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Focused self-explanation prompts and segmenting foster pre-service teachers' professional vision - but only during training!

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Abstract

When analyzing classroom video, pre-service teachers can improve their professional vision, that is, their ability to notice important events in a classroom and to interpret them based on theoretical knowledge. However, learning with video is especially challenging for novice learners. Thus, video needs to be embedded into an instructional context to be effective. In an experimental study with 89 pre-service biology teachers, we investigated the effect of a short professional vision training and whether two design principles from multimedia learning research—namely segmenting and self-explanation prompts—could additionally increase training effects. In a one-hour training session on small-group tutoring strategies, participants watched practice video examples either as a whole or segmented. After each video or video segment, respectively, they received either open or focused self-explanation prompts to analyze the scene. We assessed participants' professional vision skills before and after training. Overall, participants' performance substantially increased from pretest to posttest. Moreover, during training, both segmented video examples and focused self-explanation prompts led to increased noticing of relevant strategies. This advantage during training, however, did not result in higher professional vision improvement in posttest scores compared to participants who worked in the less supported training phase conditions. We discuss possible explanations why additional support increased training performance but not learning gains and suggest an additional fading phase as a means to achieve persistent effects.

Keywords: Professional vision, Teacher education, Video analysis, Multimedia learning, Segmenting, Self-explanation prompts

Introduction

During initial teacher education, pre-service teachers acquire an extensive knowledge base, not only in subject matter, but also in subject matter education, general educational science, and psychology. However, to succeed in managing a classroom and educating students in the respective subjects, beginning teachers need to transform their theoretical knowledge into situation-specific skills, that is, they need to use their knowledge to perceive and interpret what is happening and then decide how to act (Blömeke

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et al., 2015). In teacher education, video provides an important tool to train pre-service teachers in their situation-specific skills, more specifically their *professional vision* (PV) of classroom interactions (Gaudin & Chaliès, 2015).

However, pre-service teachers face two major challenges when learning with video. First, the information presented in video is transient (i.e., only temporarily available), which can be overwhelming and thus hinder learning (Mayer & Fiorella, 2014). Pre-service teachers without much classroom experience struggle with identifying important events in this constant flow of transient information. Second, without support, pre-service teachers often interpret classroom situations based on intuition rather than theoretical knowledge about teaching and learning (Jacobs et al., 2010). Multimedia learning research suggests two design principles to overcome these difficulties. First, presenting a video, not as a whole, but rather in short segments, provides more time for processing the transient information (Rey et al., 2019). Second, providing self-explanation prompts supports the learner in integrating new information with prior knowledge, with focused prompts that direct the learners' attention to important aspects being more effective than open prompts (Wylie & Chi, 2014).

Derry and colleagues (2014) call for greater consideration of findings on multimedia learning when designing video-based interventions in teacher education. Thus, in the present study, we investigated whether the effect of a short PV intervention could be increased by segmenting the videos and providing focused self-explanation prompts.

Teacher professional vision

Successful teaching requires—beyond subject matter content knowledge (*CK*; e.g., about biology or mathematics)—extensive knowledge about general aspects of teaching and learning (i.e., *pedagogical–psychological knowledge, PPK*; Voss et al., 2011) and subject-specific aspects, for example, about students' typical misconceptions (i.e., *pedagogical content knowledge, PCK*; Rosenkränzer et al., 2017; Shulman, 1986). However, there is a risk that pre-service teachers' theoretical knowledge remains inert, that is, beginning teachers struggle to use their knowledge when teaching (Kersting et al., 2012; Renkl et al., 1996). To be able to act professionally in classroom situations, teachers need situation-specific skills, which act as a mediator between teachers' dispositions (e.g., PPK, PCK, and CK) and actual classroom performance (Blömeke et al., 2015). These situation-specific skills include *noticing* a potentially relevant event (e.g., a student giving an incorrect answer) while simultaneously disregarding less relevant events, *interpreting* the event (e.g., the incorrect answer might indicate a typical misconception), and finally *deciding* how to react (e.g., asking further questions to diagnose the underlying misconception). Noticing, interpreting, and decision-making are based on teachers' theoretical knowledge (König et al., 2014; Schäfer & Seidel, 2015). Furthermore, these factors influence classroom performance. In teacher education, the two processes of noticing and interpreting are often summarized under the concept of PV.[1] PV provides a basis for effective teaching, as it enables teachers to make

[1] The conceptualizations of situation-specific skills (e.g., Blömeke et al., 2015), teacher noticing (e.g., van Es & Sherin, 2021), and professional vision (Goodwin, 1994) are overlapping and researchers vary in the number of components they investigate within one framework: for example, noticing only (e.g., Star & Strickland, 2008), noticing and interpreting (e.g., Schäfer & Seidel, 2015), or noticing, interpreting, and decision-making (e.g., Kaiser et al., 2015). In this study, we focused on the processes of noticing and interpreting and use the term professional vision to describe these two components.

