How university instructors apply the design principles for electronic courses: a comparative study based on Richard Mayer's model on multimedia learning

Received 27 November 2021
Revised 28 June 2022
Accepted 28 June 2022

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Abstract

Purpose – Due to the lack of standard and research-based frameworks in evaluating the content designed in electronic courses, there appears a need to examine some existing theoretical models like the cognitive theory of multimedia learning (CTML) developed by Richard Mayer on real occasions. To confirm the effectiveness of the seven principles of the model driven from this theory in different educational settings, especially amid the COVID-19 pandemic, the present study was conducted in the contexts of two universities in Iran for comparison purposes.

Design/methodology/approach – The present research is a descriptive one for which a survey method was considered to collect data. A measurement instrument was developed based on the seven principles mentioned in the last edition of the book written by Clark and Mayer (2016) as well as an extensive review of the related literature. The data gathered from 524 online questionnaires returned by students of a public university Shahid Beheshti University (SBU) and a private one Ruzbahan University (RU) were then analyzed through partial least squares using SmartPLS 3.0.

Findings – The results of confirmatory factor analysis showed that convergent and discriminant validities, as well as model fit indices, had the reliability of the theoretical model at the 99% confidence level. Based on the path coefficients found for testing hypotheses, modality and coherence principles were the first and last priorities, respectively. Moreover, the comparative study showed that t-statistics values for multimedia, contiguity, modality, redundancy and personalization but not for coherence, and segmenting and pretraining principles are significantly different between the two universities.

Originality/value – This study can be considered a pioneering research in Iran so as to increase the quality of multimedia design, instruction and learning at university levels in future research while emphasizing the importance of Mayer's principles in the design of electronic content.

Keywords Multimedia learning, E-Learning, Electronic courses, Cognitive theory of multimedia learning, Content design, Academic instruction, Higher education in Iran

Paper type Research paper

1. Introduction

Considering the fact that the world is struggling with the COVID-19 pandemic as well as an increase in instructional multimedia design over the recent years, the need for standard multimedia design has become increasingly of significance (Soicher and Becker-Blease, 2020; Tarchi *et al.*, 2021). The design of multimedia-based learning environments should be based on scientific principles and ought to follow learning theories and approaches. Learners'

Funding: The work of Hamid Keshavarz was (partially) funded from the Basic Research Program at the National Research University Higher School of Economics.

The International Journal of Information and Learning Technology
Vol. 39 No. 4, 2022
pp. 319-339

2056-4880
DOI 10.1108/IJILT-11-2021-0173

success in multimedia learning activities will occur once they can interact meaningfully with their scientific content, select relevant verbal and nonverbal information, organize information in relevant mental models and integrate new information with their existing knowledge (de Sousa *et al.*, 2017; Schrader, 2016; Mayer, 2002). Specifically, multimedia enables the display of complex processes in a fully interactive and animated way, so that instructional content can be naturally and intuitively linked to other related topics (Frey and Sutton, 2010). Through multimedia instruction, the instructor's understanding of learning strategies from a fully linear textbook-based environment would transform to a growing nonlinear environment defined by several forms of media types (Mayer, 2002, 2005).

Broadly speaking, multimedia and digital technologies for learning could enable instructional design in a way that can transform the cognitive and learning capabilities of all learners groups. Therefore, the use of multimedia tools has fundamentally changed the teaching-learning processes. However, lack of attention to the principles of instructional design, individual characteristics of the learners and human cognitive structure could lead to the materials that not only would have little effectiveness in learning but in some cases, prevent it (Lambert and Cuper, 2008). In fact, the main effort of instructional designers should be to prepare learning materials in a way that is compatible with learning processes happening in mind (Ercan, 2014). Meanwhile, the current generation of learners is showing the impact of being born and growing up in a world increasingly defined by digital technologies and media. As a result, the necessity of the multimedia literacy approach to teacher preparation and practice will trigger a need to revise educational programs as well (Schrader, 2016).

One of the most important multimedia theories is the Cognitive Theory of Multimedia Learning (CTML) developed by Mayer during his longitude research in the past decades. Mayer (e.g. 1999, 2002, 2005) believes that unlike messages with no consideration to the processes involved with cognitive capabilities, messages that are designed to consider how the human mind works would lead to meaningful learning (Mayer *et al.*, 2001). According to him, multimedia learning is a reproductive process that involves selecting appropriate audiovisual materials, organizing cognitive representations into a coherent structure in working memory and combining audiovisual representations with background knowledge (Mayer, 2005).

Research findings support the usefulness of this theory in instructional design in various fields like academic achievement (Almasseri and AlHojailan, 2019), vocabulary training (Kanellopoulou *et al.*, 2019), biology (Satyaprakasha and Sudhanshu, 2014), early childhood education (Shilpa and Sunita, 2013), English education (Shyamlee and Phil, 2012; Zhen, 2016), foreign language education (Almekhlafi, 2006; Amine *et al.*, 2012; Zhang and Zhao, 2013), mathematics (Malik and Agarwal, 2012; Milovanovic *et al.*, 2013), social studies (de Sousa *et al.*, 2017), students with learning disabilities (Greer *et al.*, 2013), vocational military training (Bradbeer and Porter, 2017), technical training (Stebila, 2011) and even in digital initiatives of libraries especially open educational resources (OER) (Theimer, 2019). The scope of these studies concerning disciplines and content areas shows the emerging importance of this theory.

