

## Comparison of dynamic visuals to other presentation formats when learning social science topics in an online setting

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Despite the widespread use of whiteboard animations in both academic and informal settings, little evidence exists about their efficacy and impact on learner experiences, especially in non-STEM fields such as the social sciences. This study examined the effects of whiteboard animations against three other instructional formats on comprehension, measured by multiple choice questions and an open-ended summary question, and subjective experiences measured by Likert scale items. In a randomised experiment, Amazon Mechanical Turk participants ( $N = 299$ ) viewed one of two social science lectures in one of four instructional formats: whiteboard animations, narrated slides, on-stage lecture, or audio/narration alone. Data was analysed using a series of ANOVA tests. Results showed that the whiteboard animation group answered significantly more questions than those who learned with on-stage lectures or narrated slides. Whiteboard animation and audio only groups also reported more enjoyment of, and engagement with, the lessons compared to the other groups. Findings contribute to the body of knowledge by providing evidence on the effectiveness of instructional materials when learning example social science topics.

### *Implications for practice or policy:*

- Considering on-stage lectures and narrated slides are commonly used video formats in online education, practitioners should consider using different lecture formats (e.g., audio only) when teaching social science subjects.
- Online course developers may consider using the whiteboard animations to enhance student learning outcomes.

*Keywords:* instructional formats, video lectures, whiteboard animations, online learning experiences, social science education

## Introduction

Video has become the primary medium to deliver instruction in online settings (de Koning et al., 2018). Despite their popularity and the diversity in styles (Chorianopoulos, 2018; Hansch et al., 2015), there is limited evidence to justify their value for the effort required, to fulfil educational objectives (Espino et al., 2021). There is a need to identify how different instructional presentations lead to improved learning outcomes across different domains (Fyfield et al., 2019; Laaser & Toloza, 2017). It is imperative to understand how different types of instructional videos (e.g., narrated slides, on-stage lectures) as well as simpler modalities such as audio-only lectures (e.g., podcasts), impact learning outcomes and subjective experiences, compared to newer formats such as whiteboard animations.

Whiteboard animations are a type of innovative video design that show the procedure of dynamically drawing a series of pictures on a white board or paper. Artists create a linear audio-visual story through narration and drawings that are sped up which give the illusion of animation. Similar to performance art, the process of creation via visual storytelling engages the audience's attention (Lee et al., 2013). Some research has found that whiteboard animations have more educational merit compared to other types of videos due to logical sequencing (Lee et al., 2013). Further they could be ideal for presenting scientific concepts to lay audiences due to their clean imagery, high contrast, and medium level of detail (Türkay, 2016). Fiorella and Mayer (2016) proposed a dynamic drawing hypothesis in their study where students learned better when instructors taught a physics lesson on the Doppler effect by dynamically creating the diagrams rather than showing static visuals. Similar results were found by Fiorella et al. (2018) when teaching biology lessons, and by Li et al. (2019) in general education science lessons using a flipped classroom setting. Learners seem to enjoy whiteboard animations more when compared to other video styles as well (Li et al., 2019; Shoufan, 2019; Türkay, 2016).

Despite the growing evidence of the effectiveness of whiteboard animations, most studies that have aimed to identify what works or does not work for instructional videos, make generalisations predominantly from science, technology, engineering, and mathematics (STEM) focused topics (Fiorella & Mayer, 2018; Stull et al., 2018). There is not much evidence on the effectiveness of whiteboard animations in topics from social sciences, although these topics are also taught online. The popular online video sharing site YouTube has a plethora of channels dedicated to animated videos created to communicate information to public in the field of social sciences (e.g., Future History, Extra Credits, psych2go). There is a distinct lack of empirical studies on the effectiveness of different types of instructional materials in social sciences, and when and how animations are effective in these contexts (Berney & Bétrancourt, 2016; Fyfield et al., 2019; Höffler & Leutner, 2007). It is crucial that we ask research questions specific to the type of animations and the instructional domain. In this study, the specific type of dynamic visuals are whiteboard animations and the specific instructional domains are the social science disciplines of philosophy and psychology.

This study aimed to investigate the effectiveness of whiteboard animations on learning outcomes and subjective experiences (e.g., enjoyment) compared to more common instructional materials when teaching non-STEM topics. Traditional on-stage lecture videos, voice-over slides, and audio/narration were selected as different instructional video formats to compare with whiteboard animations. On-stage lecture videos are commonly used in online learning (Chorianopoulos, 2018). These are the video recordings of classroom lectures. They can include an instructor, presentation slides, and the instructors' whiteboard/blackboard. Voice-over slides are created using slide decks such as PowerPoint presentations with narrations and are commonly used in online education (Chorianopoulos, 2018; Hansch et al., 2015). Prior work developing multimedia learning principles primarily used such presentations in their experiments (e.g., Mayer, 2005), thus, they make a good comparison case to whiteboard animations. Narration only materials, such as podcasts, are audio recordings of lectures which are accessible to students (Evans, 2008; Hew, 2009). Instructors can record their lectures during a live teaching session or in a studio. Podcasts became especially popular with the heightened interest in hybrid, or blended, learning (Mashhadi & Jalilifar, 2016).