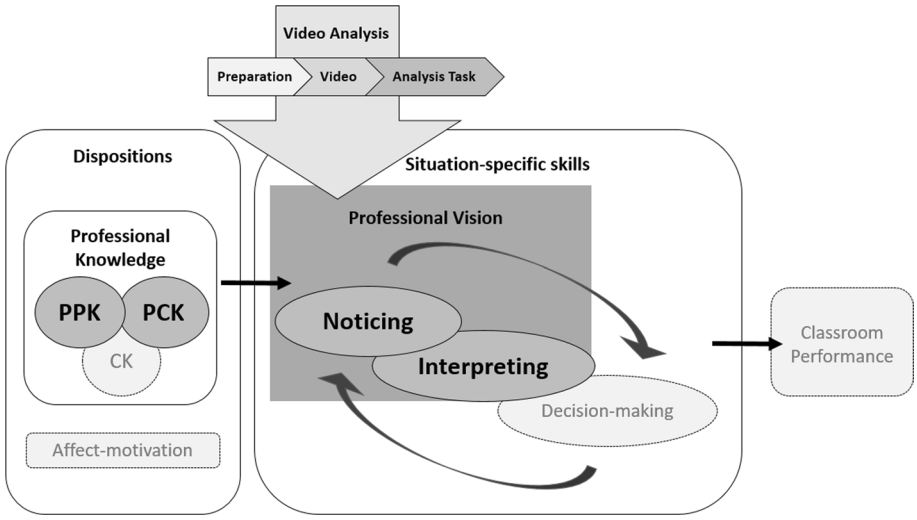

Fig. 1 Relationship Between Knowledge, Professional Vision, and Classroom Performance. This figure was adapted from Blömeke et al. (2015); from the original model, the black bolded text represents components investigated in this study while grayed-out text components are not investigated Adapted and Used with permission from Zeitschrift für Psychologie 2015; Vol. 223(1):3–13 ©2015 Hogrefe Publishing www.hogrefe.com https://doi.org/10.1027/2151-2604/a000194

theoretically-informed decisions for adapting their teaching to the students' learning progress and needs (Kersting et al., 2012). Figure 1 shows the relation between teachers' professional knowledge, their situation-specific skills (here: PV), and classroom performance.

However, PV does not automatically come along with theoretical knowledge. Instead, research shows that skills associated with attending to relevant events in a classroom and meaning-making of these events vary quite a lot, depending on the teacher's expertise (Berliner, 2001; Wolff et al., 2021). While expert teachers usually focus on events that influence students' learning and make use of theoretical knowledge when interpreting these events (Jacobs et al., 2010; Wolff et al., 2016), pre-service teachers often fail to notice important events and instead focus on salient but less important details, such as media use or general aspects of the situation like classroom climate (Sabers et al., 1991; van Es & Sherin, 2021). Thus, in pre-service teachers' analyses of classroom situations, unfocused comments about the situation often predominate over detailed descriptions and theory-based interpretations of specific events (Farrell et al., 2022; Star & Strickland, 2008).

As teacher PV is related to the ability to implement effective teaching strategies (Wiens et al., 2021) and thereby indirectly influences student performance (Kersting et al., 2012), PV training should be a standard part of teacher professional development (Seidel & Stürmer, 2014). Especially in the initial phases of teacher education, there is a plea for practice-oriented teaching formats to foster the integration of theoretical knowledge and practice examples, thereby preventing the emergence of inert knowledge right from the start (Cochran-Smith et al., 2017; Stockero et al., 2017). Working with classroom video provides a valuable opportunity for pre-service teachers to improve their PV and thus is an important tool in teacher education (Gaudin & Chaliès, 2015; Santagata et al., 2021).

Using video to foster pre-service teachers' professional vision

Video examples of classroom situations provide a suitable approximation of practice for pre-service teachers to apply their theoretical knowledge in an authentic yet manageable context (Grossman et al., 2009). Yet despite its potential for bridging the theory–practice gap, often deplored in teacher education (Korthagen & Kessels, 1999), video is not used as naturally as one would expect. For example, according to a US survey, many teacher educators scarcely use video (Christ et al., 2017). Reasons for their limited use of video include a lack of support in the form of pre-structured video courses they can adopt easily, as well as time restrictions. Although this survey only represents a limited sample of teacher educators, time constraints are nevertheless an important aspect that generally concerns teacher education (Darling-Hammond, 2006; Santagata et al., 2018).

Thus, there seems to be a need for condensed training formats that can be flexibly applied to facilitate video use for teacher educators. Video is not effective per se, but needs to be embedded within a set of instructional activities to be effective. Accordingly, there are several recommendations for designing condensed video-based training interventions in teacher education (Blomberg et al., 2013; Kang & van Es, 2019).

First, video-based courses should be designed with a clear learning goal in mind (Blomberg et al., 2013; Grossman et al., 2009). As PV of classroom situations can encompass a wide range of teaching and learning aspects, condensed training formats should focus on specific elements of teaching, such as PV of classroom management (e.g., Gold et al., 2020), of student thinking in mathematics (e.g., Stockero et al., 2017), or small-group tutoring strategies (Martin et al., 2020). Second, to foster the integration of theoretical knowledge and practice, educators should provide the student teacher with clear information about the learning goal, for example, in the form of an introductory text about teaching strategies one could observe (Kumschick et al., 2017; Prediger & Zindel, 2017; Seidel et al., 2013). Finally, video-analysis tasks should make use of tools and frameworks to guide pre-service teachers' observation and interpretation, for example by providing different lenses (e.g., the LAF by Santagata et al., 2007) or by providing a structure for analysis (e.g., VAST by van Es & Sherin, 2002).

Video-based training formats following this strong alignment of theory and practice have been shown to be effective, even for as little as a single session (e.g., with one 15-min video clip; Moreno, (2007); or with three 20-min training cases; Zottmann et al., 2012). However, the effects of these interventions were restricted. Even with guidance in the form of introductory texts, pre-service teachers show relatively limited PV in terms of failing to notice important events in classroom videos and often making unfocused interpretations with little to no connection to theory (Farrell et al., 2022). Thus, such short interventions still need further improvement to get the most out of the allocated time.