An important consequence of CTML is a shift in teaching and learning paradigms from a teacher-centered approach to a learner-centered approach to foster classroom learning (McTigue, 2009). CTML enables teachers to integrate text, graphics, animation and other media into one instructional message for a rich learning experience (Dash *et al.*, 2016; Jarosievitz, 2009, 2011). Research have shown that multimedia-based instruction can help learners understand and memorize more effectively (Schrader, 2016) and can evoke positive emotions in learners; making it easier to facilitate the transfer of new knowledge to the learners. As Moreno and Mayer (1999, 2001, 2007) explained, the learner, in a multimedia learning environment, is a sense builder who works to select, organize and integrate new information with his/her existing knowledge. According to the knowledge-building approach in learning, the purpose of inclusive guidance instruction is to create active meaning about instructional materials (Mayer, 1996).

Researchers (e.g. Acuña and López-Aymes, 2016; Clark and Mayer, 2016; de Sousa *et al.*, 2017; Evans and Gibbons, 2007; Farias *et al.*, 2007) provide evidence suggesting that students, both at university and lower levels, show significant differences when learning from multimedia content as opposed to traditional learning. Likewise, studies show that learners' success through multimedia learning environments would increase meaningfully. Mayer's CTML (e.g. Mayer, 1996, 1997, 1999, 2002, 2005; Mayer and Anderson, 1991, 1992; Mayer *et al.*, 2001, 2003; Mayer and Sims, 1994; Mayer and Moreno, 1998; Clark and Mayer, 2016) provides a very strong theoretical basis for designing multimedia instruction, creating multimedia learning contexts and environments and understanding cognition and learning as tailored to the diverse needs of learners. Particularly, in the current context of the COVID-19 epidemic and the change of educational environment from physical to virtual classrooms and increase in the design of multimedia content, this need is more tangible than ever.

Due to the lack of standard scientific frameworks and criteria in evaluating the electronic content available, there appears a need to examine some existing theoretical models like CTML in real occasions. The choice of Mayer's CTML for this study is because of the accuracy and strength of its seven principles based on years of research and feedback. Moreover, a research gap can be significantly felt through examining past research in Iran. This research can be an effective step towards the richness of this field. Many previous research studies have dealt with issues such as the effect of multimedia on learning processes and often its application in a particular learning subject. Therefore, conducting this research will have a beneficial effect on increasing the quality of multimedia learning as a result of informing instructors and educational managers about the standard criteria and scientific principles in the design and application of multimedia content. This will also be fruitful for the career development of faculty members, equipment provision, identifying student learning styles and students' interaction with electronic systems. Additionally, since it is necessary to test Mayer's model in different contexts to confirm its usefulness, the present study was conducted in the contexts of two universities in Iran for comparison purposes.

2. Literature review

2.1 CTML and designers

In the last edition of his book, Mayer and his colleague (Clark and Mayer, 2016) developed a model on E-learning design including seven principles of Multimedia; Contiguity; Modality; Redundancy; Coherence; Personalization and Embodiment and finally Segmenting and Pretraining. Some studies have emphasized the positive and maximum effect of applying one or more principles of CTML in the process of teaching, learning and optimizing multimedia tools. As a result, researchers advise educational designers and teachers to use these principles in their educational presentations. For example, Alpizar *et al.* (2020) found that there is significant learning using signaling in presentations. Signaling can direct learners' focus to the target materials and potentially enhance their learning outcomes. They also suggested presenting images in presentations that complement the lesson because images related to the lesson can enhance learning among learners as opposed to decorative images which increase cognitive load and damage individuals' ability to learn the target subject. In this regard, Theimer (2019) showed that there are many opportunities to apply CTML to different aspects of library activities in a way librarians must adhere to and support its principles when creating digital library resources or using them in the classrooms. Dash *et al.* (2016) showed that multimedia tools are essential aids in medical education and would not replace traditional curricula for students. These tools, if well designed, contribute to cognitive processing and would increase working memory capacity. They believe that the quality of animation, sound clarity and logical flow of information presented were emphasized by learners.

As an example, instructional presentations and PowerPoint files should be based on scientific principles to maximize the teaching potential and to improve the transfer of information, preserving and long-term memory of the learner. Similarly, Grech (2018) emphasized that the quality of a presentation depends on the quality, relevance and integrity of its content. Slideshows are not an opportunity for the learner to introduce a piece of software and demonstrate its capabilities, but a tool for conveying clear information to the learner. Slides should avoid detail, complexity and appeal and instead strive for simplicity, brevity, coherence and clarity. Likewise, Tarchi *et al.* (2021) showed that videos, which are more preferred by learners today should be used as instructional material to support in-depth learning processes by teachers and instructors. Instructors should inform learners that because subtitled videos (simultaneous representation of graphics and dynamic text) may over-influence learners' cognitive processing, they should make more effort to learn.

Researchers also acknowledge that using the CTML and content design expertise, as well as neurological factors and the proof-evidence approach, are essential for effective presentations. Wood and Hollier (2017) showed that successful and effective presentation requires knowledge of how the human brain processes information and the ability of the presenter in formatting effective slideshows and communicating with the audiences.

