MULTIMEDIA PRINCIPLE

Research results suggest that words and graphics are more effective when combined than just words alone, with some provisos:

- graphics should not be an afterthought: they should be **planned** alongside the text to maximise understanding
- **decorative** graphics **do not improve learning**

Clark & Mayer (2016) suggest that there are six possible functions of graphics:

Graphic type	Description
Decorative	Visuals added for aesthetic appeal or humor
Representational	Visuals that illustrate the appearance of an object
Organizational	Visuals that show qualitative relationships among content
Relational	Visuals that summarize quantitative relationships
Transformational	Visuals that illustrate changes in time or over space
Interpretive	Visuals that make intangible phenomena visible/concrete

Consistently, students who receive a multimedia lesson consisting of words and pictures perform better on a subsequent transfer test than students who received words alone. Across the eleven studies cited in Clark & Mayer (2016), a median percentage gain of 89% was achieved with a median effect size greater than 1 when comparing words with pictures and words alone. The multimedia effect "establishes the potential for multimedia lessons to improve human learning" (Clark & Mayer, 2016. p79), and it therefore belongs firmly at the top of this list of principles.

Based on these categories, it is recommended that **decorative and representational images are minimised**, and instead focus on graphics that help the learner to understand the material presented, or organise the material in a useful way.

However!

There are some important caveats to the multimedia principle.

Learners aren't always the best judge

While it is clear from the description above that not all graphics are equally effective, students frequently misjudge the value of these graphics. In a 2012 study, students did not learn better when added illustrations were purely decorative or seductive, though they reported liking the lesson better when it contained any kind of illustration.

Liking != learning

As a result of this inability to distinguish helpful and unhelpful illustrations, instructional designers should only use highly relevant, instructional illustrations, and even include pointers in the text as to what to look for in the provided illustrations.

There is a diminishing effect

A combination of words and graphics are particularly useful and important for novices, though less useful for expert learners. Experts are able to create their own mental images as they read a text, making use of relevant schema that they have formed previously in order to comprehend. The provision of words and graphics can actually negatively affect expert learners. If teaching a more advanced group of learners who are experienced in the topic being presented, they may be able to learn well mainly (or entirely) from text, or mainly from graphics.

Source

Clark & Mayer (2016). *e-Learning and the Science of Instruction*, 4th ed. Hoboken, NJ: Wiley.

COHERENCE PRINCIPLE

People learn better when extraneous words, pictures & sounds are excluded.

> *"Perhaps our single most important recommendation is to keep the lesson uncluttered. In short, […] you should avoid adding any material that does not support the instructional goal."*
>
> Clark & Mayer, 2016. p151.

There is a need to remove any media that is not central to the instructional goal of the lesson – a process that Mayer and Moreno called **weeding**. Some instructional designers have attempted to make use of background music and exciting or interesting imagery, or what Mayer calls **seductive details** in order to reduce dropout rates on e-learning courses, arguing that their inclusion may motivate learners, but this flies in the face of the body of research.

> *"When learners use their limited processing capacity on extraneous material, less capacity is available for making sense of the essential content."*
>
> Clark and Mayer, 2016. p152.

Ways to apply the coherence principle

Remove extraneous words

Cute stories and interesting pieces of trivia can feel to the instructional designer like harmless additions to a multimedia presentation, but research suggests that they may not produce the desired effects. The rationale for excluding extraneous words is based upon the cognitive theory that assumes that working memory capacity is very limited.

Clark & Mayer (2016, p155) identify three distinct types of extraneous wording used for different purposes:

- **for interest:** related to the topic but not relevant to the instructional goal
- **for elaboration:** expands upon the key ideas of the lesson
- **technical details** that go beyond the key ideas of the lesson

They recommend against all three, suggesting that when these additions are more interesting than the fundamental content of a lesson that they can distract learners away from achieving the instructional goals. Not only do they not help learning, but in some cases they can even hurt learning. Evidence for this can be found in many studies conducted over the last 20 years. Mayer, Heiser and Lonn (2001) conducted an experiment that concluded that **presenting more information can result in less learning**: the addition of additional narration segments to the lesson distracted students away from the core instructional goals.