Multimedia learning research suggests segmenting video material to minimize the risk of learners feeling overwhelmed by the amount of information presented (Mayer & Fiorella, 2014). In terms of accompanying tasks, educators could additionally support pre-service teachers in making connections to theory by providing focused self-explanation prompts (Schworm & Renkl, 2006). In the following, we will outline the advantages of these two measures and how they might be suited to improve video-based PV interventions.

Segmenting the video examples

Video offers representations of dynamic processes that cannot be fully delivered via static formats such as texts. However, since the information presented in video is transient, learners have to process a lot of incoming information while holding previously presented information active in their working memory in order to integrate them. Both processing new information and keeping previous information present might exceed the learners' working memory capacity (Mayer & Pilegard, 2014). Additionally, they might miss important details in this steady flow of information. To counteract this *transience effect* while still exploiting the advantages of dynamic learning material, multimedia learning research suggests presenting a video not as a whole, but rather in shorter segments (Mayer & Pilegard, 2014; Rey et al., 2019).

Segmenting offers two main advantages (Rey et al., 2019; Spanjers et al., 2010): First, it highlights the structure of the learning material by making event borders more visible. Especially in classroom situations, there is often a high density of overlapping events, which makes it difficult to detect the beginning and end of an event. Expert teachers usually recognize patterns in classroom events and use their knowledge about these patterns to immediately interpret noticed events. Novices, however, lack knowledge about these patterns. Instead, they observe classroom interactions as a steady flow of information and have difficulties in noticing and interpreting single events (Wolff et al., 2021). By pre-segmenting classroom videos into meaningful units representing such patterns, teacher educators could support pre-service teachers in noticing important events.

Second, segmenting interrupts the flow of incoming information and thus offers the learner time after each segment for processing previous information (Rey et al., 2019). As PV is a knowledge-driven process, an observer of a classroom situation should have the time to integrate noticed events with theoretical knowledge. In contrast to expert teachers, pre-service teachers usually do not have their knowledge about classroom situations already organized into easily accessible schemata (Berliner, 2001). Thus, although they might notice an important event, immediately interpreting it may still be difficult because they first need to recall the respective theoretical knowledge. During a video's constant flow of information, they hardly have the time to access this knowledge to make sense of individual events. However, when the video stops after an important event, pre-service teachers get the opportunity to retrieve the theoretical knowledge they need to interpret the event.

Moreno (2007) found that pre-service teachers who observed a segmented classroom video recognized more teaching skills they had learned about before than those who observed the whole 15-min video unsegmented. Event-based segmenting may not only support pre-service teachers in noticing and interpreting events within a particular classroom video, but also it may support transfer to their observations of other videos depicting similar events. In contrast to a long video with processing time only at the end, a segmented video provides multiple opportunities for pre-service teachers to link their theoretical knowledge to practice examples. With each noticed and interpreted event, they build more integrated schemata. These schemata in turn should enable the pre-service teachers to access their knowledge faster when observing a non-segmented posttest video. Moreno (2007) measured transfer with a new video on another topic that was non-segmented for all participants. As she did not expect an effect of segmenting on this

transfer video, she did not compare the transfer scores between groups but only with a control group who received no training video. Nevertheless, the descriptive values indicated at least a small advantage of the segmented group even in this non-segmented transfer video. Thus, practicing with segmented videos might also foster pre-service teachers' PV when observing a non-segmented video. However, it is still an open question whether as little as one 15-min practice video is sufficient to obtain this effect.

Focused self-explanation prompts

In their first video clubs, van Es and Sherin (2002) already proposed guiding teachers by specific analysis prompts. Since that time, a great variety of analysis prompts have been used in PV programs. Some programs use rather open prompts that, for example, instruct pre-service teachers to simply write down what they noticed (e.g., de Araujo et al., 2015). Others prompt pre-service teachers to focus on one specific aspect of the classroom situation (e.g., focus on student thinking; Walkoe, 2015). The most focused analysis prompts currently used provide distinct categories in which pre-service teachers should classify their observations (e.g., van Es & Sherin, 2002) or links to conceptual knowledge (i.e., PPK and PCK) the teachers should use when analyzing the situation (Goeze et al., 2014).

While all of these training programs appear to be effective, none of these studies compared different types of prompts. However, from other domains, different types of prompts within multimedia learning material have been experimentally evaluated (e.g., Berthold et al., 2009; van der Meij & de Jong, 2011). In typical multimedia research learning domains (e.g., learning about probability theory or electrical circuits), learners are not prompted to *analyze* a situation (typical of PV interventions), but rather to *self-explain* a problem solution. Self-explanation prompts are supposed to encourage the learner to engage in meaningful learning activities, such as linking new information about problem cases to prior knowledge about principles (Wylie & Chi, 2014). Thus, analysis prompts in PV interventions can be seen as a form of self-explanation prompts, as they are intended to engage pre-service teachers in linking new information (from practice observations) to prior knowledge about teaching and learning principles. Considering these connections to multimedia learning research, relevant findings in this field should be taken into account in teacher education (Derry et al., 2014). With specific focus on prompting, we propose utilizing findings from research on self-explanation prompts for improving the design of analysis prompts in PV interventions.