Regarding course designing, Bingham *et al.* (2016) showed that visual display of text is an effective way to communicate with target learners. By engaging dynamic, visual and audio elements in appropriate and effective ways, they appropriately engage a wide range of learners in a meaningful learning process and provide them with effective learning. In addition, using design principles like Mayer's CTML is helpful for designers to use principles like spatial proximity, coherence or personalization because of their effectiveness in previous research. For example, Beukes (2019) emphasized the use of four principles including redundancy, contiguity, coherence and personalization for designing computer production. She found out that all learners acknowledged that reading the text while looking at pictures and listening to sounds helped them remember information.

2.2 CTML and the learners

In some studies, researchers have examined the effects and the relationship between using the principles of CTML in the learning process of the learners. The results of the studies have revealed that the effectiveness of instruction can often be different according to the individual characteristics and previous knowledge of the learner. For example, Castro-Alonso *et al.* (2021) showed that applying these principles is effective for learners who tend to self-manage the learning process. The findings also showed that beginners and new students are more likely to benefit from teacher-managed strategies. Skilled students, on the other hand, may learn more from the strategies managed by the teachers. In addition, the combined teaching methods by both teachers and learners have been found to be more effective. Wang *et al.* (2020) assessed adding visual signaling in the form of eye movement modeling examples (EMMEs) for both low and high-skilled learners. They found that a short narrative animation does not depend on learners' prior knowledge.

Almasseri and AlHojailan (2019) studied the effect of a reverse classroom approach designed based on CTML on academic achievement and showed a positive effect on the learning levels of the experimental group due to Bloom's higher thinking skills, i.e. application, analysis and evaluation. In addition, learners with low prior knowledge showed higher progress in academic achievement compared to learners with high background knowledge. Oberfoell and Correia (2016) showed that audio presentations do not provide greater effectiveness, storage and knowledge transfer. Inexperienced learners use visual presentations more than audio presentations to preserve and transmit knowledge. Contrary to the results of previous studies, this study showed that knowledge retention and transfer were not more effective for learners who used PowerPoint slides with narrations.

In designing educational media, attention should be paid to learners' feelings and their emotional and motivational capabilities. Accordingly, Tomita (2017) showed that while differences in the visual design of booklets (minimalist booklets based on the coherence principle of Mayer vs. attractive booklets based on current trends) were not themselves an important factor in determining learners' motivation for learning. However, in booklets designed based on the principle of coherence, learners were more motivated to learn with the help of the order available for browsing and interaction.

Studies related to the effects of expertise and multimedia between beginners and professionals have emphasized the effect and compatibility of multimedia presentations in the group of beginners. For example, this notion was shown in the study of Lemarié *et al.*, (2016) in which they argued that learners performed better by combining texts with images rather than by text or image separately. However, this multimedia effect would disappear when it provides additional texts and images.

2.3 CTML and effectiveness of instruction

Multimedia instruction is a combination of texts and non-text materials used to promote meaningful learning and to integrate and coordinate new knowledge with pre-learned ones. There has been a lot of research on multimedia learning and the effectiveness of this type of instruction. Different results have been reported by researchers. For example, Soicher and Becker-Blease (2020), unlike many previous studies, found that segmenting does not improve the function of a multimedia presentation with healthcare content and complex biological information on kidneys. They concluded that segmenting might contribute to effective learning and retention in the transfer of knowledge under certain conditions not yet known and understood. Given that researchers such as de Koning and Jarodzka (2017) pointed out that Mayer's theory of multimedia learning is the theoretical basis of research on EMME, Wang *et al.* (2020) showed that applying visual signaling (or cueing) in the form of EMME narrated by short animation can guide visual processing and improve learning outcomes in multimedia learning in a short lesson by guiding the selection process, i.e. directing the learner's visual attention to the relevant part of the screen as well as the integration process, i.e. helping the learner to make connections between relevant words and graphics.

Chen and Yen (2019) evaluated effective and active learning to determine the effectiveness of animations, different levels of learner control, segmentation and the effects of quality on learning and cognitive load when animation was used as a pre-class guide in the reverse classroom for interaction purposes. They found out that information transfer and mimicry learning of animations were improved using multimedia principles. In particular, they argued that segmentation of learning outcomes became less important but remained important for cognitive burden.

Researchers suggest that gender is a key feature that should be considered when evaluating the educational effectiveness of dynamic and static visualizations because gender can affect interventions. Accordingly, Castro-Alonso *et al.* (2019) examined the empirical studies of learning from static versus dynamic imagery. They found that there was a small overall positive effect of dynamic visualizations compared to static ones in a way dynamic imaging was more effective on samples with fewer women and more men. Based on the principles of CTML, Iorio-Morin *et al.* (2017) identified four characteristics to improve the effectiveness of video content in the field of medical education to increase learners' participation and performance including 1) selecting the appropriate content; 2) sound optimization; 3) optimizing backup effects; 4) planning a photography program in advance.

3. Methods and materials

3.1 Methodology

The present research is a descriptive one for which a survey method was conducted to collect data. As the underlying theoretical framework was already available and tested in the related literature, a measurement instrument was developed based on the seven principles mentioned in the last edition of the book written by Clark and Mayer (2016). Before developing the questionnaire, an extensive review of the literature was considered for understanding better the principles and their specifications in online courses.

