Multimedia Instructional Design Principles: Moving from Theoretical Rationale to Practical Applications

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Since the introduction of cognitive theory of multimedia learning more than a decade back much empirical evidence has substantiated the theoretical rationale of multimedia instructional design principles. Medical educators use multimedia mostly for delivering lectures in the form of power-point presentations. Abundant literature is available giving instructions on the appropriate use of font type and size *etc*. to be used in power-point slides, but the literature applying multimedia instructional design principles for preparing effective presentations leading to active and meaningful learning is scanty. This paper deals with theoretical aspects of multimedia instructional design principles and the ways of effectively incorporating these principles for designing meaningful power-point presentations.

Keywords: *Cognitive theory of multimedia learning, Lecture, Power-point*, *Presentation*, *Slides*.

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With the advancement in the field of technology, the use of educational technology tools in medical education are on the rise. The 2007, Effective use of educational technology in medical education report of the Association of american medical colleges institute for improving medical education (AAMC-IME) highlighted the effectiveness of educational technology in medical education and emphasized that for designing instructional presentations for medical students, medical educators must apply the principles of educational technology learning [1]. Broadly, medical educational technology can be divided in to three functional divisions – computer-aided instructions (CAIs), virtual patients (VP), and human patient simulation (HPS).

Of the three functional divisions of medical educational technologies, CAIs in the form of use of multimedia is the most frequently utilized aspect in medical education. Sensing the utility of medical educational technologies and multimedia, many regulatory bodies started faculty development programs, focusing on this aspect. The Medical council of India (MCI) Basic course workshop in medical educational technologies (BCW-MET) covers the area as 'Improving self-directed learning through technology' [2]. From 2015, MCI has made it mandatory for medical colleges to make adequate provisions for conversion of lecture theatres in to E-class and virtual class rooms [3]. As per the competency-based undergraduate medical curriculum, establishment of skill labs by December, 2019, in order to enhance students' clinical, motor, communication skills and team work in medical colleges, has also been made mandatory by MCI, and guidelines for the same were issued recently [4].

The premise that medical students learn better with the use of multimedia and CAIs is based on sound theoretical rationale and empirical evidence, some of which is discussed herein.

THEORETICAL RATIONALE: THEORY OF MULTIMEDIA LEARNING

People learn better from a combination of words and pictures, than words alone. This multimedia principle makes the basis of theoretical rationale of multimedia learning [5]. Accordingly, Mayer gave a cognitive theory of multimedia learning, stating that meaningful learning using multimedia is more likely to happen if multimedia instructional messages are designed keeping in view how the human mind works [5]. The theory is primarily based upon four scientific criteria – theoretical plausibility, testability, empirical plausibility, and applicability. This theory is based upon three fundamental assumptions [5] (***Box* I**).

BOX I THREE FUNDAMENTAL ASSUMPTIONS OF COGNITIVE THEORY OF MULTIMEDIA LEARNING

- *Dual channels*: Human information processing system has separate auditory / verbal channels and visual / pictorial channels, which then work together to make cross-channel representations.
- *Limited capacity*: Humans have limited capacity of processing the information through each channel, at a time, the assumption being consistent with the cognitive load theory
- *Active processing*: In humans active learning happens by constructing a coherent mental representation of experiences, and by integrating incoming information with the prior knowledge – making mental model.

As per the cognitive theory of multimedia learning, relevant information in the form of words and pictures is first selected, then words and images are organized, and finally words and pictures are integrated by building connections to make sense. Mayor's theory gives sound theoretical rationale for the use of multimedia and CAIs in medical education too; an area where pictures and videos can address the bulk of the cognitive load of the medical student.

EMPIRICAL EVIDENCE

Although, low effect size of 'instructional media' was previously suggested [6], recent studies provide evidence in favor of CAIs. Issa, *et al*. [7], showed that the cohort of medical students instructed using principles of multimedia design, scored better than the students instructed using traditional designs, when evaluated for immediate retention of knowledge and total scores. In a follow-up study, the authors showed that the modified condition group scored significantly better than the traditional condition group on delayed tests of transfer conducted one week and four weeks after instruction, and on delayed tests of retention conducted one week and four weeks after instruction. The modified condition group participants also performed significantly better than the traditional condition group on immediate tests of retention and transfer [8].

In another study [9], multimedia was used for teaching of gross infective pathogen with a reformed courseware. Results showed that compared with non-reform classes, the reform classes had significant improvements in results [9]. Based upon these theoretical principles and empirical evidence, it is imperative that medical educators use multimedia for learning, as medical education requires a combination of verbal and pictorial learning [10].