A related study conducted in 2007 found that college students who read the lesson *with* seductive details "spent less time reading the relevant text, recalled less of the relevant text and showed shallower processing on an essay task as compared to students who read the lightning passage without seductive details" (Clark & Mayer, 2016. p156).

Adding seductive details harms learning by **distracting learners** from the important information and by **disrupting the coherence** of the lesson.

Source

Clark & Mayer (2016). *e-Learning and the Science of Instruction*, 4th ed. Hoboken, NJ: Wiley.

CONTIGUITY PRINCIPLE

On-screen text should be placed close to the graphics to which they refer.

Spatial contiguity

People learn better when corresponding words and pictures are presented near to each other rather than far from each other on the page or screen. Presenting graphics followed by explanatory text further down the screen forces the user to scroll up to see the graphic & scroll down to see the text. This physically separates the text and graphic, which should be considered to be two parts of a wider whole. This is referred to as the **spatial contiguity** principle: related text and graphics should be presented together.

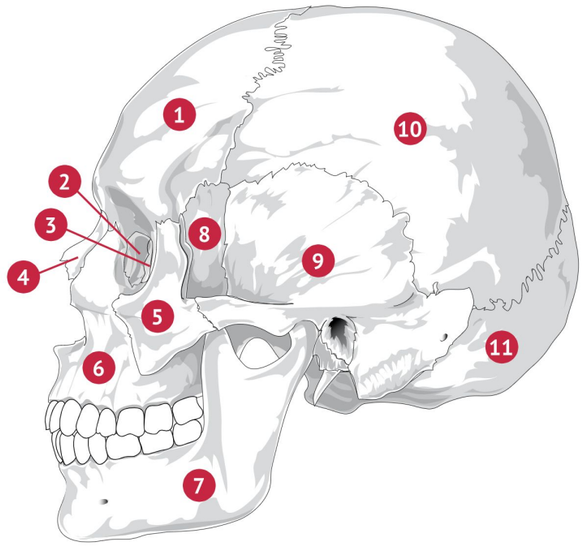
Legends presented alongside charts, with labels linked to corresponding numbers on a diagram, break this principle, forcing the user to shift their attention back and forth from the graphic to the legend. Consider the examples on the right of the page.

Temporal contiguity

Similarly, presenting an animation that is followed by audio narration separates the two in time, resulting in less learning than if the animation and narration were synchronised in time. This is referred to as the **temporal contiguity** principle: related media should be integrated and presented synchronised in time.

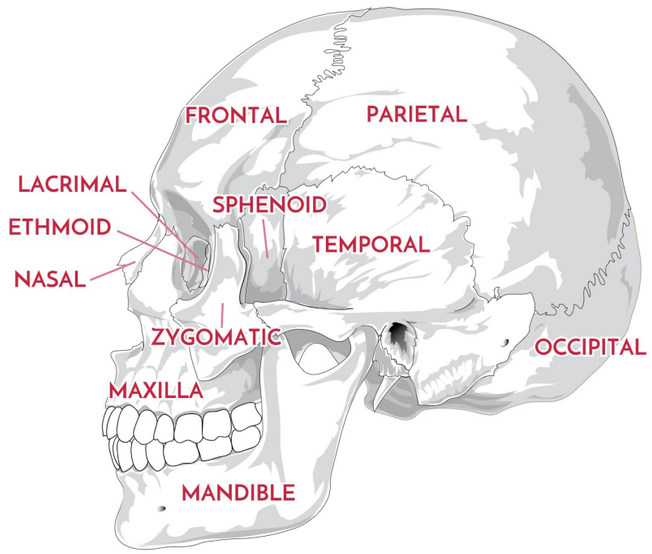
Source

Clark & Mayer (2016). *e-Learning and the Science of Instruction*, 4th ed. Hoboken, NJ: Wiley.



