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RESEARCH ARTICLE

Static, dynamic, or human? The role of slide dynamics and instructor cues in video lectures

Timo Reuter[1] · **Lukas Lazzara**[1] · **Miriam Leuchter**[1]

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Abstract
The present study investigated the interplay of cognitive cues and social cues in instructional videos on students' knowledge acquisition and sense of social presence. 312 preservice teachers took part in the study. Out of these, 238 participants were randomly assigned to one of three experimental groups receiving an asynchronous online video lecture on three research methods topics, featuring either static slides with voiceover (minimal signaling), dynamic slides with voiceover (moderate signaling), or dynamic slides with additional instructor signaling (maximum signaling). 74 participants served as a control group and completed pre- and posttests without attending the course. Perceived difficulty, invested effort, motivation, and notetaking were included as covariates. Dynamic slides did not improve knowledge acquisition compared to static slides. However, instructor signaling enhanced knowledge acquisition when perceived difficulty was high. Furthermore, instructor signaling significantly increased perceptions of social presence for two of the three investigated topics, highlighting the importance of social cues.

Keywords Instructional video · Signaling · Instructor presence · Knowledge acquisition · Social presence · Teacher education

Introduction

Asynchronous online video lectures have become a cornerstone of higher education, offering flexibility for learners to control their pace of study by pausing, rewinding, or revisiting content (Fiorella, 2022; Marinoni et al., 2020). Despite extensive research, there is no clear consensus on how to design video lectures to maximize learning outcomes (for systematic reviews and meta-analyses, Alemdag, 2022; Beege et al., 2023; Henderson & Schroeder, 2021; Polat, 2022; Polat et al., 2025; Wang et al., 2024). However, capturing and sustaining

✉ Timo Reuter
timo.reuter@rptu.de

Lukas Lazzara
lukas.lazzara@rptu.de

Miriam Leuchter
miriam.leuchter@rptu.de

[1] Department of Education, RPTU University Kaiserslautern-Landau, 76829 Landau, Germany

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learners' attention has been shown to be a key aspect of effective design for supporting meaningful learning (Fiorella & Mayer, 2022c). The signaling principle, grounded in the cognitive theory of multimedia learning (CTML, Mayer, 2022), emphasizes the use of cues to guide learners' attention, reduce cognitive load, and enhance the coherence of verbal and visual information (van Gog, 2022).

Recorded slide presentations, a widely used format for online lectures (Chorianopoulos, 2018), allow for varied implementations of signaling. For example, dynamic slides that gradually reveal content synchronized with narration serve as cognitive cues and might help learners to focus on relevant elements and organize information effectively (Fiorella & Mayer, 2022c; van Gog, 2022). Visible instructors can also employ signaling through gestures and gaze shifts, thereby directing learners' attention to relevant content while fostering a sense of interpersonal connection (Fiorella & Mayer, 2022b). From a social agency perspective, such behaviors may increase learners' perception of the instructor as a socially present partner, which in turn can enhance engagement and motivation to process the material actively (Gu et al., 2024; Mayer & DaPra, 2012). Carefully designing and combining such cues is especially important in asynchronous video-based learning, where learners navigate content independently. Although prior studies have explored various implementations of cognitive and social cues in video lectures (for meta-analysis, Alemdag, 2022; Beege et al., 2023), research on the combined effects of dynamic slide signaling and instructor signaling is relatively scarce. Yet, it is still uncertain whether the inclusion of signaling from a visible instructor enhances learning outcomes beyond possible benefits already offered by dynamic slides.

So far, most studies on video lectures have been conducted with psychology or STEM students (Beege et al., 2023). Comparatively little is known about how preservice teachers learn from video lectures that vary in design features such as signaling or instructor visibility. Although research on video-based learning is well-established in teacher education, these studies typically focus on video-based reflection, professional vision, or diagnostic judgment using classroom vignettes (e.g., Farrell et al., 2024; Ko, 2024; Nickl et al., 2024; Sommerhoff et al., 2023). Investigating how signaling and instructor visibility affect preservice teachers' learning from video lectures is particularly relevant, given their strong acceptance of video-based learning—especially when such tools foster authentic, reflective, and skill-building experiences (e.g., Stürmer et al., 2024). Additionally, they may perceive and interpret social cues such as instructor visibility differently than other learners, given their professional orientation and pedagogical perspective (Chew, 2022).

Meta-analyses (Alemdag, 2022; Beege et al., 2023) indicate that while instructor visibility has a stronger positive effect in controlled laboratory settings, its influence is less pronounced in field studies where generative activities like notetaking are allowed. Since generative activities are considered crucial for meaningful learning in online video lectures (Fiorella & Mayer, 2022a), further research is needed to explore how these activities interact with varying levels of signaling in an authentic learning setting. The present study therefore examines the effects of signaling through dynamic slides and instructor behaviors such as gestures and gaze shifts in an experimental design conducted in an authentic learning environment with preservice teachers.

Theoretical background

Designing effective video lectures: the role of signaling

Online video lectures can be realized in various formats, including recorded slide presentations with narration (Chorianopoulos, 2018). While more complex formats exist (e.g., live-composite formats, Chorianopoulos, 2018; Rosenthal & Walker, 2020), slide-based narration represents a practical and commonly used approach, particularly due to its relatively low production effort and feasibility for instructors without extensive media support. According to the cognitive theory of multimedia learning (Mayer, 2022), recorded slide presentations should maximize the coherence between verbal explanations and accompanying visuals (Fiorella, 2022). One way to achieve this is through signaling, which uses cognitive cues to guide learners' attention and facilitate the organization of information (Alpizar et al., 2020; van Gog, 2022). Signaling in recorded slide presentations can be achieved through dynamic slides, and the presence of a visible instructor using gestures and gaze shifts to emphasize key content (Fiorella, 2022; Fiorella & Mayer, 2022c).

Dynamic slides as a means of signaling

Dynamic slides provide cognitive cues by building content step-by-step synchronized with the instructor's explanations (Fiorella & Mayer, 2022c). This feature directs learners' attention to the most relevant parts of the slide, reducing the need for unnecessary searching (Fiorella & Mayer, 2022c; van Gog, 2022). Fiorella and Mayer (2016), Fiorella et al. (2019), and Zhang et al., (2024a, 2024b) have shown that students understood complex concepts such as the Doppler effect, functioning of the human kidney, or probability distributions better when diagrams were dynamically created during the explanation compared to static drawings. Similarly, Rodemer et al. (2022) found that dynamic, temporally synchronized signals in instructional videos guided students' attention more effectively, reduced extraneous cognitive load, and improved retention compared to static or absent cues. Sondermann and Merkt (2023a) found that dynamic slides had a positive effect, but only when they depicted graphics rather than text. Moon and Ryu (2021) found no significant advantage of dynamic slides for learning about climate change compared to static slides. Similarly, Sondermann and Merkt (2023b) reported no consistent benefits of dynamic slides compared to static slides in improving learning outcomes across domains like geography, biology, and physics.