DOES EVERY JINGLE MINGLE?

Though people learn deeply from combination of pictures and words than anything singularly, does that mean that any combination of words and pictures will work? Not exactly. Simply adding pictures to the words does not guarantee improved learning. This affectively means that all multimedia presentations are not equally effective. Only the multimedia instructions designed on the basis of the principles of human learning are going to provide meaningful learning [5]. Accordingly, two broad aspects which one should be conversant with, while designing effective multimedia presentations are: Science of learning and Science of Instruction [10].

Science of Learning: How People Learn

Learning is the change in the behavior of the learner. Mayer called it as the "change in the learner's knowledge attributable to experience" [11]. For fostering learning, instructors must be aware of 'how learning happens'.

For any learning to happen, material is first selected, then material is organized and finally material is integrated and connections built with previous knowledge [5]. Pursuant to the Mayor's cognitive theory, five main types of cognitive processes involved in multimedia learning have been identified *viz*, selecting words, selecting images, organizing words, organizing images, and integrating [10]. One should also take into account the Knowles' principles of adult learning, which emphasize that adults are self-directed, have prior experience on which they build-up new knowledge, and they learn better in safe learning environment [12].

The role of human memory and its processing has to be collated with other processes for driving home the concept of multimedia learning. Humans have three functional parts of memory – sensory memory, working memory, and long-term memory [10]. Sensory memory holds exact copy of information provided for <0.25 seconds. Working memory stores more processed version of the information provided for <30 seconds, with limited capacity. Long-term memory stores knowledge for a longer period of time. Sensory and long-term memory have unlimited capacity. As working memory has limited capacity, so for effective multimedia learning to happen, people must be active learners, seeking meaningful learning.

The interplay between functional parts of the human memory and cognitive processes involved in the multimedia learning has been depicted in ***Fig.* 1**.

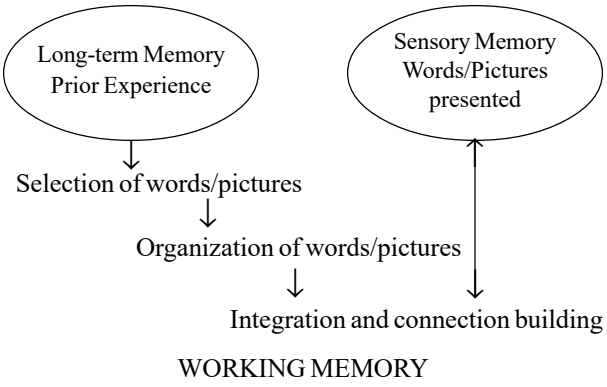

Fig. 1 *Interplay between memory and cognitive processes for multimedia learning.*

Science of Instruction: How Instructions Work

Instructional methods should be in congruence with the human learning and knowledge processing system. It is pertinent to understand how instructions work, before one can design effective instructional methods and instructions. Same applies to multimedia instructions and its application in medical education.

The first step in designing effective instructions is to specify the instructional objectives and the knowledge change in the learner [13]. An instructional objective is a statement clearly specifying – what is to be learnt, how it will be learnt and how the change in behavior will be assessed. Next in line is selecting an appropriate instructional strategy, followed by assessment. Instructional objectives, instructional strategies and assessment, all should be in alignment. Instructional objectives, strategies chosen and assessment should also be in alignment with the specific domain of learning. Well aligned instructional objectives, instructional methods and assessment, not in congruence with domain of learning will not lead to meaningful learning. Overall efforts should be made to create effective learning environments.

Authors are of the view that for designing multimedia instructions; analysis, design, development, implementation, and evaluation (ADDIE) model is best suited as it uses a behavioral approach in designing instructions [14]. As per this model, instructional designs pass through five phases of analysis, design, development, implementation, and evaluation.

In the analysis phase, the existing materials in the form of pictures, videos, exhibits, *X*-rays, ultrasounds, *etc*. will be analyzed for further use in designing multimedia instructions. In designing phase, multimedia delivery method (printed text-figures, power point presentations, computer disc, webinar, virtual classroom *etc*.) will be selected, and then instructional content will be created accordingly in next phase (***Fig.* 2**). Evaluation in multimedia instructions is largely confined to two aspects – test of retention and test of transfer [5]. Performance on these two aspects can measure learner's outcome - poor performance on both types of test indicate no learning; good performance on retention only indicates rote learning, while good performance on both types of tests indicate meaningful learning [10]. One should try to design and use multimedia assessment while using multimedia instructions, based upon cognitive theory of multimedia assessment [15].