1. Frontal
2. Lacrimal
3. Ethmoid
4. Nasal
5. Zygomatic
6. Maxilla
7. Mandible
8. Sphenoid
9. Temporal
10. Parietal
11. Occipital

In the example above, the bones of the skull are labelled using a legend, with descriptions at the side of the image. Numbers are used to link the bones with their names. This divides learners' attention and should be avoided.



In this example, labels are provided on top of the graphic, which makes it easier to focus on the content.

WHAT THE RESEARCH SAYS

SIGNALING PRINCIPLE

People learn better when cues that highlight the organisation of essential information are added.

Important information in instructional materials should be signposted and emphasised to draw the learner's attention to them. Signaling usually comes in the form of voice and visual cues.

Voice cues

Narration of content should be structured in a logical way, using **introductory sentences** and **section headings** to divide content into chunks that require the learner's focus. Using **indicator words** (like first, second, third) and varying **tone** and **inflection** can be powerful ways of emphasising an important point.

Visual cues

Learners' attention can be focused by using **colour** to highlight important content, **arrows**, **columns** or other visual hierarchy tools such as **scale**, **layout** and making good use of **white space** to separate content (in line with the contiguity principle).

Source

Clark & Mayer (2016). *e-Learning and the Science of Instruction*, 4th ed. Hoboken, NJ: Wiley.

EXAMPLE 1

Lecture 1: The Beginnings of Communication Science

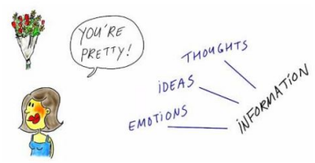
Each act of transmitting information, including thoughts, ideas & emotions. As social animals, we communicate day in day out with spoken words, non-verbal gestures, signs & symbols.

Media

Scholars don't really agree on the definition of the word media, but media can include television, telephones, radio, books, newspapers, the soapbox we stand on to deliver a speech, etc. They are all technical media, in a way. In a broader definition, we could include our hands, voice & eyes, as they are all used to communicate something, but in general when discussing media communication, or the mass media, we only mean the first category.

Above, no cues have been added to present the content. Key ideas are not highlighted and the learner has to draw out the important ideas.

EXAMPLE 2



Examples
- Act of giving flowers
- Giving a verbal compliment
- Blushing

Technical media: things we construct to amplify our communication.

LECTURE 1: WHAT IS COMMUNICATION?

Each act of transmitting information, including thoughts, ideas & emotions. As social animals, we communicate day in day out with spoken words, non-verbal gestures, signs & symbols.

MEDIA

Scholars don't really agree on the definition of the word media, but media can include television, telephones, radio, books, newspapers, the soapbox we stand on to deliver a speech, etc. They are all technical media, in a way. In a broader definition, we could include our hands, voice & eyes, as they are all used to communicate something, but in general when discussing media communication, or the mass media, we only mean the first category.

Above, cues have been added including visuals, section headings and colour. A wide margin allows for additional information including examples & definitions.

REDUNDANCY PRINCIPLE

People learn better from graphics and narration than from graphics, narration and on-screen text.

Saying the same thing twice in two different forms - text and narration - has less impact than saying it in narration only. This is explained by **dual-coding theory** which presents the idea that verbal information is processed in one area of the brain and visual information is processed in another. In doubling up the information presented, using both channels, a bottleneck forms that reduces the learner's ability to process either channel.

In an instructional video, for example, where visuals are accompanied by narration, adding on-screen text that mirrors the narration can result in:

- learners paying less attention to the **visuals**
- learners experiencing **cognitive overload** during fast-paced presentation of data
- learners trying to **compare** the different formats, or focusing in on any differences in the two different formats

Each of these results in learners being less likely to achieve the instructional objectives. It is advised to explain a visual through audio or text, but not both.

However!

It is not quite that simple. A variety of studies support this principle, though more research is needed to assess situations where it does not hold. There is a suggestion that providing additional information can be helpful for a beginner in a way that becomes redundant for a more experienced learner.