## Literature review

### Affective theory of multimedia learning and emotional design

The cognitive theory of multimedia learning implies that people recall information from instructional materials better when narration is accompanied by illustrations (Mayer, 2005). While the cognitive theory of multimedia learning explained how people cope with the cognitive processes concern learning, studies in the past decade have found evidence that motivation may also play role when learning with multimedia (e.g., Liew & Tan, 2016). The most influential theory, proposed by Moreno (2007), is the cognitive affective theory of learning with media. This theory extends the cognitive theory of multimedia learning by incorporating motivational and metacognitive factors which mediate learning by enhancing cognitive engagement (Moreno & Mayer, 2007). In a commentary piece of a special journal issue on emotional design, Mayer (2014a) highlighted that if we can keep essential processing from being overloaded, seductive and emotional design features that aim to motivate can enhance learning through generative processing.

In a similar vein, design features such as shapes, design layout, colours, and sound are found to influence situational interest, motivation, and learning outcomes by creating positive emotions (Mayer & Estrella, 2014; Plass et al., 2014; Um et al., 2012). Um et al. (2012) used colour (e.g., warm colours such as orange and pink) and shapes (e.g., round shapes) with faces to induce positive emotions in students learning a set of biology multimedia lessons. Um et al. (2012) found that when they applied emotional design principles to learning materials, these materials could generate positive emotions which enhanced learning, knowledge transfer, and satisfaction, and facilitated cognitive processes by lowering external cognitive load. Plass et al. (2014) conducted another study to replicate the results from Um et al. (2012)'s study, by varying an additional design feature (i.e., faces) in their design to induce positive emotions. They found similar results (e.g., reduced perceived task difficulty, increased learning), but unlike Um et al. (2012)'s study, Plass et al. (2014) found emotional design made no difference to knowledge transfer. The positive effect of emotional design on people's learning and intrinsic motivation were replicated to some extent in other studies (e.g., Heidig et al., 2015; Münchow et al., 2017; Schneider et al., 2016). However, multiple studies failed to elicit a positive affect with emotional design (e.g., Mayer & Estrella, 2014; Münchow et al., 2017). Schneider et al.'s (2016) study showed that positive decorative pictures might serve as an emotion facilitator to enhance

learning performance, retention, and transfer. As suggested by Leutner (2014), studies so far are encouraging to further investigate of the causal chain of varying emotional effects with different multimedia instruction by applying emotional design principles.

These studies have shown evidence that emotionally appealing yet instructionally relevant graphics can enhance learning. Yet, we know very little about how motivational, affective, and cognitive constructs relate to each other (Brünken et al., 2010), especially when learning non-STEM topics. Furthermore, there research is lacking on the presentation of emotionally appealing graphics presented as animations versus static images.

## **Animations**

Animations are perhaps the most controversial type of multimedia learning format when it comes to their impact on learning outcomes (Berney & Bétrancourt, 2016; Castro-Alonso, Wong et al., 2019; Ploetzner et al., 2020). A great number of studies examined the effects of animations versus static images on learning outcomes and cognitive load. Höffler and Leutner's (2007) meta-analysis found a medium sized effect of animations over static images on learning. The three moderators in their study were: (1) type of knowledge (procedural is better compared to declarative); (2) role of animation (representational is better); and (3) degree of realism (high fidelity is better). Another meta-analysis by Berney and Bétrancourt (2016) found an overall positive effect of animation over static images for learning. They found no significant differences on the outcomes for the type of knowledge being taught. Others showed evidence that dynamic visualisations emphasise temporal information and may improve perceptual learning to answer "what" questions, whereas static images improve cognitive learning to answer "why" questions (Wagner & Schnotz, 2017). A recent meta-analysis of 46 studies on STEM learning tasks and manipulative-procedural tasks found a small but significant effect, showing that animations were more effective than static visualisations for procedural learning (Castro-Alonso, Wong et al., 2019). Some studies suggested that the mixed results were due to extra information presented in either static images or in animations (Castro-Alonso et al., 2016; Tversky et al., 2002). Others found demographics, such as gender, to be an influential moderator determining effectiveness of animations (Castro-Alonso, Wong et al., 2019); animations were more effective in studies with more male participants than female participants.

Animations are used to communicate complex ideas by presenting events over time via visual encoding of information, helping to generate dynamic mental models of phenomena (Boucheix & Guignard, 2005; Ploetzner et al., 2020). Due to this affordance, most studies exploring the effectiveness of animations have been with science topics (e.g., formation of rocks in Lin and Atkinson [2011] and immunology in Thomas et al. [2017]). Even across STEM fields, recent meta-analyses have found differences in the effectiveness of dynamic visualisations on learning outcomes (Castro-Alonso, Wong et al., 2019; Ploetzner et al., 2020). This shows the need to examine the role of animations in different fields, including non-STEM ones (e.g., history, psychology).