3.2 Data collection

Relying on previous studies on the theoretical review of the research, a questionnaire (Appendix) was used to collect data consisting of two sections. The first section assessed the respondents' demographic information in terms of degree, gender, education department and name of the university. The second section included 35 questions in the 5-point Likert scale (very low/low/medium/high/very high) composing items related to seven principles. The reliability of the questionnaires was evaluated among a set of 30 students at the Faculty of Education and Psychology of Shahid Beheshti University (SBU). The reliability values, i.e. Cronbach's alphas were higher than 0.7, indicating that the items and components were reliable.

3.3 Participants

For comparison and analysis purposes in two different contexts in terms of university type, the statistical population was selected from all students of SBU public university and Ruzbahan University (RU) private university in the academic year 2020–2021. Due to the heterogeneity of the statistical population, a stratified random sampling method was used. As a result, a total of 524 valid returned questionnaires were considered for data analysis. The link of the questionnaire designed in the Google Form was sent to the participants by e-mail the data of which were stored in two separate Excel files.

3.4 Data analysis

Confirmatory factor analysis was used to ensure the factor constructs. This technique is a method that shows how many items would measure given constructs and are properly selected. This method determines whether the questionnaire items designed to measure each factor are appropriate or not. Therefore, confirmatory factor analysis is a tool for measuring the validity of the questionnaire and is also called the construct validity or measurement model. Therefore, using the PLS method, the relationships between latent variables and explicit variables of the model, structural equation modeling, conceptual model fitting, divergent and convergent validity, combined reliability and Cronbach's alpha reliability test were investigated.

4. Results

4.1 Demographic information results

Table 1 shows the frequency and percentage of demographic information including gender, education, university and department based on group or category.

Variable	Category/Group	Frequency	Frequency percentage	Variable	Category/group	Frequency	Frequency percentage
Degree	Associate of Arts and Science	3	6	Gender	Female	309	59.0
	Bachelor's	378	72.1		Male	215	41.0
	Master of Science	117	22.3	Education department	Social and Behavioral Sciences	176	33.6
	PhD	26	5.0		Medical Sciences	71	13.5
University	SBU	296	56.5		Basic science	75	14.3
	RU	228	43.5		Technical Engineering	150	28.6
					Art and architecture	34	6.5
					Others	18	3.4

Table 1.
Demographic profile

4.2 Divergent validity and correlation coefficient

Table 2 includes the correlation coefficients and divergent validity of the seven principles. On the main diameter of this matrix, the second root shows the average variance extracted (AVE). Confirming the divergent validity requires the value of the second root mean of the explained variance is greater than all the correlation coefficients of the relevant variable in comparison with the other variables. For example, the second root is the mean-variance explained for the multimedia variable (0.804), which is greater than the correlation value of this variable with other variables. The main diameter of the correlation coefficients is shown below. All coefficients are significant at an error level less than 0.05.

4.3 Confirmatory factor analysis

In the confirmatory factor analysis, the relationships between latent and explicit variables, convergent validity, combined reliability and Cronbach's alpha (CA) are examined. Factor loading is shown by the strength of the relationship between a factor (hidden variable) and a visible variable (questionnaire item). Factor load is a value between 0 and 1. If the factor load is less than 0.3, a weak relationship is considered and will be ignored. Factor load between 0.3 and 0.6 and greater than 0.6 are acceptable and very desirable, respectively (Fornell and Larcker, 1981). For convergent validity of the variables, there needs a value of AVE greater than 0.5. To confirm the reliability, CR and CA should be greater than 0.7. Figure 1 and Table 3 show that all reliability indicators are located in the acceptable ranges.

4.4 Hypothesis testing

The *t*-statistics for the principles of multimedia, contiguity, modality, redundancy, personalization and embodiment and segmenting and pretraining were above 2.57 at 99% confidence level while the *t* statistic for coherence was above 1.96 at a 95% confidence level. As a result, all components contributed to the main variable as electronic content design. As shown in Table 4, the values of path coefficients for modality and coherence were the first and last respectively.

4.5 Redundancy, Q^2 and R^2

The R^2 coefficients correspond to the latent endogenous variables of the model. R^2 is a criterion that indicates the effect of an exogenous variable on an endogenous variable for which the values of 0.19, 0.32 and 0.67 are considered as cut-off ones for weak, medium and strong effects respectively. Q^2 obtains three values of 0.02, 0.15 and 0.35 in the case of an endogenous construct. In this way, it indicates the weak, medium and strong predictive power of the construct or related exogenous constructs. The redundancy index is a measure of the quality of the structural model for each endogenous variable according to its measurement model. The higher the value of redundancy, the more appropriate the structural part of the model will be (Chin, Newsted, 1998).

Based on Figure 2 and Table 5, all R^2 values are considered medium and strong except for coherence. Moreover, the values for Q^2 and redundancy are at normal and acceptable ranges.