Pointing gestures and gaze shifts as means of signaling

In lecture-capture formats where the instructor stands beside a smartboard, instructors can use gaze shifts and pointing gestures to direct learners' attention to relevant slide content (Rosenthal & Walker, 2020). These behaviors provide both cognitive cues, by directing learners' attention to key content, and social cues, by mimicking social interactions that might enhance learners' sense of social presence—that is, the feeling of being connected to real people during learning (Biocca et al., 2003; Fiorella & Mayer, 2022b; Mayer & DaPra, 2012). According to social agency theory, such social cues increase learners' sense of social presence, which can, in turn, boost engagement (Fiorella & Mayer, 2022a, 2022b; Gu et al., 2024; Schneider et al., 2022). Thus, including social presence as a dependent variable, alongside knowledge acquisition, enables a more comprehensive assessment of video lecture design by capturing not only cognitive outcomes but also learners' perceived interpersonal connection with the instructor.

Research comparing instructors using gaze shifts and pointing gestures to interact with slides to instructors not using such cognitive cues mostly showed that instructor signaling was effective for learning (for systematic reviews and meta-analyses, Alemdag, 2023; Kuang et al., 2023; Li et al., 2024). For example, Rueckert et al. (2017) showed that combining gaze shifts with pointing gestures enhanced understanding of statistical analyses, while Pi et al. (2019) and Pi et al. (2020) demonstrated that pointing gestures and gaze shifts improved attention and comprehension of complex biological concepts. Similarly, Schneider and Sung (2024) showed that when instructors used gaze shifts to highlight key relations in mechanical-system diagrams, learners achieved higher comprehension. However, combining gestures, guided gaze, and expressive facial cues can impose extraneous cognitive load learners and reduce performance (Pi et al., 2023, 2024). Findings on the effects of visible instructors on social presence are mixed, with some studies reporting increased social presence (e.g., Sondermann et al., 2024), while others found no significant effects (e.g., Ng & Przybylek, 2021).

The interplay of dynamic slides and instructor signaling

In lecture-capture formats, signaling from dynamic slides can be combined with signaling provided by a visible instructor (Rosenthal & Walker, 2020). Social agency theory would predict that additional cues from a visible instructor—such as gestures and gaze shifts—enhance social presence and may thereby increase engagement and learning (Fiorella & Mayer, 2022b; Mayer & DaPra, 2012). In contrast, cognitive load theory suggests that these cues could be redundant when dynamic slides are already guiding attention or even impose extraneous cognitive load by splitting attention between the instructor and the slide content (Ayres & Sweller, 2022; Paas & Sweller, 2022), potentially impairing learning.

Few studies have specifically examined the interplay between signaling from dynamic slides and instructor signaling. The results from these studies have been mixed. Pi et al. (2017) found that pointing gestures from a visible instructor were more effective than visual cues, such as colored arrows on slides, when teaching software editing. Similarly, Schmidt-Borcherding and Drendel (2021) demonstrated that dynamic slides improved understanding of statistical concepts like covariance and correlation, but only when accompanied by a visible instructor. However, the instructor in their study did not employ additional signaling alongside the slides. Studies investigating the additive effect of dynamic slides and instructor signaling remain rare and inconclusive. For instance, Fiorella et al. (2019) reported no differences in learning outcomes between visible and invisible instructors using dynamic drawings to teach about the human kidney. In contrast, Schroeder and Traxler (2017) observed that a visible instructor's hand drawing graphics hindered learning about the inclined plane compared to drawings without the instructor's hand. More recently, Zhang et al., (2024a, 2024b) examined how instructors' emotional expressions (e.g., tone of voice, facial expression) interact with visual cues on the slides to guide learners' attention. They found that learning improved when both cues emphasized the same information, whereas incongruent or irrelevant visual cues weakened the effect of emotional signaling. These findings highlight the importance of aligning visual and social signals to maintain attentional coherence in multimodal instruction.

Motivation and learner engagement in online settings

Motivation is another critical, yet underexplored factor in the study of video lectures. In the context of online learning, motivation can be conceptualized as learners' beliefs about their ability to succeed (expectancy), the perceived relevance and importance of the content (value), and the perceived costs of engaging with the lecture (e.g., effort or opportunity costs, Eccles & Wigfield, 2020; Fiorella & Mayer, 2022a). Motivated learners are more likely to engage in active, generative processing, which might enhance learning (Fiorella & Mayer, 2022a). However, few studies have examined how motivational factors interact with varying levels of signaling in authentic video lecture settings. Motivation is likely even more important in real-world settings than in laboratory environments.

Research gaps, study objectives, and hypotheses

Despite extensive research on signaling, several gaps remain. First, only few studies have examined the combined effects of signaling from dynamic slides and a visible instructor, leaving it unclear whether instructor signaling adds an incremental value beyond dynamic slide signaling. Second, little is known about how such effects interact with content complexity and learner characteristics such as prior knowledge, notetaking, or motivation. Third, most studies were conducted in controlled settings, raising questions about their external validity. Finally, research on instructor visibility and signaling has predominantly involved psychology or STEM students, with very limited evidence from preservice teachers (Schmidt-Borcherding & Drendel, 2021).

To address these gaps, the present study examined how varying levels of signaling in video lectures impact knowledge acquisition (RQ 1) and perceived social presence (RQ 2) in a mandatory university course with preservice teachers. Signaling refers to the use of cues to guide learners' attention and help them organize information effectively. Three lecture formats were compared: (1) static slides with narration (minimal signaling), lacking dynamic elements or instructor cues; (2) dynamic slides with narration (moderate signaling), using animations to highlight key content; and (3) dynamic slides with instructor signaling (maximum signaling), incorporating gestures and gaze to enhance signaling and personalization.

The lectures addressed three research methods topics (samples, research designs, measurement). Following a between-subjects design, each participant experienced only one lecture format across all topics. Knowledge acquisition and subjective ratings of perceived social presence were the dependent variables. Participants' prior knowledge, perceived difficulty, notetaking (as a generative activity), invested effort, and motivation (expectancy, value, cost) were measured and statistically controlled.

Hypotheses—RQ 1: knowledge acquisition

With respect to knowledge acquisition, as measured by performance on a test assessing retention and conceptual understanding, the following hypotheses were formulated:

H1a *Dynamic slides with voiceover narration* (*moderate signaling*) *result in greater knowledge acquisition than static slides with voiceover narration* (*minimal signaling*).

H2a *Dynamic slides with additional instructor signaling* (*maximum signaling*) *result in greater knowledge acquisition than dynamic slides with voiceover narration* (*moderate signaling*).

We had no specific hypotheses with respect to possible interactions between the cognitive and motivational covariates and the varying levels of signaling.

Hypotheses—RQ2: social presence

With respect to social presence, the following hypotheses were formulated:

H1b *Social presence is comparable between static slides with voiceover narration* (*minimal signaling*) *and dynamic slides with voiceover narration* (*moderate signaling*).

H2b *Dynamic slides with additional instructor signaling* (*maximum signaling*) *lead to higher social presence than dynamic slides with voiceover narration* (*moderate signaling*).

No specific hypotheses were formulated regarding the possible interactions between the cognitive and motivational covariates and the varying levels of signaling.

In summary, it was hypothesized that dynamic slides and instructor signaling (gestures and gaze shifts) function as cognitive cues that promote knowledge acquisition (H1a, H2a), and that instructor gestures and gaze shifts also serve as social cues that enhance students' perceived social presence (H2b).