There are multiple types of animation ranging from high fidelity to low fidelity and from system-controlled to user-controlled animation (Castro-Alonso, Wong et al., 2019). One common characteristic among them is that they involve transient information which may increase cognitive overload (Wong et al., 2012). Recent studies showed evidence that dynamic drawings such as whiteboard animations and instructor drawn diagrams may alleviate this problem, because the visuals are drawn step by step and remain visible throughout the instruction (e.g., Fiorella & Mayer, 2016). Whiteboard animation is a type of innovative dynamic visualisation format that emerged in recent years. Due to their common use across disciplines and their difference from other instructional formats merits further investigation (Krämer & Böhrs, 2017).

## **Whiteboard animations**

Creators of whiteboard animations present a linear story using audio narration and a series of images in the process of creating a stop frame animation. Concrete and simple images presented through dynamic drawings can make the storytelling stronger and help the audience relate with the story (Heath & Heath, 2008). Mayer et al. (2020) proposed dynamic drawings as a key method to improve effectiveness of instructional videos. Prior studies showed evidence that students learn better from videos with dynamic drawings and narration than those with static visualisations and narration when learning science topics (e.g., Fiorella & Mayer, 2016, Türkay, 2016). For instance, a study on teaching about human kidneys showed

that people learn better when they see the illustrations being drawn by the instructor rather than seeing already drawn images (Fiorella et al., 2018). In a flipped common core science general education course, Li et al. (2019) found that students who watched whiteboard animations had higher quiz scores than those who watched the lecture videos. They reported that whiteboard animations were more interesting and helpful for understanding concepts compared to the lecture videos. In another study, Occa and Morgan (2022) compared whiteboard animations to brochures for providing information about clinical research to cancer patients. Their findings showed that individuals found whiteboard animations more persuasive compared to brochures and experienced higher levels of cognitive absorption when watching the whiteboard animations.

There are several differences between traditional instructional animations and whiteboard animations. While traditional instructional animations contain transient visual information, information that disappears before it can be effectively processed (Boucheix & Forestier, 2017), whiteboard animations present the creation of a complete scene before starting up the next scene. This may alleviate the negative transient effect on learning. When watching whiteboard animations, the learner sees the instructor's hand movements. An earlier study investigated the impact of observing hands when learning patterns of symbols, using animations and static images (Castro-Alonso et al., 2014). Castro-Alonso et al. (2014) suggested that human hands are redundant in animations and increase cognitive load. On the other hand, in the context of dynamic hand drawings, Fiorella and Mayer (2016) conducted a series of three experiments to test the effects of watching instructors' hand draw a short (~100 seconds long) video-based physics lesson. In each experiment, they found that students, especially those with low prior knowledge, benefited from observing instructors' hands. It might be that there are other mechanisms in play when learning with instructional videos of dynamic hand drawings.

When learning with whiteboard animations, the following multimedia learning principles may impact learning through the reduction of extraneous processing.

- The signalling principle states that people learn better when instructional materials include cues that highlight relevant elements or the organisation of the material (Schneider, Beege et al., 2018). In whiteboard animations, hands may provide a signalling mechanism during drawing which can direct learners' attention to relevant information, including written text and drawn images (Castro-Alonso, Paas et al., 2019; Mayer, 2017). In addition, when the human body and its limbs (e.g., arms, hands, and fingers) are used to signal, social cognition effects can be triggered in addition to signalling (Castro-Alonso, Paas et al., 2019).
- In line with social agency theory (Mayer, 2014b), whiteboard animations where learners observe instructor's hands may provide a social cue as opposed to animations without a hand drawing on a whiteboard (Fiorella & Mayer, 2016).
- Drawing scenes through linear narrative may provide a segmenting mechanism where the material is broken down into manageable parts (Mayer, 2017).
- In line with temporal contiguity principle, whiteboard animation drawings are created simultaneously with the instructor's narration. This helps learners better integrate visuals with oral explanations (Mayer, 2017). In whiteboard animations, visuals support the narrative rather than narrative support the on-screen visuals. Therefore, it is important to understand the added value of visuals in learners' affective experiences and recall.

While there is some evidence that whiteboard animations may improve learning and affective experiences, all the studies mentioned above were in the domains of STEM. Considering the importance of pictorial and symbolic representations for learning in the STEM domains (Danielson et al., 2014; Evagorou et al., 2015; Luzón & Letón, 2015), these results may not apply to other disciplines and pedagogical approaches. This study investigated the effectiveness of different instructional formats on multiple learning related outcomes against whiteboard animation videos when teaching topics in social sciences. The following hypothesis were proposed:

1. Participants who receive whiteboard animations will perform better on a retention test than those who receive the same lesson in other formats.

2. Participants who receive whiteboard animations will report more positive subjective experiences of enjoyment, engagement, attention, and challenge compared to those who receive the same lesson in other formats.

The study was approved by the university's ethics committee.

## Method

### Participants

The participants recruited for this study were 317 (179 female, 138 male) US-based adult participants with high English proficiency (92.3% were native English speakers) from Amazon Mechanical Turk (Mturk). Mturk is a crowdsourcing site where users, called workers, complete tasks, called human intelligence tasks for requesters (Follmer et al., 2017). Only 14.7% ( $n = 44$ ) of the participants identified as current students. Final analysis omitted people with duplicate IP addresses and those who gave irrelevant answers to open-ended questions. The final number of participants was 299 (170 female, 129 male). The average age of the participants was 36.02 ( $SD = 11.45$ ). Respondents were asked to estimate the number of hours per week they engaged in relevant activities (i.e., watching instructional videos or listening to instructional audio).