Self-explanation prompts should foster learning by prompting the learner to actively engage in integrating information instead of just passively consuming the learning material (Rittle-Johnson et al., 2017; Wylie & Chi, 2014). However, there are multiple forms of self-explanation prompts that can be considered on a continuum from extremely open (i.e., "Explain in your own words what you just learned"; e.g., Chi et al., 1994) to highly focused (e.g., menu-based prompts or fill-in-the-blanks; e.g., Berthold et al., 2009). Comparisons of different types of self-explanation prompts in multimedia learning environments indicate that focused prompts are more suited to foster learning than open prompts (Berthold et al., 2009). By providing additional information, focused prompts compensate for missing prior knowledge and thus are especially helpful for novice learners, even to generate high-quality self-explanations (Wylie & Chi, 2014). Additionally,

focused self-explanation prompts help the learner to select the most relevant information, which is essential in complex learning domains where the learner has to deal with a lot of information (Wang & Adesope, 2017; Wylie & Chi, 2014).

At the beginning of their teacher education, pre-service teachers' analyses of classroom video are characterized by vague descriptions, intuitive judgments, and overgeneralizations (Jacobs et al., 2010). Even when provided with theoretical information about what to observe (e.g., an introductory text about teaching strategies), they still often show these novice-like observational patterns (Farrell et al., 2022). Focused self-explanation prompts that refer back to information provided beforehand might have two advantages over open prompts. First, by their structure, they already pave the way for pre-service teachers to make connections to theory instead of making intuitive interpretations. Second, they guide pre-service teachers' attention away from irrelevant aspects of the situation, toward relevant events.

The present study

We investigated a video-based training session on effective small-group tutoring strategies. The training session aimed at fostering teacher students' PV skills, that is, noticing important events happening in the tutoring situation, and interpreting them based on theoretical knowledge about teaching and learning (see Fig. 1). We measured participants' PV in a video-analysis task both before and after training.

The 60-min training session followed the guidelines for integrating theory and practice outlined above. It contained a short introductory text on small-group tutoring and subsequent video analyses of a tutoring context (i.e., one teacher and four students). The introductory text represents the *preparation* element in Fig. 1. We were interested in whether additional support could increase the intervention's effect on pre-service teachers' PV and investigated effects of two suggested design principles: Regarding the design of the video examples (*video* element in Fig. 1), we applied the segmenting principle from multimedia learning research; in terms of the tasks and instructions accompanying video analysis (*analysis task* element in Fig. 1), we investigated effects of focused self-explanation prompts. More specifically, we tested the following hypotheses on student teachers' PV:

Main hypotheses

Improvement-hypothesis First, we expected the training to be effective in general. Thus, we expected all participants to improve their PV during the study, independent from experimental condition. Specifically, we expected participants to notice more relevant events in the posttest than in the pretest (noticing component), to make higher quality interpretations of these events (interpreting component), and to make less unfocused comments about the situation (e.g., about classroom climate; unfocused component).

Segmenting-hypothesis Splitting video examples into segments provides more time for processing the information presented, and thereby reduces cognitive demands. Moreover, segmenting offers more frequent opportunities to integrate observed behavior with theoretical knowledge. Thus, we expected students who worked with segmented video

examples during the training to improve more in their PV compared to students who worked with non-segmented videos.

Prompts-hypothesis Self-explanation prompts support learners in integrating concrete example cases with knowledge about the underlying theoretical construct. Focused self-explanation prompts, which explicitly activate relevant constructs and terms, offer particular guidance compared to open self-explanation prompts without such a focus. Thus, we expected students who analyzed the videos guided by focused self-explanation prompts to benefit more from the training than students who received open prompts.

Explorative research question on knowledge domain

In addition to the variations regarding the video-analysis task, we were interested in whether training effects were different for different types of teacher knowledge to be applied. Results from a previous study implicated introductory texts to be effective by providing and activating relevant prior knowledge for teacher students (Martin et al., 2020). In the present study, we used two versions of an introductory text—one focusing on PPK and one focusing on PCK—to explore whether the PV training was equally suited to train teacher students in the application of both PPK and PCK.

Method

Participants and design

The study took place in four biology education seminars from two German universities specialized in teacher education. We obtained full data sets of 89 teacher students (9 males; mean age = 23.5, $SD = 2.4$). Age and gender distribution in our sample were typical for German teacher education courses. On average, the participants were in the third semester of their study program ($M = 2.97$, $SD = 2.2$) with most participants (76%) in the first to third semester. Most participants were pursuing a teaching degree for secondary education (45%), followed by elementary education (23%), and special education (21%).

The study consisted of a PV pretest, a training phase in which the experimental variation took place, and a posttest that was parallel to the pretest. In the training phase, participants were randomly assigned to the experimental conditions consisting of combinations of three independent factors. We varied the factors segmentation (segmented videos vs. non-segmented videos), self-explanation prompts (open prompts vs. focused prompts), and introductory text (PPK vs. PCK), resulting in eight experimental conditions in total. As dependent measures, we used pre-service teachers' written analyses of the pretest and posttest videos and scored them for the three PV components. Additionally, we assessed participants' cognitive load, individual and situational interest, and utility value via self-report questionnaires as well as their theoretical prior knowledge (PPK & PCK) with a multiple-choice test; however, the research questions addressed in this article do not refer to these variables, thus, they only serve as control variables.

Fig. 2 Screenshot taken from one of the video examples (Brainstorming Video)

Materials

Video examples

All video examples used in this study showed a small-group tutoring scenario with four 8th-grade students and one teacher (see Fig. 2). The topic of the session was the human circulatory system. We scripted the videos to show a variety of tutoring moves in sections of only a few minutes. The video scripts were based on real videotaped small-group tutoring situations and the observed strategies and dialogues were condensed into four short scenarios, each showing multiple tutoring strategies relevant from both a PCK and a PPK perspective. Two of the scripts showed a clip from the beginning of such a tutoring session and two scripts showed a clip later on in the session. Table 1 shows a description of the scenes. The scripts *Drawing Task* and *Diagram Comparison* were enacted twice with different actors. We used these videos for pretest and posttest to ensure comparability.