Methods

Design

A between-subjects experimental pre-posttest design involving three experimental groups (EGs) and one control group (CG) was conducted. Participants in the EGs were randomly assigned to one of three lecture formats. The formats differed in the degree of signaling: EG 1 = static slides with voiceover narration, EG 2 = dynamic slides with voiceover narration, and EG 3 = dynamic slides with additional instructor signaling. To control for test effects (i.e., performance improvements due to repeated testing), the CG completed the pre- and posttests without participating in the course.

Sample

The EGs comprised 238 preservice elementary teachers (86% female; $M = 22.86$ years, $SD = 3.16$; $M = 5.68$ semesters, $SD = 1.43$) enrolled in a mandatory asynchronous online video lecture on "Research Perspectives in Elementary Education" at a public university in Germany. The CG comprised 74 preservice special education teachers (81% female; $M = 24.73$ years, $SD = 2.65$; $M = 7.34$ semesters, $SD = 3.95$) from the same university. These participants were recruited via convenience sampling and voluntarily participated in the study in exchange for course credit points. Using students from a different major as the control group was a necessary decision, as participation in the online video lecture was a mandatory component of the elementary education curriculum. Thus, it was neither ethically, nor practically feasible to withhold access to the lecture from any subset of these students to create a control group. Special education was chosen as a closely related teacher education program. Both groups had not yet received formal instruction in research methods at the time of the study. All participants were informed about the study's objectives and provided written consent. The study was approved by the faculty's ethics committee (application no. 2021-004).

All participants were enrolled in a teacher education program that includes both in-person and online course formats. While some courses are conducted face-to-face, others incorporate asynchronous online components. Across all formats, the university's learning platform is used to distribute course content and learning materials. Given this, students were familiar with video-based instruction.

Lecture formats

In the static slides with voiceover narration format (EG 1), PowerPoint slides were displayed on full screen, with all content (diagrams, text) appearing at once and accompanied by the instructor's voiceover narration. In the dynamic slides with voiceover narration format (EG 2), slide content was built up gradually using PowerPoint animations, synchronized with the instructor's voiceover narration. In the dynamic slides with additional instructor signaling format (EG 3), the instructor was shown standing next to a smartboard displaying the slides, narrating the content as it built up gradually through animations. The instructor shifted gaze between the camera and the slides, using pointing gestures to emphasize key content. Figure 1 provides visual examples of the three lecture formats, illustrating the differences in slide design and instructor presence across conditions.

The dynamic slides with additional instructor signaling format were recorded first. For the dynamic slides with voiceover narration format, the same slide animations with only the voiceover narration were used. The static slides with voiceover narration format was recorded separately, using full-content slides and a new voiceover narration. In all formats, the first author served as the instructor.

Measurements

Knowledge tests and social presence

The knowledge tests on the topics of samples, research designs, and measurement were developed by the authors and reviewed by two educational psychologists for content validity. The knowledge tests assessed student's retention and conceptual understanding of the video content. Each test comprised 10 k-prim choice items. For each item, a question or incomplete statement was followed by four answers or additions (e.g., for the knowledge test on samples: *"In addition to the random sample, what other sample types exist? (1) Individual sample, (2) Design sample, (3) Convenience sample, (4) Effect sample"*). For each answer, a decision had to be made as to whether it is correct or incorrect. Participants received 1 point if all four answers were correct. If one answer was incorrect, they were given 0.5 points as partial credit. No points were given for two or more incorrect answers. This partial scoring resulted in a Likert-like three-level scale for each item. Although the reliability of the pretests was rather low with α=.49 for samples, α=.40 for research designs, and α=.39 for measurement, posttest reliability was acceptable to good with α=.78 for samples, α=.73 for research designs, and α=.65 for measurement. Sum

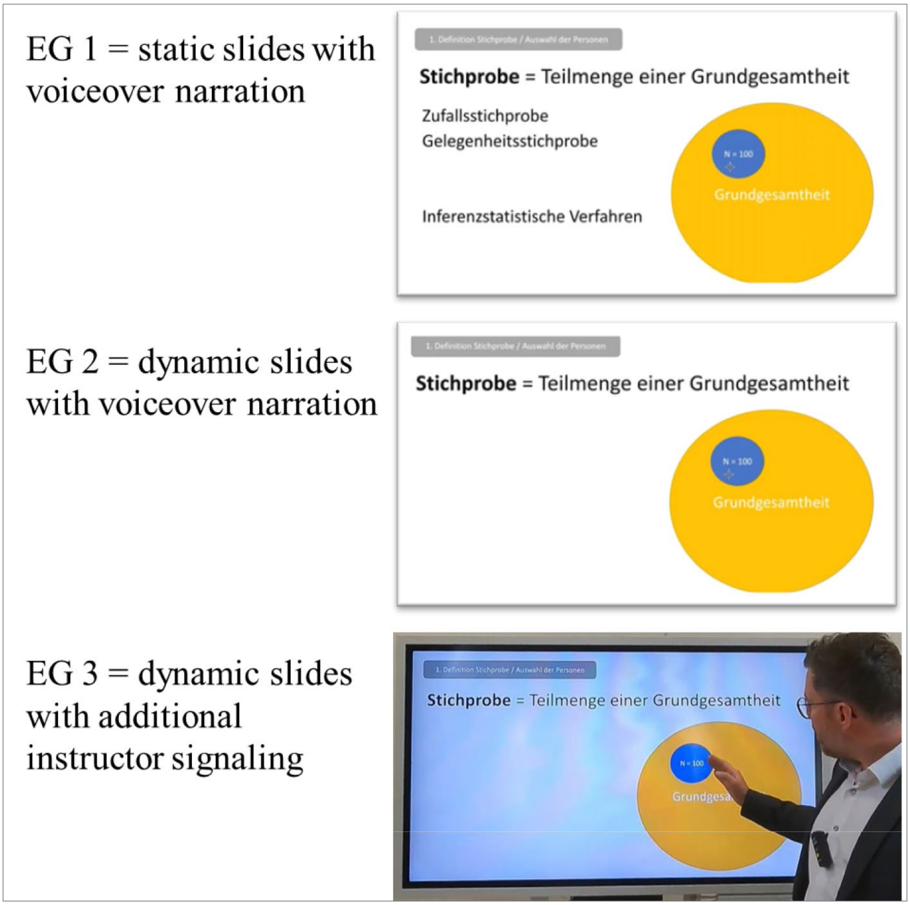

Fig. 1 Examples of the Three Lecture Formats Used in the Study. Note. Dynamic slides included animated elements that built information step by step, whereas static slides presented all information at once. Original slides in German. Englisch translations: Stichprobe = Teilmenge einer, Grundgesamtheit = Sample = subset of a population, Zufallsstichprobe = random sample, Gelegenheitsstichprobe = convenience sample, inferenzstatistische Verfahren = inferential statistical methods

scores (0 to 10 points) were computed for samples (pretest and posttest), research designs (pretest and posttest), and measurement (pretest and posttest). To measure social presence, a sub-scale of the lecture experience questionnaire was used (Pilegard & Fiorella, 2021; Stull et al., 2018) with three items (e.g., "I felt like the instructor was working with me to help me understand the material", α = .87) on a 7-point Likert scale from 1 = "I do not agree at all" to 7 = "I completely agree". Mean scores for social presence with each topic (samples, research designs, and measurement) were computed.