### Study design

Participants were first randomly assigned to one of two social science lessons (either Lesson 1 or Lesson 2) to control for the effect of a specific lecture topic or lecturer on outcome variables. They were then assigned to one of the four instructional formats (on-stage lecture videos, voice-over slides, narration, or whiteboard animation) by the automatic randomisation feature of *Qualtrics* (Table 1).

Table 1  
*Participant numbers per group in each lesson*

	Whiteboard animation	Slides	On-stage lecture	Narration	<i>n</i>
Lesson 1	33	38	37	48	156
Lesson 2	44	39	30	30	143
Total	77	77	67	78	299

### Stimuli

Materials for the study were based on publicly available YouTube videos from the Royal Society for Arts Manufacturers and Commence animate channel. In this channel, whiteboard animations were created based upon on-stage lectures. At the time of this study, the site contained 21 whiteboard animations, all of which were made in the same style. Among those, two videos with similar on-stage lecture style were chosen. They were both video recordings of on-stage lectures taught in front of an audience for later online viewing. The Lesson 1 video was *The Truth about Dishonesty* by Dan Ariely. The Lesson 2 video was *The Power of Outrespectation* by Roman Krznaric. These on-stage lectures were comparable to each other, in that they did not involve any interaction with the audience and had contained a minimal amount of multimedia in their presentations. The whiteboard animations of the chosen videos were shorter than the on-stage lectures. Other formats, voice-over slides and narrations, were created using the whiteboard animations (see Figures 1 and 2 for example screenshots from different instructional materials for Lesson 1). Narrations refer to audio only versions of the lessons. These were created by exporting the audio from the video. Voice-over slides were created by taking a screenshot of the completed drawings in whiteboard animations and editing them with the original audio. These slides showed the resulting image, but neither showed the process of creating the images nor the hands of the artist. Finally, the length of the on-stage lecture video was adjusted to the length of the associated whiteboard animation. End credits were removed from all materials. The length of all the instructional materials (whiteboard animation, on-stage lecture, voice-over slides, and narration) within each lesson was the same (Lesson 1: 10 minutes and 48 seconds; and Lesson 2: 10 minutes and 7 seconds). While these videos were shorter than a typical lecture, they were comparable to online videos, especially those developed for massive online open courses (MOOCs) (Guo et al., 2014).



Figure 1. Screenshots from whiteboard animations (left) and slides (right) of Lesson 1

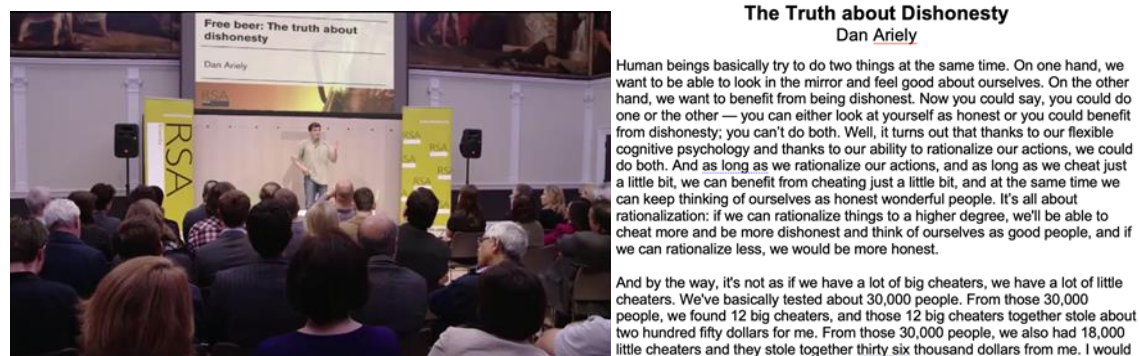


Figure 2. Screenshots from on-stage lecture (left) and the transcription of the audio as the representative of the narrative (right) of Lesson 1

### Procedure

Participants completed the study online via *Qualtrics* (Figure 3). After reading the information sheet about the study, they indicated their consent to participate by clicking on the “next” button on the interface. The first section of the survey asked about participants’ age, gender, and educational background. It also included six 5-point Likert scale questions on familiarity and interest in the lecture topics (e.g., “How familiar are you with the following topics?”, “How interested are you in learning about the following topics?”) with 1 being *not at all*, and 5 being *very much*. After the survey, participants proceeded to the main experiment (Figure 3). The lessons were system-paced (i.e., participants did not have a pause or a stop option).



Figure 3. Study procedure

After their lesson, participants rated their level of enjoyment, engagement, attention, and challenge using four items with a 5-point Likert scale (1 = *not at all*; 5 = *very much*). Previous studies which used these items, alongside interviews, found that they highly correlated with behavioural outcomes (Kinzer et al., 2012; Türkay, 2016). Other researchers also used single item questionnaires to test subjective experiences in learning contexts (e.g., Mayer & Estrella, 2014; Obergrösser & Stoeger, 2020; Thomas et al., 2017).