Special situations where redundancy may help

Using redundant text in addition to narration is acceptable and even suggested when:

- there is an **absence of onscreen pictorial information**
- enough **time is provided** for the learner to process pictorial information
- related audio might be difficult for the learner to understand - such as with **foreign language learning** or for learners with some **auditory learning disabilities**.

It is helpful to remember this proviso when considering how to differentiate instruction for EAL learners - subtitles that can be toggled on or off by the user may be very helpful for some learners, but displaying them at all times would be redundant.

Example

Schwartz, D. (2014). *Not all scientific studies are created equal* [online]. Available from: https://ed.ted.com/lessons/not-all-scientific-studies-are-created-equal-david-h-schwartz [Accessed 16/09/2020].

Sources

Clark & Mayer (2016). *e-Learning and the Science of Instruction*, 4th ed. Hoboken, NJ: Wiley.

Mayer, R. E., & Johnson, C. I. (2008). *Revising the redundancy principle in multimedia learning*. Journal of Educational Psychology, 100(2), 380-386. doi: 10.1037/0022-0663.100.2.380.

McCrudden, M. T., Hushman, C. J., & Marley, S. C. (2013). *Exploring the Boundary Conditions of the Redundancy Principle*. The Journal of Experimental Education., 82(4), 537–554. doi: 10.1080/00220973.2013.813368.

SEGMENTING PRINCIPLE

People learn better from a multimedia lesson when it is presented in segments that a learner can access at their own pace rather than a continuous unit.

Breaking a continuous lesson, unit of study or large amount of content into bite-sized segments is an established characteristic of good teaching. Breaking down a large, unwieldy and complex problem into more manageable components to be tackled individually reduces the likelihood of **overloading working memory**. As McAlinden (2020) put it, if your concept is a loaf of bread, it's best consumed one bite of one slice at a time.

The use of short, single-task video tutorials that focus on a single aspect, tool or function of database software, for example, allows TES Computing students to progress at their own pace through constructing their own databases. Rather than teacher-led instruction where all students watch a teacher demonstration that they then attempt to replicate in a timeframe dictated by the teacher, students are presented with a selection of tasks that are each supported by a video tutorial to assist them in completing the task, all the while having the ability to pause, rewind and watch again in case they missed something on first watching. Regular checkpoints can be established by the teacher to ensure enough progress is being made, but the students work at whatever pace suits them. See the examples to the right.

Working in concert with pre-training principle

Important considerations when segmenting content include how big a chunk should be, how many chunks should learners be introduced to and at what pace. A good way to inform this is through pre-training or a pre-test to assess learners' understanding before commencing with a course or unit, and using the results of a pre-test to inform the pace at which new content is introduced.

EXAMPLE 1

Instructions

1. Set your computer's regional settings to **English (Canada)**.

Find out how

2. Open Microsoft Access and create a new database called **Officeline.accdb**

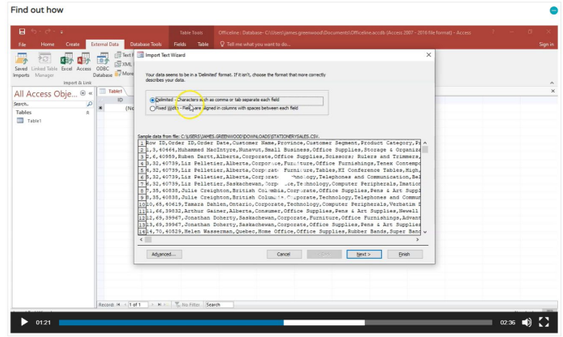
Find out how

3. Download this dataset (**stationerysales.csv**) and import it to your database as a new table called **tbl_Orders**. When importing, make sure:

- You tick the box that says "**First row contains field names**"
- Set the field **Row ID** to be the primary key

Above, students have specific instructions to create a database, with expandable 'find out more' links that display video tutorials.

EXAMPLE 2



When toggled, the student is shown a video tutorial that helps them progress through the task, narrated by their teacher.