Covariates

Perceived difficulty (*"I felt that the subject matter was difficult"*) and invested effort (*"Please rate the amount of effort you put into understanding the material"*) were assessed with single item measures also taken from the lecture experience questionnaire (Pilegard

& Fiorella, 2021; Stull et al., 2018) after each topic with a 7-point Likert scale from 1 = "I do not agree at all" to 7 = "I completely agree". To measure motivation, participants completed a 10-item expectancy-value-cost questionnaire adapted from Kosovich et al. (2015). On a 6-point Likert scale, three items measured participants' expectancy (e.g., *"I know I can learn the material in my online lecture"*, α = .77), three items measured perceived value of the lecture (e.g., *"I think the online lecture on research perspectives in elementary education is important"*, α = .88), and four items measured participant's perceived costs (e.g., *"I have to give up too much to do well in the online lecture on research perspectives in elementary education"*, α = .72). Mean scores for expectancy, value, and costs were computed. To measure notetaking, participants were asked after each topic whether they took notes or not (dichotomous item).

Topics of the videos and procedure

The study was conducted within an ecologically valid a-synchronous online video lecture on research methods. The course followed a given curriculum and was made available on the university's online learning platform. Participants watched three videos on the topics of (1) samples, (2) research designs, and (3) measurement. The video on samples introduced concepts such as random and convenience sampling, representativity, and the distinction between dependent and independent samples. The video on research designs explained the difference between experimental and non-experimental designs, the role of random assignment, and criteria for internal and external validity. The video on measurement instruments was concerned with the distinction between observable and latent constructs, different methods of assessment (e.g., self-report vs. external evaluation), and psychometric criteria including reliability, validity, and objectivity. A summary of the key features and instructional content of the video lectures is provided in Table 1.

Participants' motivation (expectancy, value, cost) to learn research methods was assessed at the beginning of the video lecture (Fig. 2). For each topic, the participants first completed a knowledge test as a pretest. After having completed the pretest, the video started. Each video was divided into individual chapters and participants could jump to the chapters, fast forward, rewind, pause, and stop the video whenever they wanted. Moreover, they were allowed to watch the video multiple times. After the video was started, the knowledge test (as a posttest) on the respective topic, and the questionnaire on social presence, perceived difficulty, invested effort and notetaking were unlocked. Once participants started taking the posttest and questionnaire, they had to complete it and were not allowed to go back to the video. All tests were conducted via online questionnaires. Participants of the CG were invited via e-mail to answer the knowledge tests (pretest and posttest) at similar time points as the participants of the research methods course did.

Data analysis

All analyses were conducted using R (version 4.4.2; R Core Team, 2024). Parametric and non-parametric tests were selected based on the scale level and distribution of the data. For continuous, approximately normally distributed variables, we used hierarchical regression models and ANOVAs. For non-parametric variables (e.g., notetaking), Cochran's Q and Kruskal–Wallis H tests were applied.

To analyze the effects on knowledge acquisition based on pre-post measurements nested within individuals, hierarchical multilevel regression models were estimated using

Table 1 Overview of video lecture features and procedure

Aspect	Samples	Research designs	Measurement instruments
Duration	14 min	23 min	14 min
Slides	8 slides (7 figures, 224 words)	12 slides (10 figures, 489 words)	4 slides (2 figures, 227 words)
Instructor signaling	63 gaze shifts & pointing gestures (EG3 only)	116 gaze shifts & pointing gestures (EG3 only)	51 gaze shifts & pointing gestures (EG3 only)
Key content	Definition of sample; random vs. convenience sampling; representativity; sample size; dependent vs. independent samples	Quantitative designs; experimental vs. non-experimental; random assignment; internal/external validity; pre-post-test logic	Measurement constructs; observable vs. non-observable variables; self-report vs. external assessment; reliability, validity, objectivity
Lecture formats	EG1: Static slides with voiceover; EG2: Dynamic slides with voiceover; EG3: Dynamic slides + instructor signaling		
Video designer	First author		
Video editor	Trained student assistant		
Platform features	Pause, rewind, fast forward, chapter navigation		
Other learning activities	None		
Viewing guidelines	No specific instructions were provided		

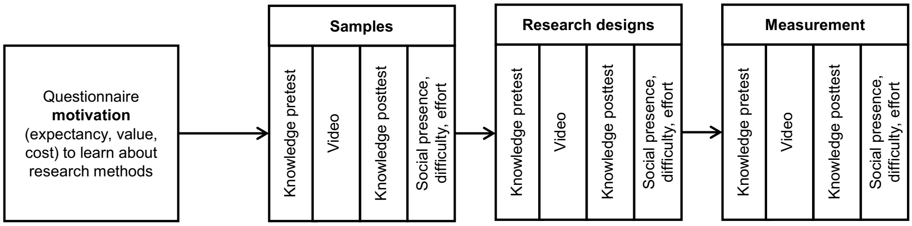

Fig. 2 Procedure of the study

the *nlme* package (Lischetzke et al., 2015; Pinheiro et al., 2024). To analyze the effects on perceived social presence, hierarchical regression models were conducted as well. All models were run separately for each of the three topics (samples, research designs, measurement). Predictors were entered in pre-defined blocks: Model 1 included cognitive covariates (prior knowledge, perceived difficulty, invested effort), Model 2 additionally included motivational covariates (expectancy, value, cost), and Model 3 included planned contrasts comparing levels of signaling: static slides with voiceover narration (minimal signaling) vs. dynamic slides with voiceover narration (moderate signaling; contrast 1), and dynamic slides with voiceover narration vs. dynamic slides with additional instructor signaling (maximum signaling; contrast 2). Interaction terms involving covariates and signaling contrasts are reported in the text but omitted from the tables due to space constraints. Where appropriate, effect sizes (Cohen's *d*) are reported to support the interpretation of the findings. Prior to the analysis, all predictors were grand-mean centered. The unstandardized regression coefficients represent the expected change in the dependent variable associated with a one-unit increase in the predictor, holding other variables constant.

Results

Preliminary analyses

Before addressing the primary research questions, several preliminary analyses were conducted. These analyses aimed to validate the experimental manipulation, evaluate the overall effectiveness of the video lectures, and assess participants' perceptions of topic difficulty, invested effort, and notetaking behaviors. Additionally, differences in perceived difficulty, invested effort, and notetaking across lecture formats were examined.

Manipulation check

The video lecture was hosted on the universities' online learning platform. Via this platform, we were able to retrieve information on the streaming of the videos. Due to the system, this data was only available in anonymized form and could therefore not be linked to participants' questionnaire data. The mean number of streamed minutes per user was 12.30 min for samples ($SD = 4.76$), 17.21 min for research designs ($SD = 8.46$), and 13.48 min for measurement ($SD = 4.89$).[1] The means did not significantly differ between the lecture formats for samples, $F(2, 241) = 1.53$, $p = .219$, research designs, $F(2, 230) = 0.73$, $p = .485$, and measurement, $F(2, 214) = 0.18$, $p = 835$.