A distraction task was used to delay the retention test. Participants played a puzzle game, 2048, for about two and a half minutes, and reported their highest score. The retention test for each lesson had 10 multiple-choice questions (e.g., “If you wanted to change/improve your co-workers’ recycling behaviours, which of the following would Krznaric recommend?”). The questions were iteratively created by the research team and approved by experts in corresponding fields. Participants’ answers were coded as one or zero for correct or incorrect and averaged to create a single score. Participants were also asked to summarise the lesson in an open-response question. A coding scheme was prepared for two independent coders to code the main ideas. The final inter-rater reliability for the qualitative coding was 90%. Each main idea unit was given one point. These scores were standardised before averaging across the lessons.

## Results

The extracted data was tested to determine whether there were any differences in how participants experienced the two lessons. Two-way ANOVA found no significant main effect of the lessons on enjoyment ( $F[1,296] = .36, p = .551$ , attention,  $F[1,297] = .79, p = .375$ ), engagement ( $F[1, 296] = .35, p = .556$ ), and challenge, ( $F[1,296] = .81, p = .370$ ). Similarly, there was no significant interaction between the lessons and instructional formats on participants' enjoyment ( $F[3,290] = 2.01, p = .113$ ), attention ( $F[3,290] = .50, p = .68$ ), engagement ( $F[3,291] = .82, p = .48$ ), and challenge ( $F[3,290] = .62, p = .60$ ). This was also true for learning outcomes. It was concluded that overall, participants had similar affective experiences with the two lessons and learned similarly from each. Therefore, the rest of the statistical analysis compared the main effects of instructional formats on affective experiences and learning outcomes without differentiating two lessons.

### Equality of the groups

A series of one-way ANOVA and chi-square tests showed no statistically significant difference between the mean age of the groups ( $F[3, 294] = .56, p = .64$ ), weekly engagement with instructional videos ( $F[3, 295] = .70, p = .56$ ), instructional audio ( $F[3, 295] = 1.15, p = .33$ ), level of education ( $X^2 = 16.16, p = .76$ ), proportion of men and women ( $X^2 = 4.30, p = .23$ ), and reported interest in ( $F[3,295] = .40, p = .75$ ) and familiarity with ( $F[3,295] = 1.18, p = .32$ ) the lecture topics as measured prior to viewing the lessons. Therefore, it was concluded that prior to the experiments the groups were equal.

### Comprehension

To test hypothesis 1, a one-way ANOVA test was conducted. Results showed that the format of instructional material had a significant effect on participants' multiple choice test scores ( $F[3, 295] = 5.08, p = .002, \eta^2 = .22$ ) (Table 2), and on the number of main ideas reported in the open-response summary ( $F[3, 295] = 4.39, p = .005, \eta^2 = .21$ ) (Table 2 and Figure 4). A planned contrast test showed that compared to those in other groups, the whiteboard animation group performed better in multiple choice tests ( $t[295] = 25.10, p < .001$ ) and included more key points in their summaries ( $t[295] = 2.53, p = .012$ ).

Tukey HSD post hoc test showed the whiteboard animation group answered significantly more questions accurately compared to those who in the Slides ( $p = .005$ ) and Lecture ( $p = .006$ ) groups. For the number of main ideas, the whiteboard animation group listed significantly more ideas than the Lecture group ( $p = .003$ ). There were no significant differences between other groups for multiple choice questions and main ideas.

Table 2  
*Descriptive statistics on the comprehension scores per group*

	Whiteboard animation		Slides		Narration		Lecture	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Multiple-choice scores	6.41	2.13	5.2	2.2	5.8	2.2	5.2	2.4
Main ideas (normalised)	.27	1.09	-.06	.96	.08	.88	-.28	.84

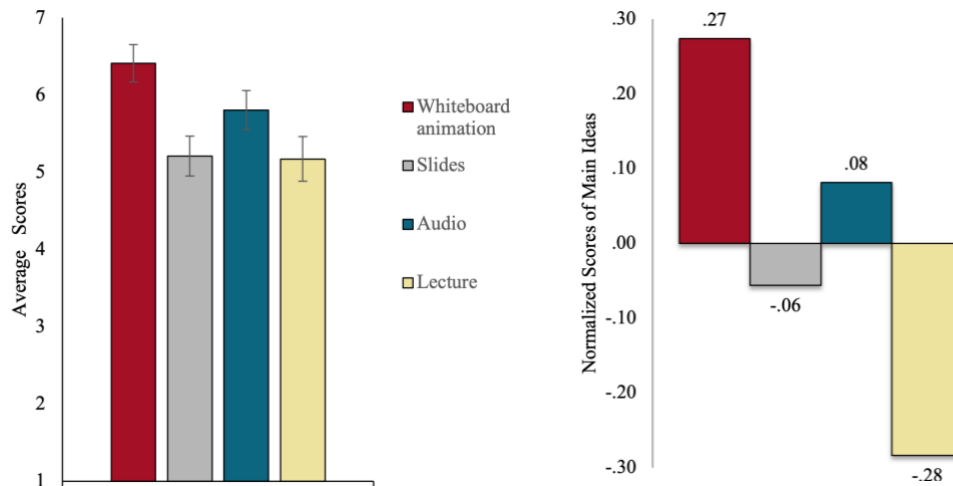


Figure 4. Average scores on multiple choice questions by group (left) and normalised scores of main ideas by group (right).