For the segmented condition in the training phase, we split the videos into four (*Brainstorming* video) and three (*Exchange Student* video) segments, respectively. The length of the segments varied between 30 s and three and a half minutes (see Appendix for a detailed description of a segmented video). We defined the segments based on meaningful events rather than strictly splitting the video into segments of the same length. We chose *Communicative Events* (*CE*; Hennessy et al., 2016) as a medium grain size level. In one-on-one-tutoring, a prototypical CE would consist of five steps with the tutor first asking a question, the student responding, the tutor providing short feedback on the response, then the tutor and student collaboratively working on improving the students' initial response, and finally the tutor checking the student's understanding (Graesser et al., 1995). However, as our videos showed a small group instead of one-on-one tutoring, the segments did not all match this standard procedure.

Table 1 Contents of the video examples used for pretest, training phase, and posttest

Video title	Description of the scene	Duration	Used for
Drawing Task	*(beginning of the session)* The tutor asks the students to draw into a blank figure outline, how they imagine the blood flows in the human body. Then they discuss their drawings in the group	4 min	Pretest/Posttest
Diagram Comparison	*(later in the session)* The tutor hands out a scientific diagram of the circulatory system and asks the students to compare their drawings to the diagram	4 min	Pretest/Posttest
Brainstorming	*(beginning of the session)* The scene starts with a brainstorming activity on the topic „blood ", then the tutor elicits and discusses the students ' prior knowledge of the circulatory system	8 min	Training Phase
Exchange Student	*(later in the session)* The tutor starts a role-play by introducing himself as an exchange student who has not yet learned about the circulatory system. He asks the students to explain everything they know about the topic	6 min	Training Phase

Introductory texts

The introductory texts first introduced small-group tutoring as a teaching–learning arrangement that enables individualized and adaptive teaching. Then they contrasted four beneficial strategies of a student-centered tutoring style with four less beneficial strategies of a more instructive tutoring style (see Chi et al., 2001). There were two versions of the introductory text, each highlighting slightly different aspects: One text version contrasted these tutoring styles from a general pedagogical-psychological perspective (version PPK, 1027 words), the other version focused on aspects more specific to biology education (version PCK, 1098 words). In a prior study, both introductory texts effectively activated relevant theoretical knowledge for a subsequent video-analysis task (Martin et al., 2020). Additionally, video scripts and introductory texts were developed in parallel to ensure all video examples (pretest/posttest and training phase) portrayed multiple tutoring strategies from the introductory texts.

The PPK text, for example, stated that teachers using an instructive tutoring style often ignore mistakes within student utterances to maintain initial lesson plans for elaborating on the topic. In contrast, a tutor adhering to a student-centered tutoring style would react to incorrect utterances by asking further questions to get more information about possible underlying misconceptions. The PCK text, for example, portrayed specific misconceptions students commonly hold about the circulatory system (e.g., blood flows back and forth in the same vessels) and stated that instead of just explaining a topic (instructive tutoring style), a tutor should first elicit the students' misconceptions on that topic in order to reshape them (student-centered tutoring style). In addition, each text version comprised a figure summarizing the information on the tutoring styles.

Self-explanation prompts

For the video-analysis task in the training phase, we used two different types of self-explanation prompts. Participants in the open-prompts condition received a plain text box and were instructed to simply describe and interpret what they had noticed in the scene. We instructed participants to try to recognize the tutoring strategies (4 student-centered and 4 tutor-centered) outlined in the introductory text. However, they did not

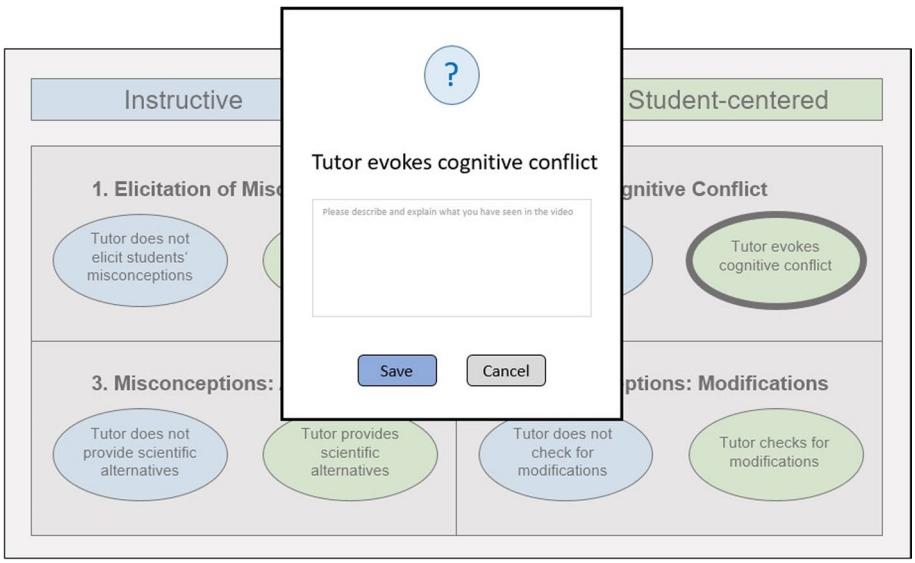

Fig. 3 Analysis Task Display in the Focused-Prompts Condition. This figure (in a non-interactive version) was presented to all participants as an overview in the introductory texts. In the focused-prompts condition, participants additionally received this interactive version in which they could add examples from the training phase videos

receive additional support to recall the strategies. In contrast, the analysis task in the focused-prompts condition consisted of an interactive version of the introductory text figure (see Fig. 3). Participants were instructed to click on an oval displaying a tutoring strategy they noticed and then to describe in a textbox a concrete example of how the tutor enacted the respective strategy. Table 2 shows examples of what participants' comments in the respective self-explanation prompts conditions looked like.