Overall effectiveness of the video lecture

Prior to analyzing participants' knowledge acquisition, group comparability in terms of prior knowledge was assessed with an ANOVA. Participants in the CG and the EGs did not differ significantly in pretest scores for any of the three topics (samples: $F(3, 308) = 0.83$, $p = .969$; research designs: $F(3, 304) = 1.92$, $p = .126$; and measurement: $F(3, 307) = 0.86$, $p = .464$). These results justify comparing knowledge acquisition between groups, despite variations in participants' academic backgrounds.

To investigate the overall effectiveness of the video lectures, the three EGs were combined into one group and compared with the CG. Significant interactions between change over time (pre-posttest) and group in participants' knowledge of samples, $B = 3.03$, $SE = 0.25$, $t(312) = 11.90$, $p < .001$, research designs, $B = 2.84$, $SE = 0.27$, $t(312) = 10.44$, $p < .001$, and measurement, $B = 4.50$, $SE = 0.23$, $t(312) = 19.44$, $p < .001$, were found, indicating an overall effectiveness of the video lectures.

Comparison of perceived difficulty, effort, and notetaking across topics

Perceived difficulty differed significantly between the topics, $F(2, 466) = 77.42$, $p < .001$. Post-hoc tests with a Bonferroni-corrected significance level of.016 revealed that participants rated research designs ($M = 4.37$, $SD = 1.51$) more difficult than samples ($M = 2.97$, $SD = 1.41$, $t(235) = 12.68$, $p < .001$, $d = 0.96$), and more difficult than measurement ($M = 3.60$, $SD = 1.51$, $t(236) = 6.26$, $p < .001$, $d = 0.50$). Moreover, measurement was rated significantly more difficult than samples, $t(235) = 5.79$, $p < .001$, $d = 0.43$. Invested effort differed significantly across the topics, $F(2, 622) = 4.779$, $p = .009$. Post-hoc tests with a Bonferroni-corrected significance level of.016 revealed that participants reported more invested effort for samples, $M = 5.23$, $SD = 0.98$, than for measurement, $M = 5.06$, $SD = 1.15$, $t(235) = 3.206$, $p = .001$, $d = 0.19$ Invested effort for research designs, $M = 5.15$, $SD = 1.13$, did not differ from the other topics. Notetaking did not significantly differ between the topics (77% samples, 81% research designs, 78% measurement), as indicated by a Cochran's Q Test, $Q(2) = 2.86$, $p = .239$.

Comparison of perceived difficulty, effort, notetaking, and motivation across lecture formats

Perceived difficulty did not differ significantly between lecture formats for any of the three topics: samples, $F(2, 232) = 1{,}77$, $p = .173$; research designs, $F(2, 234) = 0.85$, $p = .429$; measurement, $F(2, 232) = 1.33$, $p = .267$. Similarly, invested effort did not differ significantly between lecture formats for the topics: samples, $F(2, 232) = 2.18$, $p = .116$; research designs, $F(2, 234) = 1.44$, $p = .239$; measurement, $F(2, 233) = 2.70$, $p = .069$. Also, Notetaking did not differ between lecture formats, as indicated by Kruskal–Wallis H tests: samples,

[1] Mean values were calculated for cases with a transmission time of 1 min or more.

$H(2) = 0.06$, $p = .973$; research designs, $H(2) = 1.40$, $p = .497$; measurement, $H(2) = 3.26$, $p = .196$).

In addition, participants' motivation was examined across the lecture formats. One-way ANOVAs revealed no significant differences between the EGs in expectancy, $F(2, 235) = 1.29$, $p = .277$, value, $F(2, 237) = 0.02$, $p = .981$, or cost, $F(2, 235) = 0.59$, $p = .555$. These results, along with the non-significant differences in other learner characteristics, support the comparability of the experimental conditions prior to the intervention.

Main analysis

Effects of signaling on knowledge acquisition

For knowledge of samples (Table 2), significant main effects were observed for post-test scores ($B = 3.50$, $SE = 0.27$, $p < .001$) and the interaction between post-test and difficulty ($B = -0.27$, $SE = 0.09$, $p < .01$), indicating a substantial increase in knowledge at post-test and a moderating effect of difficulty on this improvement. The higher the perceived

Table 2 Hierarchical multilevel model with knowledge score on samples as dependent variable

	Step 1			Step 2			Step 3		
Fixed	coef		(SE)	coef		(SE)	coef		(SE)
Intercept	3.80 ***		(0.22)	3.79 ***		(0.22)	3.80 ***		(0.22)
Difficulty	– 0.14	*	(0.07)	– 0.14		(0.07)	– 0.14		(0.07)
Effort	0.18		(0.11)	0.18		(0.12)	0.18		(0.12)
Notetaking	0.15		(0.25)	0.16		(0.25)	0.15		(0.26)
Post	3.50	***	(0.27)	3.51	***	(0.22)	3.50	***	(0.27)
Post*Difficulty	– 0.28	**	(0.09)	- 0.27	**	(0.09)	– 0.27	**	(0.09)
Post*Effort	0.12		(0.14)	0.14		(0.14)	0.14		(0.14)
Post*Notetaking	– 0.05		(0.31)	– 0.07		(0.31)	– 0.06		(0.31)
Expectancy				0.23		(0.20)	0.24		(0.20)
Value				0.03		(0.17)	0.02		(0.17)
Cost				0.05		(0.12)	0.06		(0.12)
Post*Expectancy				– 0.10		(0.24)	– 0.10		(0.25)
Post*Value				– 0.35		(0.20)	– 0.35		(0.20)
Post*Cost				– 0.22		(0.14)	– 0.23		(0.14)
Contrast1							0.03		(0.14)
Contrast2							0.06		(0.15)
Post*Contrast 1							– 0.01		(0.17)
Post*Contrast 2							– 0.06		(0.18)
Random			*SD*			*SD*			*SD*
Intercept			1.56			1.56			1.56
Post			1.90			1.88			1.88

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$;

Contrast 1 = static slides with voiceover narration (minimal signaling) vs. dynamic slides with voiceover narration (moderate signaling), Contrast 2 = dynamic slides with voiceover narration (moderate signaling) vs. dynamic slides with additional instructor signaling (maximum signaling).

difficulty, the lower was the students' knowledge acquisition. The planned contrasts showed no effect concerning the three different lecture formats.

For *knowledge of research designs* (Table 3), post-test scores demonstrated a significant positive effect ($B = 2.71$, $SE = 0.30$, $p < .001$). The interaction between post-test and effort was also significant ($B = 0.45$, $SE = 0.13$, $p < .001$), suggesting that higher effort was associated with greater knowledge acquisition. Additionally, a significant three-way interaction was observed for the topic of research designs (post*contrast2*difficulty), $B = 0.29$, $SE = 0.13$, $p = .027$, suggesting that the positive effect of a visible instructor's gestures and gaze shifts on knowledge acquisition improved as perceived difficulty increased.