MOVING FROM THEORY TO PRACTICE

The above mentioned theories and instructional design aspects make sound foundation for how the faculty members in medical colleges can design multimedia instructions. Mostly medical college faculty uses multimedia only for designing power point (PPT) slides-based instructions and presentations. Other multimedia contents are mostly made available by software developers as 'ready-to-use' materials. Most of the papers found in literature have restricted the discussion only about font type and size to be used in PPT slides, color combinations, number of lines *etc*. for making slides better presentable; in the next section we discuss briefly how effective PPTs can be designed based upon multimedia instructions developed through empirical evidences and practical issues.

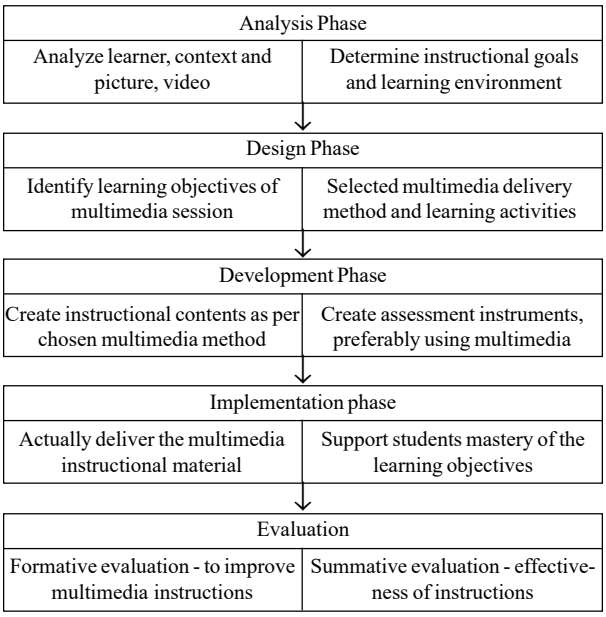

Fig. 2 *Phases and activities for designing multimedia instructions as per ADDIE model.*

After scanning almost 100 studies, Mayer identified 12 principles of developing and designing multimedia instructions [7,10,16]. These 12 principles have broadly been factorized into three generic principles in literature *viz.* curtail extraneous processing; manage essential processing, and nurture generative processing [7,10].

Extraneous processing is a type of cognitive processing that does not support the learning objective, often caused by poor instructional design, like picture on one slide and its explanation on another slide of presentation. No doubt, such processing must be reduced to have less cognitive load. Essential processing is the process of representing the essential material to the working memory, through the process of selecting and organizing. This cognitive processing must be managed. Generative processing involves the process of making sense from the presented material through integrating and organizing. This needs learners motivation and engagement too, thus generative processing needs to be nurtured. Readers interested in details of these processes may refer Mayer's write-up on the same [17].

These factors along with strategies which can be devised for effective designing of PPT based multimedia instructions have been depicted in ***Fig.* 3** [7,10,17].

Above mentioned principles can be easily incorporated to make slide presentations interesting, engaging and effective. In the next section, we have tried to present graphically the strategies to incorporate major multimedia instructional design principles for preparing effective power-point presentations.

Multimedia principle: While preparing slides, both words and pictures should be used, instead of using words alone ***(Web Fig.* 1**). This will also be in accordance with the 'dual channel' assumption of the cognitive theory of multimedia learning.

Coherence principle: Do not use unnecessary and unimportant pictures, words and animations in your presentation (***Web Fig.* 1**). These unnecessary elements are bound to increase cognitive load on the learners. Exclusion of unnecessary elements from slides will also be in accordance with the 'limited capacity' assumption of the cognitive theory of multimedia learning.

Signalling principle: The essential and important material in the slides must be highlighted (***Web Fig.* 2**). This can be done by using a text box option or by using the glow text effect.

Contiguity principle: Learning from slides is better when pictures and concerned words are presented near to each other than separated from each other on a slide (Spatial contiguity). Similarly, learning is better when pictures and related words are presented simultaneously and on the same slide rather than successively or on the next slide (Temporal contiguity) (***Web Fig.* 2**). This enhances 'active processing', another assumption of the cognitive theory of multimedia learning.