**Affective experiences**

To test hypothesis 2, a multivariate analysis of variance (MANOVA) was conducted to assess if there were differences between groups on a linear combination of enjoyment, engagement, attention, and difficulty. The assumptions of independence of observations and homogeneity of variance/covariance were checked and met (Table 3). A statistically significant difference was found (Wilks’ Lambda = .93,  $F[12, 770.205] = 1.89, p = .032, \eta = .16$ ). Examination of the coefficients for the linear combinations of different instructional formats indicated that all four subjective experience measures contributed significantly to distinguishing the groups. Follow-up univariate ANOVAs indicated that there was a significant effect of format of instructional material on enjoyment ( $F[3, 294] = 5.56, p = .001, \eta = .23$ ) and engagement, ( $F[3, 294] = 4.53, p = .004, \eta = .21$ ), but not on attention ( $F[3, 294] = 2.48, p = .061, \eta = .16$ ) or challenge ( $F[3, 294] = 2.27, p = .081, \eta = .15$ ) (Figure 5). A planned contrast test showed that compared to those in the other three groups, the whiteboard animation group reported higher levels of enjoyment ( $t[294] = 40.85, p < .001$ ), engagement ( $t[295] = 34.76, p < .001$ ), attention ( $t[294] = 55.08, p < .001$ ), and challenge ( $t[294] = 31.96, p < .001$ ).

Tukey HSD post-hoc analysis showed that participants in the whiteboard animation group reported higher levels of enjoyment ( $p = .001$ ) and engagement ( $p = .004$ ) than those in the Lecture group. Similarly, participants in the Narration group reported higher amounts of enjoyment ( $p = .026$ ) and engagement ( $p = .016$ ) than those in the Lecture group. Tukey HSD post-hoc analysis showed no other significant differences between instructional formats on participants’ affective experiences.

Table 3  
Average ratings and standard deviation of subjective experiences

	Enjoyment		Attention		Engagement		Challenge	
	M	SD	M	SD	M	SD	M	SD
Whiteboard animation	4.06	.91	4.38	.65	4.01	.99	3.68	1.02
Slides	3.77	.96	4.35	.64	3.79	1.04	3.48	.98
Narration	3.90	.75	4.23	.73	3.94	.99	3.63	1.02
Lecture	3.48	.86	4.09	.76	3.43	1.02	3.27	1.02



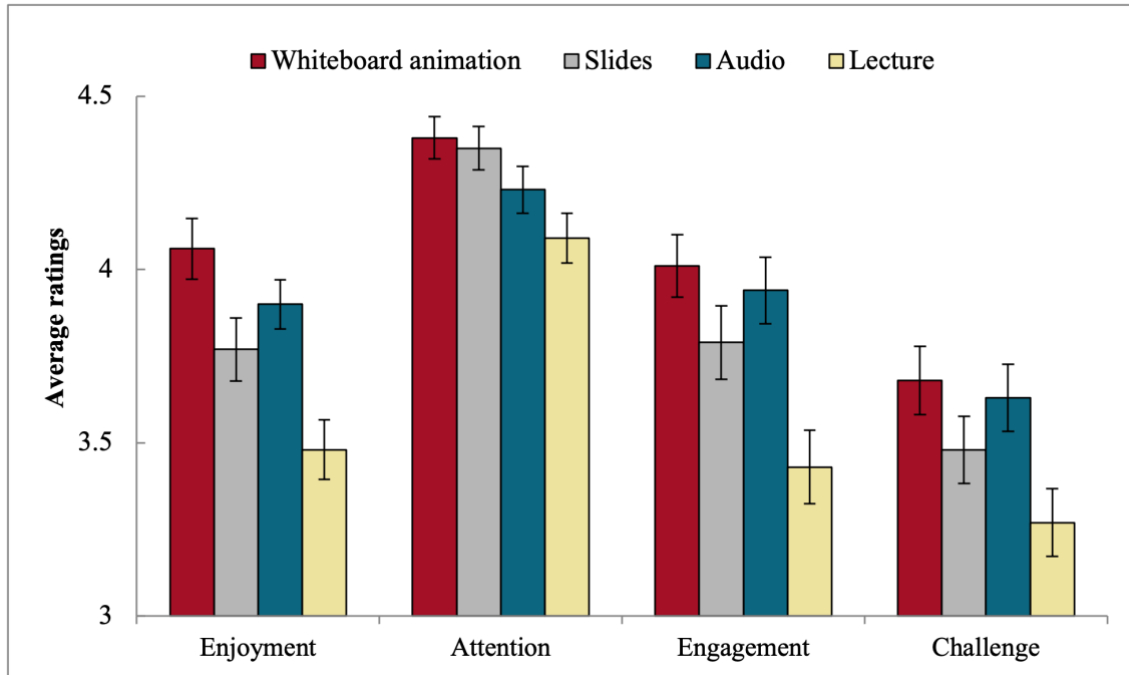


Figure 5. Average ratings of subjective experiences.