For *knowledge of measurement* (Table 4), significant main effects were observed for post-test scores ($B = 1.89$, $SE = 0.24$, $p < .001$) and effort ($B = 0.25$, $SE = 0.09$, $p < .01$). Additionally, post-test interactions with expectancy ($B = -0.48$, $SE = 0.21$, $p < .05$) and cost ($B = -0.29$, $SE = 0.13$, $p < .05$) were significant, indicating moderating effects of these variables. These negative coefficients suggest that knowledge acquisition was lower for students who reported higher expectancy and higher perceived cost. In other words, while learners knowledge generally improved through the intervention, those

Table 3 Hierarchical multilevel model with knowledge score on research designs as dependent variable

	Step 1			Step 2			Step 3		
Fixed	coef		(SE)	coef		(SE)	coef		(SE)
Intercept	3.38 ***		(0.23)	3.40 ***		(0.23)	3.38 ***		(0.23)
Difficulty	–0.08		(0.06)	–0.08		(0.06)	–0.07		(0.07)
Effort	0.04		(0.09)	0.05		(0.10)	0.06		(0.10)
Notetaking	–0.02		(0.26)	–0.04		(0.26)	–0.03		(0.26)
Post	2.66	***	(0.29)	2.69	***	(0.30)	2.71	***	(0.30)
Post*Difficulty	–0.05		(0.08)	–0.05		(0.08)	–0.06		(0.09)
Post*Effort	0.44	***	(0.12)	0.46	***	(0.13)	0.45	***	(0.13)
Post*Notetaking	0.63		(0.33)	0.59		(0.34)	0.57		(0.34)
Expectancy				0.01		(0.19)	0.01		(0.19)
Value				–0.17		(0.16)	–0.17		(0.16)
Cost				–0.12		(0.11)	–0.11		(0.11)
Post*Expectancy				–0.23		(0.25)	–0.21		(0.25)
Post*Value				–0.12		(0.21)	–0.12		(0.21)
Post*Cost				–0.13		(0.15)	–0.13		(0.15)
Contrast1							–0.14		(0.14)
Contrast2							0.01		(0.14)
Post*Contrast1							0.15		(0.18)
Post*Contrast2							0.07		(0.19)
Random			*SD*			*SD*			*SD*
Intercept			1.51			1.49			1.49
Post			1.97			1.95			1.95

Note. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$;

Contrast 1 = static slides with voiceover narration (minimal signaling) vs. dynamic slides with voiceover narration (moderate signaling), Contrast 2 = dynamic slides with voiceover narration (moderate signaling) vs. dynamic slides with additional instructor signaling (maximum signaling).

Table 4 Hierarchical multilevel model with knowledge score on measurement as dependent variable

	Step 1		Step 2		Step 3	
Fixed	coef	(SE)	coef	(SE)	coef	(SE)
Intercept	4.68 ***	(0.21)	4.67 ***	(0.21)	4.69 ***	(0.22)
Difficulty	– 0.07	(0.06)	– 0.07	(0.06)	– 0.09	(0.06)
Effort	0.23 **	(0.09)	0.22 *	(0.09)	0.25 **	(0.09)
Notetaking	– 0.03	(0.07)	– 0.03	(0.24)	– 0.06	(0.25)
Post	1.90 ***	(0.24)	1.92 ***	(0.24)	1.89 ***	(0.24)
Post*Difficulty	– 0.03	(0.07)	– 0.02	(0.07)	– 0.00	(0.07)
Post*Effort	0.18	(0.10)	0.23 *	(0.10)	0.19	(0.10)
Post*Notetaking	0.33	(0.28)	0.30	(0.27)	0.34	(0.27)
Expectancy			0.17	(0.19)	0.20	(0.19)
Value			0.04	(0.16)	0.02	(0.16)
Cost			0.07	(0.11)	0.11	(0.11)
Post*Expectancy			– 0.44 *	(0.21)	– 0.48 *	(0.21)
Post*Value			– 0.32	(0.18)	– 0.29	(0.13)
Post*Cost			– 0.25	(0.13)	– 0.29 *	(0.13)
Contrast1					– 0.06	(0.13)
Contrast2					0.22	(0.14)
Post*Contrast1					0.06	(0.15)
Post*Contrast2					– 0.29	(0.16)
Random		*SD*		*SD*		*SD*
Intercept		1.49		1.48		1.46
Post		1.72		1.66		1.64

Note. *$p<.05$, **$p<.01$, ***$p<.001$;

Contrast 1 = static slides with voiceover narration (minimal signaling) vs. dynamic slides with voiceover narration (moderate signaling), Contrast 2 = dynamic slides with voiceover narration (moderate signaling) vs. dynamic slides with additional instructor signaling (maximum signaling).

with high initial expectancy or perceived cost showed less pronounced knowledge gains. As with the other models, differences between lecture formats were non-significant.

Effects of signaling on perceived social presence

Concerning social presence in the topic of samples (Table 5), difficulty ($B = -0.19$, $SE = 0.05$, $p < .001$), effort ($B = 0.27$, $SE = 0.07$, $p < .001$, and value ($B = 0.29$, $SE = 0.11$, $p < .01$) were significant predictors. Neither of the contrasts were statistically significant, suggesting no differences in perceived social presence between minimal, moderate, and maximum signaling for this topic.

Concerning social presence in the topic of research designs (Table 6), difficulty ($B = -0.23$, $SE = 0.05$, $p < .001$), effort ($B = 0.18$, $SE = 0.07$, $p < .01$), and value ($B = 0.48$, $SE = 0.12$, $p < .001$) were significant predictors. Additionally, both planned contrasts showed significant effects. Perceived social presence was higher for moderate signaling (dynamic slides with voiceover narration) compared to minimal signaling (Contrast 1: $B = 0.23$, $SE = 0.10$, $p < .05$). Furthermore, maximum signaling (dynamic slides with a visible instructor) further increased perceived social presence compared to moderate signaling

Table 5 Hierarchical Regression Model with Social Presence as Dependent Variable for the Topic of samples

	Step 1			Step 2			Step 3		
	coef		(SE)	coef		(SE)	coef		(SE)
Intercept	5.67	***	(0.07)	5.66	***	(0.06)	5.66	***	(0.06)
Prior knowledge	0.05		(0.04)	0.05		(0.04)	0.05		(0.04)
Difficulty	– 0.19	***	(0.05)	– 0.18	***	(0.05)	– 0.19	***	(0.05)
Effort	0.32	***	(0.07)	0.26	***	(0.07)	0.27	***	(0.07)
Expectancy				– 0.04		(0.13)	– 0.02		(0.13)
Value				0.30	**	(0.11)	0.29	**	(0.11)
Cost				– 0.14		(0.07)	– 0.14		(0.07)
Contrast 1							0.15		(0.09)
Contrast 2							0.13		(0.09)
Adjusted R^2	.16			.20			.21		

Note. *$p<.05$, **$p<.01$, ***$p<.001$;

Contrast 1 = static slides with voiceover narration (minimal signaling) vs. dynamic slides with voiceover narration (moderate signaling), Contrast 2 = dynamic slides with voiceover narration (moderate signaling) vs. dynamic slides with additional instructor signaling (maximum signaling).