Measures

Pretest and posttest

We assessed participants' PV skills in the pretest and posttest with a video-analysis task in an open answer format. Participants watched two video examples of a tutoring session (videos: *Drawing Task* and *Diagram Comparison*, see Table 1). For each video, we asked them to comment on two to five events they had noticed involving tutor actions and explain why these events were relevant for the students' learning.

To obtain the participants' pretest and posttest PV scores, we coded whether they noticed important events and how they interpreted these events within the two video examples. For each video, we first defined events relevant to the tutoring context, for example, the tutor commenting on a student's drawing. In total, we defined 11 relevant events (4 in *Drawing Task* video, 7 in *Diagram Comparison* video). The number of noticed events constituted the *noticing component* of the PV score.

Additionally, we rated the quality of the comments. Table 3 shows example comments for the respective interpretation quality levels. For each noticed relevant event, we assigned one to four points, with one point indicating a superficial mention of an event, and four points indicating an explicit description of the behavior with a detailed interpretation. For example, the statement scored with 1 in Table 3 does not contain a

Table 2 Training phase example comments for the different self-explanation prompts conditions

Open prompts condition	Focused prompts condition
At the beginning, the tutor tried to collect and then organize the students' naïve preconceptions about blood. This is important because the teacher should pick up on the everyday ideas of the students.[a] One student then also associated Dracula with blood, but the tutor did not go into this further. The tutor then asked how blood is pumped through the body. Here the different students described different procedures. Most of the students described it as being pumped into the arm, back to the heart and then on to the leg, and so forth. Only one girl said that she thought it was a cycle because it was called a blood cycle. The tutor then worked with this statement to provoke a conflict among the other students. The girl then said that there must be two cycles. One upper and one lower. The lower one flows into the two arms. *Then the tutor wanted to know whether or not the legs needed oxygen. Again, he wanted to provoke a conflict in the girl's thinking, since that can't be.* He then explained to her that it is just one cycle and how it works. *In the end, he wanted to check whether she understood and modified her knowledge but this was not the case. She did not understand it!* He wanted to come back to it later on. What I noticed was that while he was discussing with the girl, he was only talking to the girl and did not include the other children, even though they also had no real idea about the blood circulation. [not scored because the strategy was not part of the PCK introductory text][b]. The other students attended to other things during this time	T does not elicit students' misconceptions[c]: The tutor has the students speak about their ideas but does not respond to them, he does not provide relatable examples [incorrect] T evokes cognitive conflict: He responds to the girl's idea and clarifies that her idea is not fully correct [incorrect use of the "cognitive conflict" button] T elicits students' misconceptions: *He has the students explain their ideas (voluntarily)* T provides scientific alternatives: The tutor tries to correct the girl's misconception. However, he only responds to her and ignores the other students [incorrect use of the "providing alternatives" button] T checks for modifications: *The tutor asks the girl to once again demonstrate how the blood circulates (which she can't)* T does not evoke cognitive conflict: The other students don't listen to the conversation between the tutor and the girl [incorrect use of the "cognitive conflict" button] T does not check for modifications: *He only checked the girl on the right but he did not check for modifications in the other students' understanding*

Table shows example comments of two participants on training phase video 1 (*Brainstorming Video*); both participants read the PCK introductory text and watched the non-segmented videos; both comments were scored 3 in the training phase score; one point was awarded for each correctly identified strategy outlined in the respective introductory text;

[a] Italics: these phrases were awarded one point each;

[b] [Further information about why a statement was not scored];

[c] Underlined: title of the respective button the participant clicked on to write a comment.

description of one particular event but more an overall impression of the scene. Instead of a theoretical interpretation of a specific event, this comment contains assumptions about the student's learning process without a justification. In contrast, for example, the statements scored with 3 in Table 3 contain either thorough interpretations including a reference to broader teaching and learning principles ("Removal of the naïve preconception by pointing out scientific alternatives only becomes possible when the students doubt their previous assumptions.") or at least a detailed description of the event ("[The tutor] question[s] their prior knowledge, namely how oxygen gets into the blood") accompanied by some interpretation ("encouraging the students to question their knowledge"). Statements scored as explicit descriptions typically included some kind of direct or indirect quotation from the video. Single "buzzwords", that is, special terminology (e.g., *misconceptions, cognitive conflict,* etc.) mentioned without visible context, were usually not coded. However, the coders took a moderately liberal approach, and interpretations were coded as correct when it seemed obvious that a participant meant the right thing although the comment was written somewhat imprecisely. The mean rating of a participant's comments on relevant events constituted the *interpreting component* of the PV score.