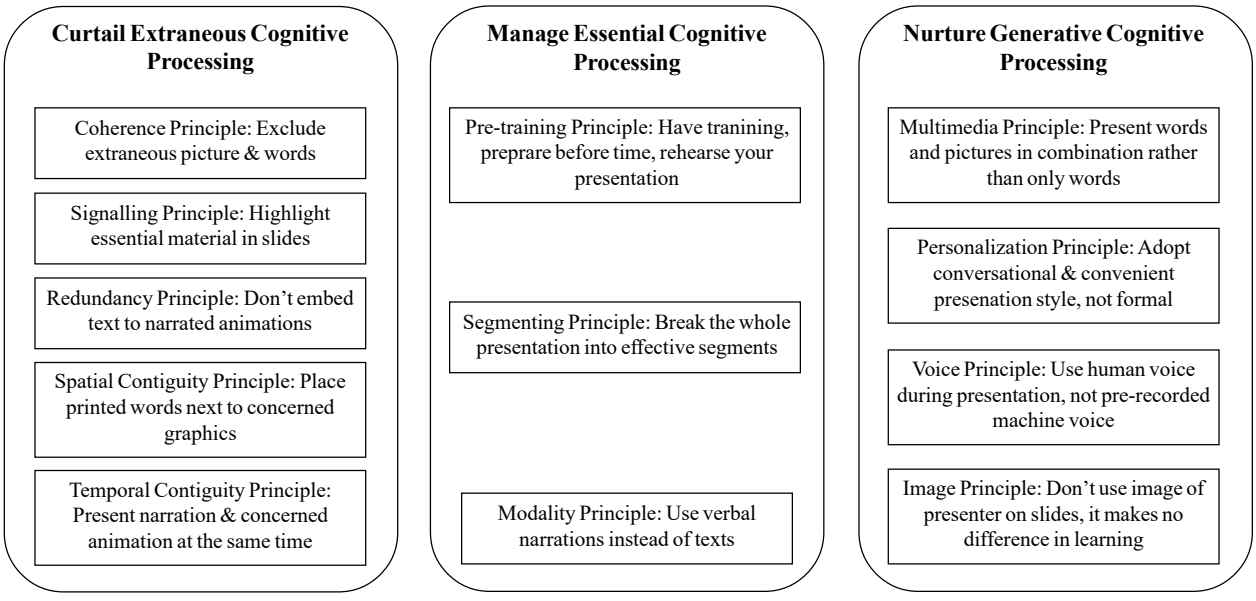

Fig. 3 *Principles of instructional design for multimedia presentations adapted for effective power-point based presentations.*

Segmenting principle: Presentation should be divided into different effective segments for better interaction with the content of the presentation and meaningful learning (***Web Fig*. 2**). Same can apply to one slide, where space must be used in different sections, if required.

Redundancy principle: While using an animation in the presentation, don't overload the slides / presentation with text also. Narration with animation makes better learning than animation, narration and text. If text is used along with animation, it will compete for the visual channel.

Multimedia presentation tools such as power point outshines in context to its applicability and feasibility at presenting knowledge in the form of visual information. The message during large group interactive sessions having embedded colored figures, charts, and graphics along with text can be better conveyed by using multimedia instructional principles while preparing power point presentations [18]. It has been proven beyond doubt that adapting powerpoint slides of lectures according to multimedia principles is likely to translate in to improved short-term retention among medical students [7].

FACULTY READINESS AND TRAINING

It has been noticed worldwide that the effective use of educational technology in medical education depends largely upon faculty readiness, which in turn depends upon faculty training. Medical faculty must be trained in at least three wider aspects of educational technology in medical education *viz*, understanding of technical operations of the technology, understanding of the ways to utilize this technology for teaching-learning, and understanding the ways to utilize the technology for students' assessment [1].

Are Faculty Members Trained and Ready?

Traditionally, medical educators are trained to use clinical settings for teaching-learning and assessment purposes. There are lot of differences between clinical setting-based teaching-learning and computer-based teaching-learning. Both will call, not only for different teaching styles but also different methods of feedback and assessment. As mentioned earlier in this paper, faculty members are most verse with theoretical aspects of the same, but application part is missing. This calls for shifting our focus from delivering 'knowledge' aspects of the training to 'competency' aspect. It is the need of the hour to structure 'competency-based faculty training programs for using advanced educational technologies' in medical education by incorporating the principles of cognitive theories of multimedia learning, and principles of multimedia design.

CONCLUSION

Cognitive principle of multimedia learning and principles of instructional designs need to be practically implemented. These principles must be used while making power-point presentations for medical education, so as to make lectures interesting, interactive and effective. These slight modifications will definitely improve the retention of the medical students.