As a post-hoc analysis, a series of Pearson correlations tested the relationship between subjective experiences and learning outcomes. Significant positive correlations were found between both enjoyment ratings and scores in multiple choice questions as well as the recalled number of main ideas from the lecture. There were no significant correlations between post-test scores and engagement or challenge (Table 4).

Table 4  
Pearson correlation matrix for subjective experience measures and post-test scores

	Attention	Engagement	Challenge	MCQ	Main ideas
Enjoyment	.503**	.565**	.471**	.123*	.181*
Attention	1	.435**	.307**	.166**	.140*
Engagement		1	.445**	.019	.071
Challenge			1	-.042	-.023

Note. \*\* $p < .001$ , \* $p < .05$

## Discussion

Digital materials, especially videos, are commonly used in online and face-to-face classrooms and have become quite popular in recent years, especially during the COVID-19 pandemic (Fyfield et al., 2019; Muthuprasad et al., 2021). However, there is a substantial cost associated with designing and developing these digital materials (Hollands & Tirthali, 2014). This study investigated the impact of whiteboard animations compared to slides, audio narration, and on-stage lecture videos on participants' comprehension of, and subjective experiences with, materials when learning a social science topic. The instructional format was found to have a positive effect on participants' comprehension scores as measured by an immediate test that included an open-response and 10 multiple-choice questions after a distractor task. The whiteboard animation group did better on the multiple-choice questions and summarised significantly more main ideas from the lessons compared to the other groups. Therefore, Hypothesis 1: participants who receive whiteboard animations will perform better on a retention test than those who receive the same lesson in other formats, was accepted. This result was in line with affective theory of multimedia learning and emotional design (Mayer & Estrella, 2014; Plass et al., 2014; Um et al., 2012) where the particular aesthetics of cartoon-like graphics and animations of whiteboard animations have been found to induce positive emotions leading to increased learning outcomes, when compared to other conditions. The hand movement in the whiteboard animations may have helped participants shift their attention between text and image to promote their reflective thinking, in addition to the multimedia effect. The main mechanism put

forward in some studies is the signalling effect, which states that cues highlight the organisation of relevant information which can lead to improved learning (Schneider, Beege et al., 2018). In the case of the whiteboard animations, linear unfolding of the images and text may have acted as a signalling effect and helped regulate the information flow. These cues facilitated absorption of the content (Schneider, Beege et al., 2018) and reduced searching demands and unnecessary processing during learning from multimedia materials for the participants.

Despite being one of the common video formats (Chorianopoulos, 2018; Hansch et al., 2015), the on-stage lecture produced the lowest scores in learning outcomes in this study. This result supports and extends prior studies which showed that adding the image of the instructor on a presentation does not significantly improve learning outcomes (e.g., Guo et al., 2014; Kizilcec et al., 2014). The slides group also had one of the lowest comprehension scores. Considering that both the whiteboard animations and the slides group saw the same cartoon-like images, mechanisms other than multimedia principle must have created this effect. The embodiment effect, which is the effect of using gestures, eye gaze and body movements on learning outcomes (Mayer & DaPra, 2012), alone could not have been the main reason, as the on-stage lecture condition had the speakers shown as opposed to showing only a hand. It might be the case that emotional design has to be accompanied with interactive animations and narration to cue relevant information in order to make the most educational impact (Mayer, 2017).

Consistent with the Hypothesis 2: participants who receive whiteboard animations will report more positive subjective experiences of enjoyment, engagement, attention, and challenge compared to those who receive the same lesson in other formats, participants in the whiteboard animation group reported the highest ratings on all four subjective experience items. They enjoyed and engaged with the lessons significantly more than the on-stage lecture group did. Perhaps hand drawings provide the audience with a sense of first-person involvement that enhances illusion of interactivity resulting in increased engagement and curiosity (Pedra et al., 2015). In a similar vein, and in line with social agency theory (Mayer, 2014b), seeing the animator's hands might have signalled social cues, which in turn might have encouraged effortful learning and meaning making (Fiorella & Mayer, 2016). However, social cues cannot have been the only effect since the lecture format showed the instructor and did not result in high positive subjective experiences. Participants might have found the whiteboard animations more emotionally appealing due to their animation style, which in turn might have positively affected their subjective experiences (Mayer & Estrella, 2014; Plass et al., 2014).

In addition, while the whiteboard animation group was the most engaged group, the audio group enjoyed the lessons and engaged with them as much as the whiteboard animation group did. This is a novel finding as the prior studies in multimedia learning only compared images to images and narration in STEM learning omitting the audio only materials (Mayer, 2017). This supports the increasing popularity of educational podcasts (Casares, 2020) and implies that online courses developers might investigate short audio only instructional materials for topics like philosophy, which may not require learning spatial or procedural knowledge. This is a significant finding as audio lessons might be more easily developed and could be more accessible than videos for some student groups (Taylor & Clark, 2010). The slides group reported paying attention to the lessons as much as the whiteboard group did which may be explained by the multimedia effect (Mayer, 2017).