Table 6 Hierarchical regression model with social presence as dependent variable for the topic of research designs

	Step 1			Step 2			Step 3		
	coef		(SE)	coef		(SE)	coef		(SE)
Intercept	5.19	***	(0.08)	5.19	***	(0.07)	5.19	***	(0.07)
Prior knowledge	– 0.01		(0.05)	–0.00		(0.05)	– 0.00		(0.05)
Difficulty	– 0.27	***	(0.05)	– 0.23	***	(0.05)	– 0.23	***	(0.05)
Effort	0.29	***	(0.07)	0.20	**	(0.07)	0.18	**	(0.07)
Expectancy				0.08		(0.14)	0.15		(0.14)
Value				0.48	***	(0.12)	0.48	***	(0.12)
Cost				– 0.04		(0.08)	– 0.02		(0.08)
Contrast 1							0.23	*	(0.10)
Contrast 2							0.38	***	(0.10)
Adjusted R^2	0.17			0.24			0.28		

Note. *$p<.05$, **$p<.01$, ***$p<.001$;

Contrast 1 = static slides with voiceover narration (minimal signaling) vs. dynamic slides with voiceover narration (moderate signaling), Contrast 2 = dynamic slides with voiceover narration (moderate signaling) vs. dynamic slides with additional instructor signaling (maximum signaling).

(Contrast 2: $B = 0.38$, $SE = 0.10$, $p < .001$). These results suggest that increased signaling enhanced students' perceived social presence for the topic of research designs.

Concerning social presence in the topic of measurement (Table 7), effort ($B = 0.27$, $SE = 0.05$, $p < .001$) and value ($B = 0.44$, $SE = 0.09$, $p < .001$) were significant predictors. Furthermore, maximum signaling (dynamic slides with a visible instructor) significantly

Table 7 Hierarchical Regression model with social presence as dependent variable (DV) for the topic of measurement

	Step 1			Step 2			Step 3		
	coef		(SE)	coef		(SE)	coef		(SE)
Intercept	5.26	***	(0.07)	5.25	***	(0.07)	5.26	***	(0.07)
Prior knowledge	0.02		(0.05)	– 0.00		(0.05)	– 0.02		(0.05)
Difficulty	– 0.09		(0.05)	– 0.07		(0.05)	– 0.06		(0.04)
Effort	0.34	***	(0.07)	0.24	***	(0.07)	0.27	***	(0.05)
Expectancy				0.15		(0.14)	0.19		(0.11)
Value				0.47	***	(0.12)	0.44	***	(0.09)
Cost				– 0.07		(0.09)	– 0.04		(0.07)
Contrast 1							0.06		(0.06)
Contrast 2							0.31	**	(0.08)
Adjusted R^2	0.12			0.20			0.23		

Note. *$p<.05$, **$p<.01$, ***$p<.001$;

Contrast 1 = static slides with voiceover narration (minimal signaling) vs. dynamic slides with voiceover narration (moderate signaling), Contrast 2 = dynamic slides with voiceover narration (moderate signaling) vs. dynamic slides with additional instructor signaling (maximum signaling).

increased perceived social presence compared to moderate signaling (Contrast 2: $B=0.31$, $SE=0.08$, $p<.01$). However, there was no significant difference between minimal and moderate signaling (Contrast 1: $B=0.06$, $SE=0.06$, $p=.276$) for this topic. We did not find significant two–way interactions (covariates*contrasts) for any of the three topics.

Discussion

This study examined the effects of dynamic slides and instructor signaling in online video lectures about research methods on preservice teachers' knowledge acquisition and perceived social presence. Using a pre-post experimental design, three lecture formats were compared: static slides with voiceover narration (minimal signaling), dynamic slides with voiceover narration (moderate signaling), and dynamic slides with additional instructor signaling (maximum signaling). These formats were applied to three research methods topics: samples, research designs, and measurement. Participants' prior knowledge, perceived difficulty, notetaking (as a generative activity), invested effort, and motivation for learning research methods (expectancy, value, and cost) were held constant and included as covariates, and possible interactions between these variables with varying levels of signaling were investigated.

Effects on knowledge acquisition

Hypothesis H1a, which predicted that dynamic slides with voiceover narration (moderate signaling) would enhance knowledge acquisition compared to static slides with voiceover narration (minimal signaling), was not supported by the data. Across all topics, dynamic slides did not improve knowledge acquisition relative to static slides. This contrasts with findings from prior studies reporting beneficial effects of dynamic slides for guiding learner's attention and reducing extraneous cognitive load (Fiorella & Mayer, 2016; Fiorella et al., 2019; Rodemer et al., 2022; Zhang et al., 2024a, 2024b). One possible explanation is that the slides predominantly featured simple figures or tables with clear reading conventions, enabling learners to locate and understand information effectively alongside the instructor's narration, even in static versions. As a result, the dynamic slides may not have provided additional guidance or cognitive benefit, which could explain the absence of significant effects. In contrast, for topics involving complex processes or mechanisms, dynamic presentation methods may be more beneficial, as shown by Fiorella et al. (2019) and Rodemer et al. (2022). Similarly, Sondermann and Merkt (2023a) found that slide dynamics improved learning only for graphical slides, not for text-based slides. Another possible explanation is that the authentic learning setting allowed participants to pause or rewind the videos, which may have reduced their reliance on built-in signaling. These results suggest that when slide content is simple and visually clear, the signaling benefits predicted by the Cognitive Theory of Multimedia Learning (Mayer, 2022) may be less pronounced, as learners can process the information without additional guidance. This pattern aligns with predictions derived from cognitive load theory on reducing extraneous cognitive load and suggests that baseline material clarity can moderate the effects of signaling.

Hypothesis H2a, which predicted that dynamic slides with additional instructor signaling (maximum signaling) lead to greater knowledge acquisition than dynamic slides with voiceover narration (moderate signaling), was partially supported by the data. While dynamic slides with additional instructor signaling did not lead to greater knowledge acquisition compared to dynamic slides with voiceover narration in general, a significant interaction emerged for research designs: instructor signaling improved knowledge acquisition as perceived difficulty increased. This suggests that gestures and gaze shifts may provide additional cognitive support for more complex material, which is consistent with findings from Alemdag (2023), Kuang et al. (2023), and Li et al. (2024). This finding reinforces the assumption that signaling is particularly effective when learners face higher intrinsic cognitive load, as cues can help to manage cognitive processing demands (Schneider & Sung, 2024). The videos on research designs were perceived as the most difficult, likely due to their greater number of figures and longer duration compared to other lecture topics. These findings partially align with the CTML theory. In our study, signaling improved knowledge acquisition only when content complexity was high, suggesting that the effectiveness of cues may depend on the cognitive demands of the learning material. However, apart from perceived difficulty, no interactions were found between lecture formats and effort, notetaking, or motivational factors. The varying levels of signaling did not influence knowledge acquisition, regardless of students' effort, notes, or motivation. According to social agency theory, cues from a visible instructor enhance engagement and motivation, potentially improving learning outcomes (Fiorella & Mayer, 2022a, 2022b; Schneider et al., 2022). Our findings, however, suggest that cues from a visible instructor may not be an effective design element in educational videos for compensating for low motivation or encouraging greater engagement (e.g., increased effort or notetaking).