4.6 Model fit

The Goodness of Fit (GoF) criterion depends on the general part of the structural equation models. The GoF standard was developed by Tenenhaus *et al.* (2004) as there are no fit indices in the PLS method. For this fitting index, the values of 0.01, 0.25 and 0.36 are considered weak, medium and strong, respectively. The formula for measuring GoF is as follows:

Table 2. Correlation coefficients and validity matrix

Principles	Multimedia	Contiguity	Modality	Redundancy	Coherence	Personalization and embodiment	Segmenting and pretraining
Multimedia	*0.804*						
Contiguity	0.788	*0.772*					
Modality	0.686	0.764	*0.737*				
Redundancy	0.591	0.668	0.744	*0.739*			
Coherence	0.234	0.227	0.239	0.286	*0.849*		
Personalization and embodiment	0.490	0.497	0.563	0.506	0.149	*0.788*	
Segmenting and pretraining	0.624	0.651	0.658	0.659	0.233	0.657	*0.785*

Note(s): The Italic values on the diagonal are the square roots of AVE

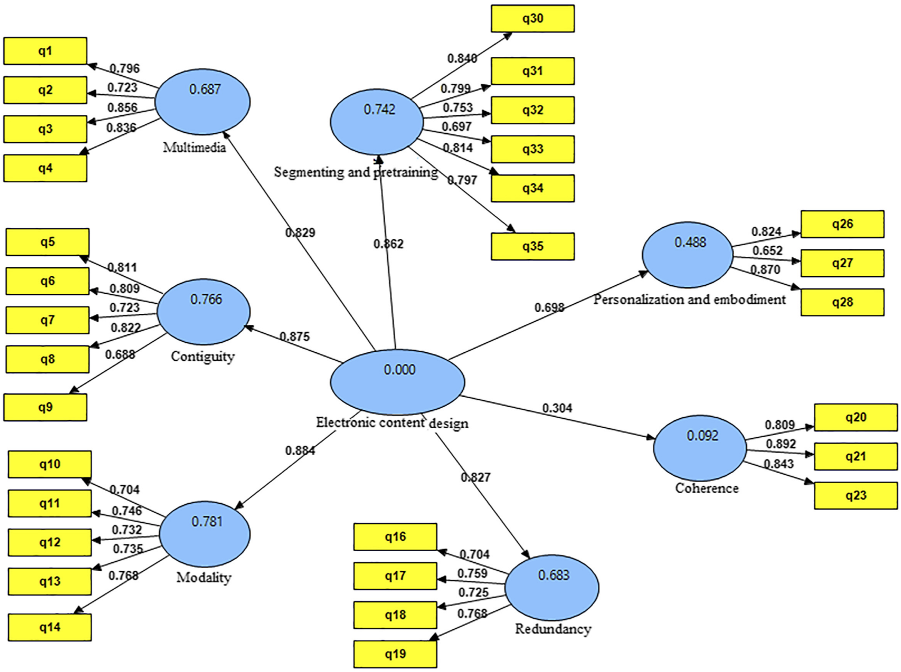

Figure 1.
PLS results
(estimation mode)

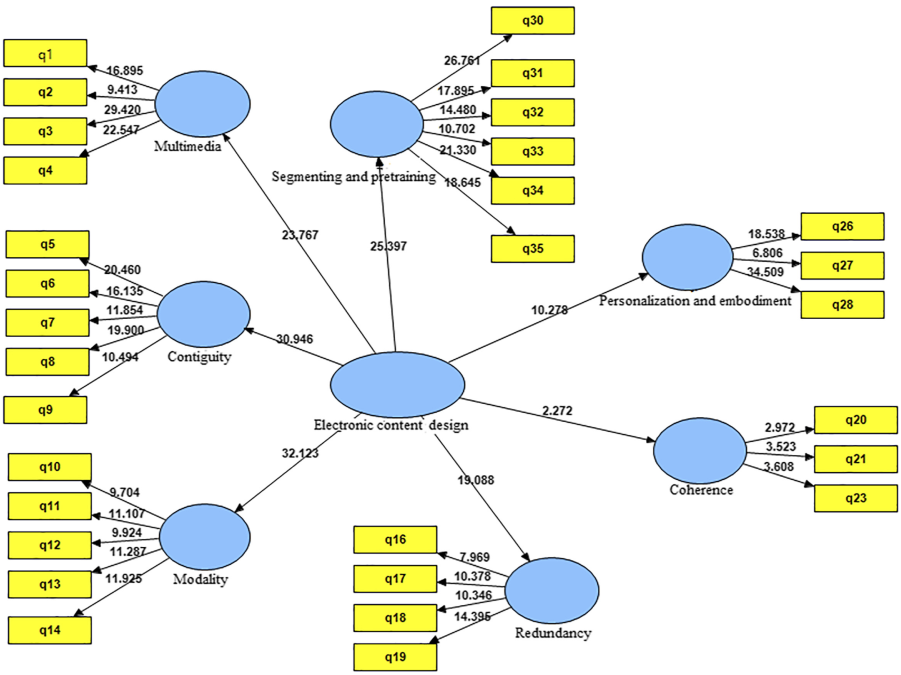

Figure 2.
PLS results
(significance mode)

LV	OV	Mean	FL	t-value	AVE	CR	CA
Multimedia	Q1	2.992	0.796	16.895	0.647	0.879	0.816
	Q2	3.214	0.723	9.413			
	Q3	2.101	0.856	29.420			
	Q4	2.170	0.836	22.547			
Contiguity	Q5	2.933	0.811	20.460	0.597	0.880	0.829
	Q6	2.847	0.809	16.135			
	Q7	2.357	0.723	11.854			
	Q8	3.105	0.822	19.900			
	Q9	2.168	0.688	10.494			
Modality	Q10	3.069	0.704	9.704	0.544	0.856	0.790
	Q11	2.920	0.746	11.107			
	Q12	2.521	0.732	9.924			
	Q13	3.080	0.735	11.287			
	Q14	2.750	0.768	11.925			
Redundancy	Q16	2.672	0.704	7.969	0.547	0.828	0.724
	Q17	2.761	0.759	10.378			
	Q18	3.229	0.725	10.346			
	Q19	2.500	0.768	14.395			
Coherence	Q20	2.040	0.809	2.972	0.720	0.885	0.805
	Q21	1.704	0.892	3.523			
	Q23	1.817	0.843	3.608			
Personalization and embodiment	Q26	3.489	0.824	18.535	0.621	0.829	0.691
	Q27	3.046	0.652	6.806			
	Q28	3.229	0.870	34.509			
Segmenting and pretraining	Q30	2.800	0.840	26.761	0.616	0.905	0.874
	Q31	2.933	0.799	17.895			
	Q32	2.269	0.753	14.480			
	Q33	2.141	0.697	10.702			
	Q34	2.813	0.814	21.330			
	Q35	2.802	0.797	18.645			