Sources

Clark & Mayer (2016). *e-Learning and the Science of Instruction*, 4th ed. Hoboken, NJ: Wiley.

McAlinden, D. (2020). *Principles of Multimedia Learning* [online], available from: https://www.linkedin.com/pulse/principles-multimedia-learning-dave-mcalinden/ [Accessed 11/09/2020].

WHAT THE RESEARCH SAYS

PRE-TRAINING PRINCIPLE

People learn better when they have a frame of reference for lesson components, concepts or ideas.

This is relevant in situations where learners are presented with complex material and terms they are unfamiliar with. Learning the terms for constituent parts of a complex idea at the same time as learning about the idea can overwhelm the learner. It is helpful if some of this processing can be done in advance.

Pre-training has been shown to be particularly beneficial for beginners, and enable them to access more complex materials. In a pre-training activity, key concepts or vocabulary are unpacked and explained before the main lesson.

Checking prior knowledge can also be achieved through **pre-testing**, where learners are asked a series of questions about new, unseen material.

For an example of pre-training in action, consider a novice learner who has never before encountered a microscope being presented with the task below.

TASK: USING A MICROSCOPE

Place the slide on the microscope.

Use stage clips to secure it in place.

Click nosepiece to the lowest (shortest) setting – scanning objective.

Look into the eyepiece.

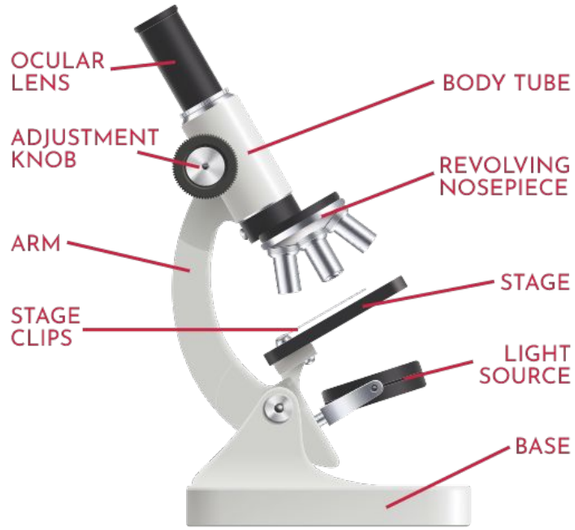
Use the adjustment knob.

Once the slide is focused, rotate the nosepiece to the low power objective.

Refocus using the adjustment knob.

Move slide to get a centered view.

This activity could be improved by providing pre-training in the form of a labelled diagram. This could be set as homework in the lesson before.



The task that follows should then use the terms from the pre-training consistently. These terms could be provided in bold or in colour to **signal** their importance.

TASK: USING A MICROSCOPE

Place the slide on the **stage**, using **stage clips** to secure it in place.

Click the **revolving nosepiece** to the lowest setting (the shortest lens). Look into the eyepiece of the **ocular lens**. Use the **adjustment knob** to focus.

Once the slide is focused on what you want to examine, rotate the **revolving nosepiece** to the highest magnification (the longest lens).

Refocus using the **adjustment knob**. Move the slide to get a centered view.

Sources

Clark & Mayer (2016). *e-Learning and the Science of Instruction*, 4th ed. Hoboken, NJ: Wiley.

WHAT THE RESEARCH SAYS

MODALITY PRINCIPLE

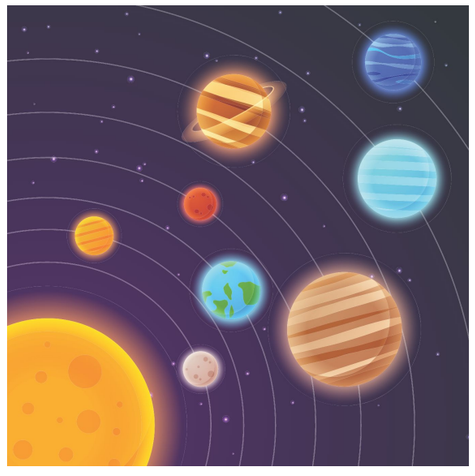
People learn better when words are presented as narration rather than on-screen text.