Effects on social presence

Hypothesis H1b, which predicted that social presence is comparable between static slides with voiceover narration (minimal signaling) and dynamic slides with voiceover narration (moderate signaling), was partially supported by the data. For samples and measurement, dynamic slides with voiceover narration did not increase social presence compared to static slides with voiceover narration. However, for research designs—which was perceived as the most difficult of the three topics –, participants reported higher social presence when dynamics were added to the slides. The effect of signaling through dynamic slides on social presence may depend on content difficulty, as more complex material may heighten learners' need for social guidance (Sondermann et al., 2024). For contents that learners perceive as difficult, signaling through dynamic slides may increase the feeling of being connected with the instructor—even without having the instructor visible on the screen.

Hypothesis H2b, which predicted that dynamic slides with additional instructor signaling (maximum signaling) lead to higher social presence than dynamic slides with voiceover narration (moderate signaling), was partially supported by the data. Dynamic slides with additional instructor signaling significantly enhanced social presence compared to dynamic slides with voiceover narration for research designs and measurement. This result is in line with previous studies, which have observed that visible instructors enhanced social presence (Sondermann et al., 2024). Our finding also aligns with social agency theory (Mayer & DaPra, 2012), which posits that human-like elements promote learners' sense of connection with the instructor. However, for the topic of samples, social presence did not differ across the three lecture formats. This contrasts with the study of Sondermann et al. (2024), which has found consistent social presence benefits across topics. One explanation might be that simpler topics like samples do not elicit the same need for social connection, which might consequently reduce the impact of social cues. The topic-specific effects in our study suggest that benefits of social cues might depend on perceived instructional needs. No interactions were found between covariates and lecture formats suggesting that signaling (e.g., dynamic slides or pointing gestures and gaze shifts) was effective for social presence independently of perceived difficulty, invested effort, and motivation.

Motivation and generative activities

Invested effort and perceived value positively predicted social presence across all topics, with perceived value having the strongest effect. Learners who found the content more relevant felt a stronger connection to the instructor, regardless of signaling. The findings indicate that perceived value of the learning content may play a critical role in fostering social presence in online video lectures, potentially extending the scope of social agency theory (Fiorella & Mayer, 2022b; Schneider et al., 2022). However, higher perceived value did not lead to greater knowledge acquisition, which was unexpected according to the expectancy-value-cost theory (Eccles & Wigfield, 2020). Moreover, the results revealed that learners with higher expectancy and higher perceived cost showed less pronounced knowledge acquisition for the topic of measurement. For instance, high expectancy could lead students to underestimate the difficulty of the content and to invest less effort. In contrast, high perceived cost may reflect that students are facing competing academic demands or time constraints, which may reduce their ability to fully concentrate on the learning material. Notetaking, which was assumed to enhance knowledge acquisition through generative engagement, was not a significant predictor in any of the models. This diverges from studies that emphasize the importance of generative strategies in multimedia learning (Fiorella & Mayer, 2022a).

Limitations

Several limitations warrant consideration. First, for videos with instructor signaling, the instructor was standing next to a smartboard. As a result, slides were smaller in the dynamic slides with additional instructor signaling format than in the voiceover formats. The slide content may not have been as clear or easy to view as in the full-screen voiceover version. The smaller slide content in the visible instructor formats may also have reduced the potential benefits of the instructor's gestures and gaze shifts. Second, the fixed order of topics may have introduced order effects, potentially influencing the results. Third, the research was conducted in a mandatory university course—which, on the one hand, enhances the study's ecological validity and strengthens the practical relevance of the findings. On the other hand, this naturalistic setting limited certain aspects of experimental control, such as the standardization of viewing conditions and potential external influences on learning behavior. Moreover, relying on self-reported measures for notetaking and video usage limits the ability to fully assess learners' engagement with the learning material. Furthermore, as the study was conducted with preservice teachers in a course on research methods, the generalizability of the findings to other academic domains, such as STEM-related subjects, may be limited. Fourth, the absence of a delayed posttest does not allow for conclusions about the long-term effects on student's knowledge acquisition.

Future research

The above-mentioned limitations highlight promising directions for future research. First, future studies could use live-composite video formats, where instructors are overlaid on full-screen slides, thus maintaining slide visibility while allowing for instructor signaling (Rosenthal & Walker, 2020). Second, topic sequences could be counterbalanced across participants to address possible order effects. Third, future studies may apply more controlled experimental settings, enabling systematic manipulation of variables such as viewing conditions or individual learner factors. Fourth, future studies could employ personalized log-file analyses to gain more detailed insights into how individual learners interact with instructional videos—such as pausing, rewinding, or replaying specific segments—and how these behaviors relate to learning outcomes. Fifth, the relationship between notetaking and knowledge acquisition could be explored more in depth by using objective measures like a digital note-taking system, that assess both note quality and quantity. Eye-tracking methods also offer a promising avenue for capturing learners' visual attention and providing deeper insight into how signaling cues guide focus and engagement. Sixth, future research could replicate the present design—comparing static slides, dynamic slides, and instructor signaling—in STEM-related domains and authentic learning settings to examine the robustness and potential transferability of the observed effects. Seventh, delayed posttests would allow researchers to assess participants' long-term retention of knowledge and better understand the durability of instructional effects. Finally, future studies could assess learners' transfer performance.

Conclusion

The present research examined how varying levels of signaling influence knowledge acquisition and social presence in authentic online video lectures. While dynamic slides and instructor signaling enhanced perceived social presence, their effects on knowledge acquisition depended on the complexity of the topic. For educators, this suggests that instructor cues such as pointing gestures and gaze shifts may be particularly helpful when teaching complex relationships, abstract constructs, or procedural content (e.g., research designs, experimental setups). In such cases, social and cognitive cues from the instructor can help students to follow the structure and relevance of the material. In contrast, when slides contain mostly static information or clearly labeled graphics, and learners have full video control (pause, rewind), the benefits of additional signaling may be reduced.

While our findings diverge from the prevailing evidence that signaling generally enhances learning across contexts (Alemdag, 2023; Alpizar et al., 2020; Kuang et al., 2023; Li et al., 2024), they suggest that content complexity and learner control as potential boundary conditions may moderate these effects. This may be particularly relevant in pre-service teacher education, where video lectures are not only widely used but also where social cues such as instructor visibility are interpreted through a pedagogical lens (Chew, 2022). Educators should therefore align signaling strategies with content complexity and the degree of learner control. Our findings offer initial insights into how such adaptations in asynchronous online video lectures can shape learning and social presence, highlighting their relevance to core principles of the Cognitive Theory of Multimedia Learning and Social Agency Theory.

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Data availability The data that support the findings of this study are available from the corresponding author upon request.

Declarations

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethics approval The study was approved by the faculty's local ethic committee (application no. 2021–004). Participants gave their informed consent prior to their inclusion in the study.

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Dr. Timo Reuter is a post-doc researcher at the RPTU University Kaiserslautern-Landau. His research focuses on scientific thinking, early science learning, and multimedia learning.

Dr. Lukas Lazzara is a post-doc researcher at the RPTU University Kaiserslautern-Landau. His work focuses on early science education, play-based learning, and data-based decision making.

Dr. Miriam Leuchter is a professor of Educational Psychology at the RPTU University Kaiserslautern-Landau. Her research focuseson cognitive development, early science learning, and professional development in educational contexts.