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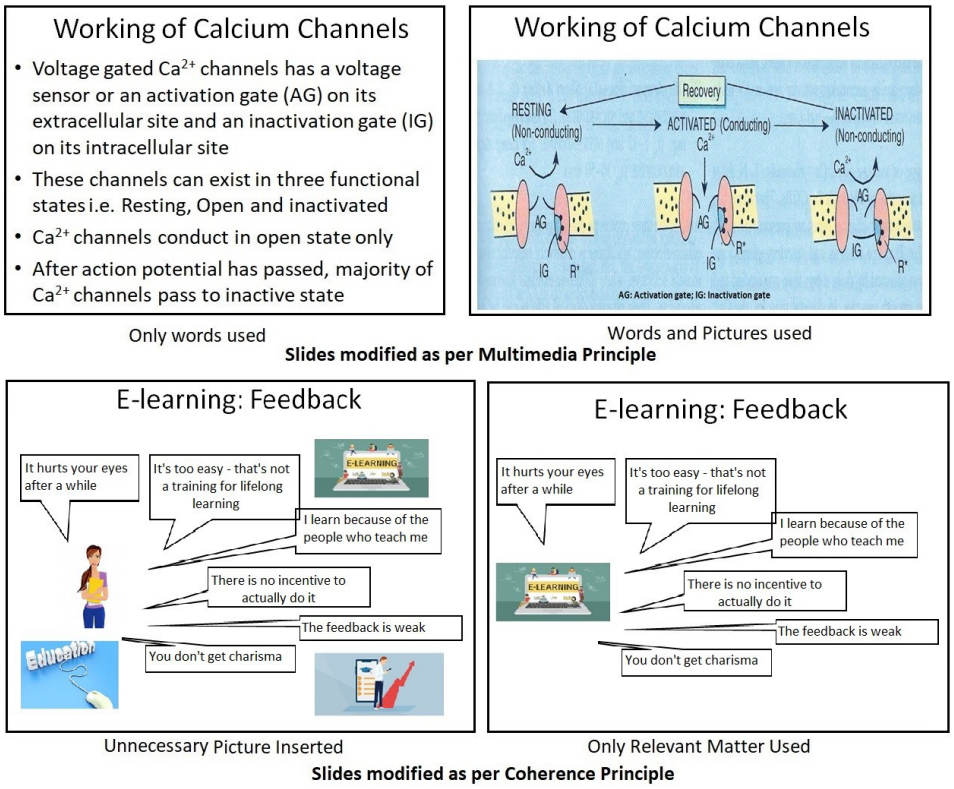
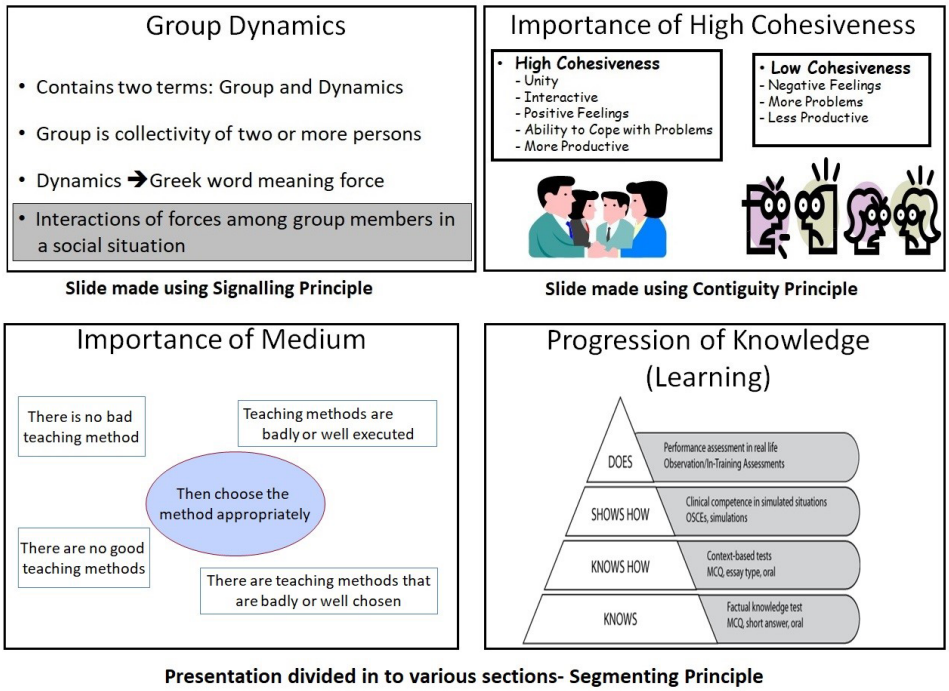


Web Fig. 1 *Examples of effective slides made using different multimedia instructional design principles.*



Web Fig. 2 *Effective slides made using multimedia instructional design principles.*