As a post-hoc analysis, Pearson correlations were run between the reported subjective experience items (i.e., enjoyment, engagement, attention, difficulty) and comprehension scores (i.e., multiple choice scores, open response scoring). Significant positive relationships were found between the comprehension scores and reported enjoyment and attention. This finding supports prior studies which found that enjoyment positively influences students' effective use of learning strategies (Obergruesser & Stoeger, 2020), and extends the results from studies where students learned STEM topics, to other learning contexts (Türkay, 2016).

Overall, the findings of this study show evidence that aesthetically pleasing static drawings (as shown to the slides group) are not sufficient to aid learning even when there is a strong connection between text and the images presented (e.g., Schneider, Dyrna et al., 2018). This study showed that whiteboard animations, presentations in the form of storytelling through dynamic representation of concepts through drawing and the visibility of hand, lead to more engagement and better learning outcomes. Second to whiteboard animations was the audio only materials.

## Limitations and future research directions

This study has some limitations. First, this study used only self-reports to measure enjoyment, attention, and challenge. Future studies would benefit from objective measures to investigate the cognitive mechanisms when learning with different types of instructional formats (e.g., Brünken et al., 2015; Lin & Li, 2018). For example, an eye-tracking study by Kizilcec et al. (2014) found that students prefer instruction with the instructor face in the video, even though it does not impact neither short nor long term retention. Future studies using eye tracking methods may investigate how learners visually follow instructors' hands in whiteboard animations, and whether their eye gaze patterns relate to learning gains.

In this study, comprehension and near-transfer, were measured, but not far-transfer. Plass et al. (2014) found cartoons affected both knowledge transfer by inducing different moods. Mayer and Estrella (2014), however, did not find a significant impact of emotional design on immediate transfer. Future studies might investigate the effectiveness of whiteboard animations for knowledge transfer and whether the benefits persist in delayed tests.

Prior knowledge was not objectively measured in this study. Meta-analysis by Schneider, Beege et al. (2018) did not find prior knowledge as an important moderator for the effect of signalling. On the other hand, Fiorella and Mayer (2016) found prior knowledge as an important factor determining the impact of seeing instructors' hand draw. Therefore, future studies may consider measuring participants' prior knowledge and familiarity with the topic objectively, beyond using subjective Likert scale items.

A common weakness of true experiments is that they are low in ecological validity. In a traditional learning situation, instructional videos would be supported by further study materials, such as complementary readings and peer learning opportunities in discussion forums. Future studies may extend this line of research and replicate the experiment in a more authentic learning environment to investigate whether the findings from the current study generalise to those settings. In a MOOC setting, for instance, learners would have a choice to study a topic. Therefore, future studies may consider providing different choices of topics to participants for study. Relatedly, the participant population and their motivations to participate in this study may differ from those we may find in online classrooms. Hence, future studies are needed to ameliorate this limitation. In addition, this study used two social science lessons as example; non-STEM topics from philosophy and psychology. Future studies are needed to provide further evidence on the effectiveness of instructional materials in other non-STEM fields (e.g., history) in order to be able to generalise the findings.

## Conclusion

Advancements in digital media and widespread access to these materials require multimedia learning principles to be improved and extended to apply to different disciplines, novel instructional methods and materials, and different learner populations (Schweppe et al., 2015). Online and blended learning are part of educational reality, and in order to provide the best learning materials to students, recent innovative technologies and instructional formats need to be tested for their effectiveness on instructional goals. This study contributes to the body of knowledge regarding effective instructional materials when teaching social science topics. In addition, this study used relatively longer instructional materials (~10 minutes) compared to short materials in prior studies (~1 to 3 minutes) (Fiorella & Mayer, 2016; Fiorella et al., 2018; Türkay, 2016). The results indicated that the whiteboard animation mode in this study outperformed other formats in promoting learning, enjoyment, and engagement, extending the prior work on STEM topics with short videos (Fiorella & Mayer, 2016; Mayer et al, 2020; Türkay, 2016). Evidence was also shown that whiteboard animations and audio alone can be effective in teaching lessons in social science disciplines, which may help improve learners' interest in the topics studied. Another novel finding was that compared to other instructional formats, on-stage lecture videos and narrated slides led to the lowest comprehension scores and relatively low ratings on affective experiences. Considering these are some of the most used video formats in online education, practitioners may consider providing optional materials in different instructional formats (e.g., audio only) when teaching social science subjects. In addition, educators are encouraged to evaluate students' subjective experiences of enjoyment and attention in online classes, as there is evidence that these predict learning outcomes.

Given the substantial investments necessary to create and produce online multimedia learning materials, it is surprising that very few recent innovations have been tested for efficacy and impact on learning outcomes. Overall, this study provides initial evidence that whiteboard animations can be effective in teaching non-STEM topics and therefore may justify the cost. It also draws attention to the potential efficacy of more cost-effective materials such as audio recordings in comparison to traditionally used narrated slides and on-stage lectures in these learning contexts.

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