Table 3 Example comments on event "following up on a student's idea" (Drawing Task Video)

Score	Description	Example comment
0	Event not mentioned	–
1	Superficial mention of the event; no explicit description; no theoretical interpretation	"The tutor asks critical questions that prompt learners to reflect. Deepening allows students to learn together and recognize the mistakes of others."
2	An explicit description, but no interpretation OR No explicit description, but some interpretation	"One student presents her drawing, but the lungs are missing. The tutor discusses with the students where the oxygen comes into the lungs." "Tutor asks specific questions to the students. Students recognize for themselves where their concepts contain illogical points. Tutor questions the existing ideas of the students. This stimulates the reflection process and leads to a more intensive discussion."
3	An explicit description AND some interpretation OR No explicit description, but a thorough interpretation (including reference to general teaching and learning concepts)	"After explaining, he asks a question that is supposed to move the students forward and question their prior knowledge, namely how oxygen gets into the blood, thereby encouraging the students to question their knowledge without telling them that it is wrong." "The tutor uses clever questions to create cognitive dissonance. In doing so, he addresses different ideas of the students and lets them check them on their sketches. The cognitive conflicts are caused by the students themselves. Removal of the naïve preconception by pointing out scientific alternatives only becomes possible when the students doubt their previous assumptions."
4	Explicit description AND a thorough interpretation	"The tutor brings oxygen into play in the first drawing and asks the students where it comes into the blood. The students realize that something in their drawing can't be right because they didn't pay attention to where the oxygen comes from. The tutor has thus evoked a cognitive conflict."

Additionally, we coded comments as *unfocused* when they mentioned general features of the situation rather than particular events. Comments in this category mainly contained general observations of classroom climate and the tutor's role in this small-group situation (e.g., "The tutor is really nice and relaxed. This behavior is relevant because it determines the learning climate."). We calculated the *unfocused* score by adding up the number of references a participant made to these topics within all comments on the two videos.

Two independent raters coded 35% of the pretest and posttest comments. We calculated intraclass correlation coefficients (ICC) based on a mean-rating ($k=2$), absolute agreement, and using a two-way random-effects model. According to Koo and Li (2016) interrater agreement was good for the noticing score (ICC [2,1] = 0.79) and the unfocused score (ICC [2,1] = 0.90) and excellent for the interpreting score (ICC [2,1] = 0.91). As we obtained sufficient interrater agreement, one rater coded the remaining comments.

Training phase

To explore whether there were any differences between the conditions during the training phase that did not translate to the posttest, we additionally coded the participants'

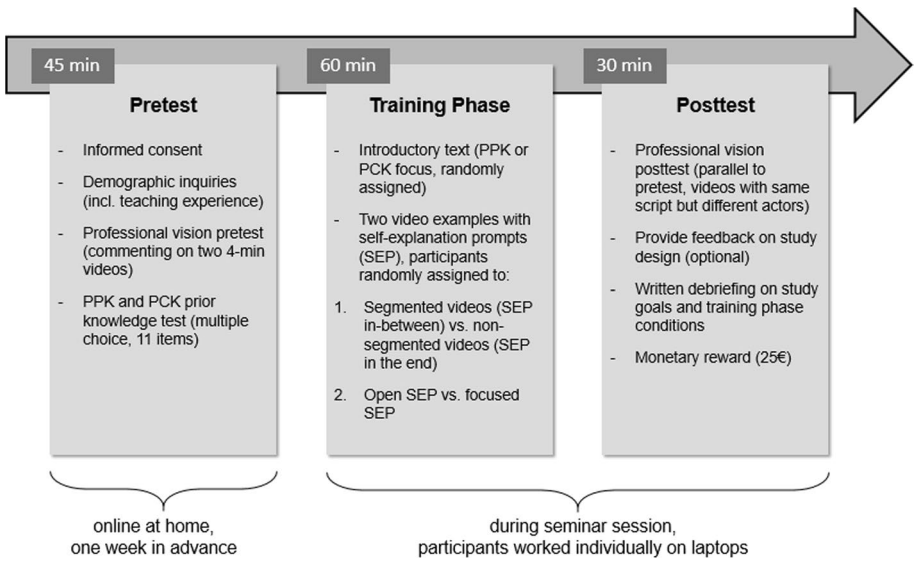

Fig. 4 Overview of the study procedure

comments on the training phase videos. The structure of participants' comments varied considerably, depending on the self-explanation prompts condition (see Table 2). For example, in the focused prompts condition, participants wrote fewer complete sentences, and rather used more of a "note-taking" style, as the interactive figure (see Fig. 3) already provided a text stem for the comments. Thus, to obtain a comparable measure, we used a different coding scheme than that of the pretest and posttest, which could be applied to the structure of both the open prompts comments and the focused prompts comments. As participants were instructed to link the introductory texts to the videos, we assessed their performance by counting references to strategies outlined in the introductory text.

Two independent raters coded all training phase comments. Each comment was assigned to one of eight introductory text categories (e.g., evoking cognitive conflict) or an "other" category when it referred to aspects not covered in the introductory text (e.g., the students' presentation skills). This coding scheme is also described in more detail by Martin et al. (2020). Interrater agreement across these nine categories was excellent with $\kappa = 0.88$. We computed participants' training phase scores as the sum of references to introductory text contents within their comments on the two videos.

Procedure

Figure 4 shows the study procedure in detail. The study included two parts. Participants could access the first part (pretest) via an online link and were given one week to complete it at home. They first granted their informed consent electronically to continue on to the study. The study started with demographic inquiries, including questions about teaching experience, number of courses attended, and previous experience analyzing teaching video examples. Next, participants worked on the PV pretest. There were two parallel versions of the two pretest videos based on the same scripts, but played by different actors; participants were randomly assigned one of the two versions for the pretest.

Participants watched the two video examples back to back without the opportunity to pause. Afterward, they commented on noticed events. Participants had to work on this commenting task for at least eight minutes. There was no strict maximum time limit, but most participants did not exceed the suggested eight-minute minimum. The first part of the study ended with a multiple-choice test on PPK and biology PCK. Completion of the first part took about 45 min in total.

