because animation has a dynamic visual ability, which helps learners to understand how CAD functionality works. In addition, it may lead to better design accuracy, as 3D building modelling using CAD is a dynamic visual process. This particular result also supports the findings of several other studies (Dwyer, 1994; Hegarty, 1992; Mayer & Anderson, 1992; Reiber, 1990) where it was found that animation can help to make the dynamic content easier to understand and to explain how things work.

Animation VM seems to increase learning time considerably with the text instructional mode alone. The increase in learning time may be due to information overload, where participants were required to follow on-screen animation of VM and read a printed text of instructional mode. This may have complicated the learning task, and may have resulted in a steep learning curve. This result appears to be in agreement with Koroghlanian and Klein's (2004) findings, who reported that participants who received animation, spent more time on practice achievement than those who received static illustrations, with no corresponding improvement in practice achievement and attitude. On the basis of these findings, it may be possible to infer that animation helped to enhance the design accuracy for both instructional modes (text and audio) more than with the illustration mode alone.

Mayer (2010) recommended that graphics-based learning environments should be consistent with a research-based theory of how people learn. CAD tutorial designers, software developers and tutors can use the findings to ensure that the courseware meets students' requirements. CAD tutors in architectural engineering education can equally benefit from the implications of the findings by selecting and fine-tuning CAD learning materials for effective learning. The findings shed light on some of the key conditions architectural engineering students' benefit most from multimedia CAD learning materials, which include using the animation mode to enhanced drawing accuracy and the audio mode to shorten the learning time. The results also encourage the use of a dynamic presentation, by mixing animation and auditory presentation modes, for effective teaching and learning of CAD tasks. In addition, it advocates the use of static illustration presentation mode to help learners discover how to use CAD commands and enhance their drawing accuracy.

Despite these encouraging findings, this study had several limitations. The experimental design dealt with only a representative sample of design tasks, such as building walls, inserting doors and windows, constructing a roof and the like. Consequently, it would not be appropriate to generalize the findings for other design learning tasks using multimedia approach. In other words, the pattern may change for other design learning tasks, level of experience and samples.

The implications of the findings of this study could be more significant, if similar results were replicated in larger samples. These findings reinforce the need for further research within this line of enquiry. In addition to further experimentation and replication, there is a need for additional testing with different instructional tasks, alternative learners' experiences and stage of design conditions to validate the proposed model and confirm the study findings.

CONCLUSION

Recently, most instructional materials for learning built environment design using CAD have shifted from a printed text and illustrations to a multimedia learning format. However, up to now this field of study has been characterized by trial and error in the design and development of instructional material for learners and there has been little effort to guide research and practice in this field. The findings reported in this article sought to contribute to the evidence base on how students learn with multimedia.

The results of this study argue for an evidence-based approach to the adjustment of the delivery media, presentation modes and sensory modalities in architectural engineering education using multimedia. It is reported that the potential for learning is greater and more effective if the content of the multimedia is delivered to suit learners' characteristics, specific learning tasks and design concepts to be conveyed. Consequently, selecting and mixing multimedia features needs a careful consideration to achieve optimum learning opportunities.

These findings reinforce the need for further research within this field of study. In addition to further experimentation and replication, there is a need for further testing with varying design tasks, learners' with diverse experiences and different multimedia characteristics to test the findings of the study.

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