This principle draws from information processing theory that posits that visual and auditory information are processed in different parts of the brain and are processed in separate channels. Graphics are processed by the visual channel and narration is processed by the audio channel. When text is added, the visual channel becomes overloaded because of the overlap between text and graphics. This adds unnecessary complexity as the two compete for the learner's attention.

As a result, presenting graphics with audio narration alone is optimal for learning as it makes more effective use of working memory capacity, allowing the learner to remember it for longer. Research suggests that this is particularly true of novice learners.

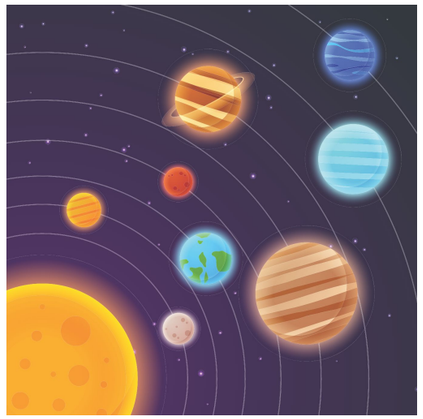
Mayer conducted an experiment where learners were shown information about the solar system. The first group were shown a graphic and text, which was also read aloud to them::

GROUP 1



This is our solar system. The center of the solar system is the sun. There are 8 planets that revolve around the sun. The planet closest to the sun is Mercury, followed by Venus, then Earth, Mars, Jupiter, Saturn, Uranus and finally Neptune.

GROUP 2



A second group of learners were shown only the graphic. The accompanying information (using exactly the same wording) was spoken aloud.

Group 2 **retained 80% more** than group 1, and this principle has been replicated in numerous other studies.

However!

There remain some important caveats to this principle:

- **Consider your audience:** this principle is less relevant for skilled learners who have a higher capacity for processing information in one channel.
- **Text is helpful for supporting memory:** adding words is beneficial when presenting technical terms, words not in the home language of the learner or when the terms are needed for future reference.

Source

Clark & Mayer (2016). *e-Learning and the Science of Instruction*, 4th ed. Hoboken, NJ: Wiley.

WHAT THE RESEARCH SAYS

PERSONALISATION PRINCIPLE

People learn better where words are spoken in conversational style rather than formal style. In a series of experimental studies, Moreno & Mayer (2000, 2004) compared two versions of an educational game, one using a conversational style and the other using a formal style. For the purposes of this principle, the differences between these styles are outlined below:

Conversational style	Formal style
Use of first- and second-person	Passive voice
Personal tone	Impersonal tone
Feedback is polite and friendly	Feedback is direct

By employing social cues, a sense of social presence is activated in the learner, meaning a feeling of connection and being in a conversation with the author of the instructional material. This causes the learner to engage in deeper cognitive processing during learning - working harder to understand what the author is saying - which results in better learning outcomes. This contradicts a widely-held belief that a formal tone conveys a sense of seriousness and gravity that mean learners take them more seriously and therefore learn more.

In the examples on the right, adapted from Clark & Mayer (2011), a resource about compound interest is revised from formal to conversational tone.

Sources

Moreno & Mayer (2000). Engaging students in active learning: The case for personalized multimedia message. *Journal of Educational Psychology, 93,* 724-733.

Moreno & Mayer (2004). Personalized messages that promote science learning in vertical environments. *Journal of Educational Psychology, 96,* 165-173.

Clark & Mayer (2016). *e-Learning and the Science of Instruction,* 4th ed. Hoboken, NJ: Wiley.

EXAMPLE 1: FORMAL TONE

Calculating Interest

Overview | Interest | FDIC | Test

Interest is compounded or added to the existing cash balance monthly. For disclosure on client statements, the annual percentage yield earned is calculated as follows:

All interest paid amounts divided by the average available cash balance for the quarter divided by the number of actual days in the quarter multiplied by the number of actual days in the year.