Note(s): Latent variable (LV), observe variable (OV), factor loading (FL), average variance extracted (AVE), Composite reliability (CR), Cronbach's alpha (CA**)**

Table 3. Results of confirmatory factor analysis

Principles	Path coefficients	t-statistic
Multimedia	0.829	23.767**
Contiguity	0.875	30.946**
Modality	0.884	32.123**
Redundancy	0.827	19.088**
Coherence	0.304	2.272*
Personalization and embodiment	0.698	10.278**
Segmenting and pretraining	0.862	25.397**

Note(s): $^{**}p < 0.01$, $^{*}p < 0.05$

Table 4. Path analysis

$$\text{GoF} = \sqrt{\overline{R^2} * \overline{COMMUNALITY}}$$

Since the obtained value of the GoF is 0.609 (more than 0.36) as shown in Table 6, it can be said that the model has a strong fit.

4.7 Comparative study

To compare the mean values of research variables between SBU and RU universities, a paired comparison test was considered at first. In this test, if the significance level of the Levin test is greater than 0.05, the results of the first row are used, which accepts the assumption of the equality of variance between the two groups. However, if the significance level of the test is less than 0.05, the results of the second row are used, which accepts the assumption of inequality of variance for the two groups.

The results of this test consist of two outputs. The first output (Table 7) presents descriptive statistics related to the hypothesis test and the calculated values to show the frequency, mean, standard deviation and mean error, respectively. Nevertheless, this must be

Table 5.
Redundancy, Q^2 and R^2

Principles	R^2	Q^2	Redundancy
Multimedia	0.687	0.274	0.444
Contiguity	0.766	0.395	0.457
Modality	0.781	0.315	0.425
Redundancy	0.683	0.250	0.373
Coherence	0.092	0.428	0.066
Personalization and embodiment	0.488	0.271	0.303
Segmenting and pretraining	0.742	0.408	0.457

Table 6.
Model fit

Principles	R^2	Communality
Multimedia	0.687	0.647
Contiguity	0.766	0.597
Modality	0.781	0.544
Redundancy	0.683	0.547
Coherence	0.092	0.720
Personalization and embodiment	0.488	0.621
Segmenting and pretraining	0.742	0.616
GoF	0.606	0.613
	0.609	

Table 7.
Statistical results of the *t*-test

Principles	University	Frequency	Mean	S.D	Mean st. error
Multimedia	SBU	296	2.71	0.956	0.056
	RU	228	2.50	0.912	0.060
Contiguity	SBU	296	2.77	0.913	0.053
	RU	228	2.57	0.895	0.059
Modality	SBU	296	3.02	0.808	0.047
	RU	228	2.67	0.847	0.056
Redundancy	SBU	296	2.95	0.838	0.049
	RU	228	2.59	0.805	0.053
Coherence	SBU	296	1.84	0.926	0.054
	RU	228	1.87	0.924	0.061
Personalization and embodiment	SBU	296	3.37	0.960	0.056
	RU	228	3.11	1.008	0.067
Segmenting and pretraining	SBU	296	2.68	0.948	0.055
	RU	228	2.55	0.916	0.061

confirmed by inferential statistics (hypothesis testing or uncertainty interval), as the second output (Table 8).

The two-way significance value for multimedia, contiguity, modality, redundancy and personalization components is less than 0.05%, so there is a difference between the mean values of these principles between SBU and RU universities. Since the values of *t*-statistic are positive, the average values of multimedia, contiguity, modality, redundancy and personalization components in SBU are higher than RU. The value of two-way significance for the components of coherence and segmenting and pretraining is more than 0.05%, so there is no significant difference between the average components of these principles regarding the two universities.

5. Discussion

Although a review of studies showed that little research have been conducted on Mayer's model during the COVID-19 pandemic in a realistic way, but some similarities can be found with previous studies. Findings from confirmatory factor analysis showed that the factor loads of all principles' items had the appropriate fit for the model and the ability to explain the variance. To evaluate the fit of the measurement model, Cronbach's tests and convergent and divergent validity scores were considered, which all indicated the fit of the obtained data to be used for analyzing the structural model. Regarding the structural part of the model, it was found that all items and relationships between variables are significant at a 95% confidence level indicating the contribution of all principles to the theoretical model.

It can be mentioned that Mayer's principles had the quality in three aspects of measurement model, structural and general models, which in turn showed their validity for the contexts studied. This finding, which is the most important achievement of this research, indicates the high validity of this model at the theoretical and real-world levels. In other words, the findings confirmed Mayer's model in general and reminded the importance of all factors in the design of electronic content. There are many studies to confirm these results, including Theimer (2019) who emphasized the need to apply CTML to various aspects of library activities, especially in the preparation and arrangement of digital resources for classrooms. Dash *et al.* (2016) also confirmed that the use of multimedia tools as teaching and complementary materials would help in cognitive processing if well suit to the principles. Moreover, Wood and Hollier (2017) emphasized that an effective presenter, in addition to design expertise, should use techniques, templates and presentation styles based on the principles of Mayer's CTML to better communicate with the learners. Bingham *et al.*, (2016) showed that the use of Mayer's theory in the form of seven principles as well as the multimedia learning principles would provide a systematic approach in designing and developing online instructional courses.

Since the analysis of causal relationships was not among the objectives of the study, we can compare the strength of the relationships between the main variable and its components. Specifically, given that multimedia learning is generally dependent on the evaluation and cognitive abilities of the learners with multitudes of features, there is no capability to explain and formulate causal relationships to predict this behavior. However, it was decided to examine only the seven factors of the model from students' perspectives because conducting research in which all factors from human characteristics influencing the multimedia learning process in online environments was beyond the research scope.

More specifically, path coefficients showed that modality (0.884) had the highest priority among the seven principles indicating the importance of considering several human senses in the teaching-learning process. This priority should be of value to all people involved in E-course design including designers, policymakers, instructors and even the students themselves. This finding would confirm the results of Iorio-Morin *et al.* (2017) who found the

Table 8.
T-test results with two independent samples

		Levine test		*T*-test results						
Principles	Variance assumed	F	Sig	t	Degree of freedom	Two way significance level	Mean difference	Standard error	95% confidence level Lower	Upper
Multimedia	EVA	0.491	0.484	2.486	522	0.013	0.205	0.083	0.043	0.368
	EVNA			2.502	499.01	0.013	0.205	0.082	0.044	0.367
Contiguity	EVA	0.038	0.846	2.406	522	0.016	0.192	0.080	0.035	0.349
	EVNA			2.412	493.04	0.016	0.192	0.080	0.036	0.348
Modality	EVA	1.401	0.237	4.899	522	0.000	0.356	0.073	0.213	0.499
	EVNA			4.869	476.62	0.000	0.356	0.073	0.213	0.500
Redundancy	EVA	0.004	0.947	4.920	522	0.000	0.357	0.073	0.215	0.500
	EVNA			4.946	497.54	0.000	0.357	0.072	0.215	0.499
Coherence	EVA	0.889	0.346	−0.447	522	0.655	−0.036	0.082	−0.197	0.124
	EVNA			−0.447	488.93	0.655	−0.036	0.081	−0.197	0.124
Personalization and embodiment	EVA	0.216	0.643	2.965	522	0.003	0.256	0.086	0.087	0.426
	EVNA			2.946	476.08	0.003	0.256	0.087	0.085	0.427
Segmenting and pretraining	EVA	0.281	0.596	1.552	522	0.121	0.128	0.082	−0.034	0.290
	EVNA			1.559	496.07	0.120	0.128	0.082	−0.033	0.289

Note(s): EVA: Equal Variance Assumed; EVNA: Equal Variance Not Assumed importance of several senses and their quality in the material designing process to increase the final educational value, especially in video content or multimedia presentations. Courses including sound, images and content altogether would increase the participation and effective performance of learners and would improve the teaching process at the same time. On the other hand, the coherence with a beta coefficient value of 0.304 had the lowest priority, the reason of which should be examined more seriously. According to Tomita (2017), observing the principle of coherence in the design of curriculum and electronic learning content would have a significant effect on increasing the motivation of the learners. Beukes (2019) also showed that the coherence principle in computer programming courses would improve the retention of new words in special situations according to the characteristics of learners even if there is irrelevant content. There is logical and strong support from studies on the effectiveness of content coherence although it seems that more detailed studies are needed to know more about the extent and type of coherence with special conditions. For example, conditions like individual characteristics of learners; beginners as opposed to highly knowledgeable and experienced learners; short-term training in laboratory-controlled studies compared to long-term training in a real learning environment.

If multiple research studies are considered on such influencing factors as age, gender, education, personal differences, personality traits, work tasks and the like, many other studies can be conducted in which causal relations can even be made. For example, Castro-Alonso *et al.* (2019) confirmed the effect of gender on learning from dynamic imagery, or Beukes (2019) figured out the potential impact of language learners' nationality on vocabulary retention. Similarly, Castro-Alonso *et al.* (2021), Wang *et al.* (2020) and Almasseri and AlHojailan (2019) conducted their studies on two different groups of learners, including beginner and expert learners, and found different results.

A comparative study of SBU and RU universities showed a significant difference between the mean of multimedia, contiguity, modality, redundancy and personalization principles. Overall, the average mean of these principles in SBU was higher than RU. However, the two-way significance for coherence and segmenting and pretraining principles was more than 0.05% showing that there was no significant difference between the mean of these two principles between the two universities.

6. Implications and limitations

Based on the validated model of the research, it is possible to provide practical implications that are of interest to people involved such as online learning system designers, instructors, content designers, or even educational policymakers and planners. The following implications are of importance to be considered: using the final research model in educational contexts lower than university, such as high and elementary schools, using the research tools for conducting related research, designing learning assessment systems based on the prioritization of the principles, considering the most important principles from the students' perspectives, taking into account the personality and individual characteristics of the students in instructional programs and some kinds of consideration from the higher education institutions in creating the competencies and motivations for multimedia learning among students based on Richard Mayer's model.