Example: $50.00 divided by $20,000 divided by 91, multiplied by 365 = 1.00%

Rather than using the passive voice as above, the example below uses second person active voice, and includes a comment about how the concept relates to the learner's job. The overall result is more user-friendly.

EXAMPLE 2: CONVERSATIONAL TONE

Calculating Interest

Overview | Interest | FDIC | Test

Clients will often ask you to explain how the Annual Percentage Yield on their statement was calculated. This can be confusing, so let's run through an example:

1. Take the interest earned during the quarter.	**$50.00**
2. Divide it by the average cash balance in the account.	$50,000/$20,000 = **0.0025**
3. Divide the answer by the number of days in the quarter	0.0025/91 = **0.0000274**
4. Multiply by 365 days in the year	0.0000274 x 365 = **0.01**

APY earned would be 1.00%

VOICE PRINCIPLE

People learn better when the narration in multimedia lessons is spoken in a friendly human voice rather than a machine voice.

For reasons outlined in the personalisation principle, social cues engender social responses in learners that encourage deeper cognitive processing and therefore improved learning outcomes. These social cues are diminished by the use of text-to-speech software that produces a robotic-sounding voice to narrate learning materials, and this effect can also be observed in narration that is heavily accented in a way that learners are not familiar with.

A median effect size of d = 0.74 was supported in 5 out of 6 experimental studies (Mayer, 2014). Despite improvements made in text-to-speech software in recent years, there is no substitute for narration recorded by a human.

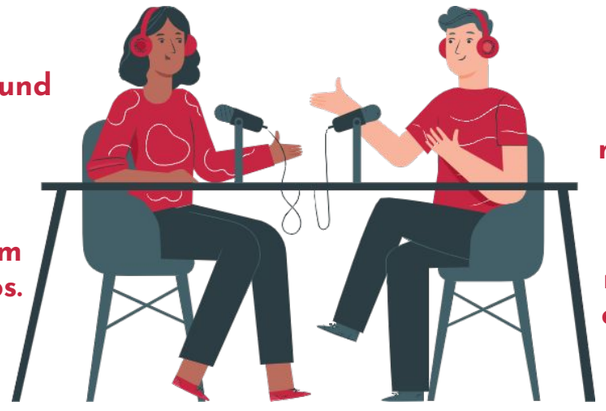
Audio quality is also a factor in effective narration. See the graphic below for practical tips on improving the quality of your narrations.

Use a good quality microphone rather than the on-board one on your laptop.

Save your narration with low compression in editing software - preferably CD quality (192kbps).

Take steps to reduce background noise in your recording.

Recording in a small, quiet room will reduce echos.



Position your microphone 6-12 inches from your mouth, and test it before you start.

A pop filter will reduce the impact of plosive sounds.

In the same way as the personalisation principle, the feeling of social presence is an important enabling factor in encouraging learners to engage with multimedia activities.

IMAGE PRINCIPLE

People do not necessarily learn better from a multimedia lesson when the speaker's image is added to the screen.

The inclusion of an image of the instructor as a "talking head" during a multimedia presentation has not been shown to improve learning outcomes. Though research on this is preliminary, an instructor does not necessarily add value to a lesson by showing their face when delivering a multimedia presentation. There are some important caveats to this principle, however. Instructors should consider showing their faces when:

- There are **no words or pictures** for learners to engage with.
- There is benefit to be gained from establishing **social presence** with learners, such as at the beginning of a lesson, or when chairing a discussion or debate.

Sources

Moreno & Mayer (2000). Engaging students in active learning: The case for personalized multimedia message. *Journal of Educational Psychology, 93,* 724-733.

Moreno & Mayer (2004). Personalized messages that promote science learning in vertical environments. *Journal of Educational Psychology, 96,* 165-173.

Clark & Mayer (2016). *e-Learning and the Science of Instruction,* 4th ed. Hoboken, NJ: Wiley.