The basic subject of the present study, namely multimedia learning, has been studied by many researchers in various fields leading to the dispersion of the literature on the subject. The current study examined only the views of students, while the perspectives of instructors, as well as system and content designers, can also be considered. The outbreak of COVID-19 caused very difficult access to students at the two universities, which made data collection difficult. While helpful, but using online questionnaires cannot take the place of a researcher in the real world. In other words, the current study did not seek to investigate the actual behavior of users in natural or laboratory conditions nor did it take the path of designing or proposing a system of multimedia learning. Although multimedia learning in the online environment is a new issue and one cannot expect multiple related theories and discussions in psychology and sociology, little attention has been paid to this issue in Iran as the context of the study.

7. Conclusion

The present research was conducted amid the rapid changes happening in e-learning technologies and tools triggered by the global pandemic of COVID-19 in order to examine a theoretical model in two different contexts. The overall findings confirmed the seven-dimensional model arising from Richard Mayer's CTML, revealing its importance and influence in instructional processes at university levels. Moreover, exploring the students' priorities showed that the two principles of modality and coherence had the highest and lowest ones, which could be regarded in the design and presentation of online instructional content. Comparison of public and private universities also showed that the average of five principles in the public university of SBU was higher indicating a need for non-public universities like RU to consider these principles more. The results can be considered pioneering research in Iran to increase the quality of multimedia instruction and learning at university levels in future research while emphasizing the importance of Mayer's principles in the design of electronic content.

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Appendix
Research questionnaire

Principle	Index	Item	Very low	Low	Medium	High	Very high
Multimedia	Q1	Instructors present the electronic courses in the form of “written descriptions and static images (drawings, tables, diagrams or photos)" and not just written explanations					
	Q2	Instructors present the electronic courses in the form of “spoken explanations and static images” and not just with spoken explanations					
	Q3	Instructors use dynamic images (animation, video or moving pictures) along with “written explanations” in the presentation of electronic course materials					
	Q4	Instructors use dynamic images (animation video or moving pictures) along with “spoken explanations” in their electronic course materials					
Contiguity	Q5	Instructors display written descriptions and related images on a page, “inside image” or “close to them"					
	Q6	Instructors create a link between an image and a description of its components in a “slide” using a cursor (arrow) to show the connection between them					
	Q7	If the exercise is provided, the instructors provide a step-by-step guide to solve the exercise on the “same” page					
	Q8	Instructors provide “speech explanations” “simultaneously” with the display of related or dynamic images					
	Q9	Instructors “simultaneously” use “written descriptions” on other pages to provide dynamic images (animation and video)					
Modality	Q10	Instructors use the combination of “spoken explanations and pictures” more than the display of “written explanations and pictures” in presenting the electronic courses					
	Q11	Instructors use “written explanations” to describe difficult specialized concepts					
	Q12	Instructors use “written explanations rather than spoken explanations” to provide a step-by-step guide to solving exercises					
	Q13	Instructors use “spoken explanations” to describe complex images or animations					
	Q14	Instructors use more slides to provide “spoken explanations” for short lessons					
Redundancy	Q15	Instructors use “spoken explanations” without written explanations for better understanding an image					
	Q16	Instructors use written explanations when the presentation is “only” through spoken explanations (without images)					
	Q17	Instructors use written explanations to present unfamiliar specialized words or words in a foreign language					
	Q18	Titles and short texts are elaborated with instructors’ “spoken explanations”					
	Q19	Instructors use “written explanations” when presenting multimedia video content					

(*continued*)

Principle	Index	Item	Very low	Low	Medium	High	Very high
Coherence	Q20	Instructors use additional "written words and explanations" disproportionate to the main teaching objectives of the course					
	Q21	Instructors use irrelevant and unnecessary background music and sound when giving spoken explanations					
	Q22	Instructors do not ignore the material during the "spoken explanations" and avoid expressing irrelevant material					
	Q23	Instructors use "decorative images" that are not related to the subject and purpose of the electronic courses					
	Q24	Instructors use "simple images" instead of complex images to better understand the content					
Personalization and embodiment	Q25	Instructors use "colloquial and informal language" in the first person (I and we) when presenting the electronic courses					
	Q26	Instructors make their teaching recommendations in a "friendly and polite" manner, not grammatically					
	Q27	Instructors use "their own voice" in animations containing spoken explanations, not machine-made voices					
	Q28	Instructors present the electronic courses materials in a "natural and quality" format that is visible and audible					
	Q29	Instructors use "teaching aids" with human facial expressions that have human-like movements and gestures					
Segmenting and pretraining	Q30	At the beginning of each session, instructors explain the "highlights and key concepts" of the new content "before" presenting the general processes and concepts					
	Q31	Instructors reduce the complexity of the electronic course by breaking it down into "smaller content sections and phrases."					
	Q32	Instructors give the student more control over the learning process by providing "stop" and "continue" buttons on short videos or instructional animations related to the content					
	Q33	Instructors provide instructional materials in the form of "short-term" and "short films"					
	Q34	Instructors define specialized terms before entering the main discussion of the course and explain them with "examples"					
	Q35	At the beginning of each session, the instructors review the learning materials presented in the "past" session in general					