The second part of the study contained the training phase and the PV posttest. Participants worked on the second part during one 90-min seminar session. In the training phase, they first read one of the two versions of the introductory text on tutoring strategies (PCK or PPK). Next, participants were instructed to apply what they had learned about tutoring when commenting on two video examples (videos: *Brainstorming* and *Exchange Student*). After each video (non-segmented condition) or video segment (segmented condition), respectively, participants analyzed the scene. To ensure that time on task was similar between the segmented and the non-segmented condition, we implemented a countdown, requiring participants to work on the analysis for a minimum amount of time. Thus, participants had to work at least 10 min (or $3+3+3+1$ min in the segmented condition, respectively) on the analysis of the first video before they could continue, and eight minutes (or $3+3+2$ min) on the analysis of the second video. The minimum time on task was defined based on pilot testing and depended on the length of the respective video (or video segment). Similarly, in the focused-prompts condition, participants had to comment on at least one event for each segment (segmented condition), or four events for the first video and three events for the second (non-segmented condition).

The PV posttest was parallel to the pretest. Participants who had analyzed version 1 of the video examples in the pretest, were assigned version 2 in the posttest, and vice versa. After the posttest, they received written debriefing and monetary reward (25€).

Results

Preliminary analyses

Participants in the eight training phase conditions did not differ significantly on any measure of pre-service teachers' pre-requisites (i.e., courses attended, final school grade, experience with teaching or tutoring, and theoretical PPK and PCK prior knowledge) nor in their personal interest in tutoring at the beginning of the study, all $ps > .05$. To check whether the two parallel pairs for the pretest and posttest video examples were similarly difficult, we compared the participants' PV change scores. We did not find significant differences between participants who watched version 1 of the videos in the pretest and version 2 in the posttest, and those who watched version 2 in the pretest and version 1 in the posttest in the noticing, interpreting, or unfocused change scores (all $Fs < 1$). Hence, the video order had no substantial effect on participants' improvement from pretest to posttest.

To check whether the introductory text (PPK vs. PCK) affected participants' learning, we computed a repeated-measures MANOVA with the pretest and posttest PV scores (i.e., noticing, interpreting, and unfocused) as within-subjects factor, and introductory text, segmenting, and self-explanation prompts as between-subjects factors. We found no significant effect of text condition on participants' improvement

Table 4 Means (standard deviations) of the pretest and posttest scores and training phase score

	Segmented videos		Non-segmented videos		All groups
	Focused PR	Open PR	Focused PR	Open PR	
	n = 18	*n* = 26	*n* = 26	*n* = 19	*N* = 89
Pretest and posttest scores					
Noticing[a]					
Pretest	2.28 (1.23)	1.92 (0.98)	2.35 (1.33)	1.89 (1.24)	2.11 (1.19)
Posttest	3.67 (1.28)	3.15 (1.08)	3.85 (1.38)	3.53 (1.22)	3.54 (1.25)
Interpreting[b]					
Pretest	2.00 (1.02)	2.02 (0.87)	2.14 (0.77)	2.04 (1.05)	2.05 (0.90)
Posttest	2.42 (0.55)	2.20 (0.66)	2.60 (0.60)	2.30 (0.52)	2.38 (0.60)
Unfocused[c]					
Pretest	2.28 (1.27)	1.92 (1.06)	2.12 (1.31)	2.21 (1.55)	2.11 (1.27)
Posttest	0.89 (0.83)	0.85 (0.88)	0.77 (0.86)	1.16 (1.17)	0.90 (0.93)
Training phase score[d]	13.78 (3.26)	9.73 (3.33)	7.69 (3.82)	6.74 (2.54)	9.31 (4.13)

[a] Number of noticed relevant events; Minimum (theoretical/observed in pretest/observed in posttest): 0/0/1, Maximum: 11/6/7; [b] Mean quality of description and interpretation of noticed events; Minimum (theoretical/observed in pretest/observed in posttest): 0/0/1, Maximum: 4/4/3.75; [c] Number of unfocused comments (not related to specific events in the video); Minimum (theoretical/observed in pretest/observed in posttest): 0/0/0, Maximum:—/6/4; [d] Number of references to the introductory text in training phase; Minimum (theoretical/observed): 0/2, Maximum:—/20

from pretest to posttest, Wilk's $\Lambda = .92$, $F(3, 79) = 2.23$, $p = .09$. Additionally, there were no significant interactions of text condition with segmenting, Wilk's $\Lambda = .99$, $F < 1$, $p = .84$, or self-explanation prompts, Wilk's $\Lambda = .99$, $F < 1$, $p = .96$. Thus, to obtain larger cell sizes, we pooled the two text conditions in our following hypotheses tests. For clarity, we present descriptive values separated only for the segmenting and self-explanation prompts conditions (see Table 4).

Main hypotheses

In a repeated-measures MANOVA, we included the pretest and posttest PV scores as the within-subjects factor, and segmenting and self-explanation prompts as between-subjects factors. As a measure of effect size, we report partial η^2, with values smaller than 0.06, between 0.06 and 0.14, and larger than 0.14 indicating small, medium, and large effects, respectively.

Independent from the training phase condition, we expected all participants to improve in their PV during the training phase (Improvement-Hypothesis). Overall, we found a significant main effect of time of test on PV, indicating an improvement from pretest to posttest, Wilk's $\Lambda = .44$, $F(3, 83) = 35.5$, $p < .001$, partial $\eta^2 = .56$. There was a significant increase for both the noticing score, $F(1, 85) = 88.4$, $p < .001$, $\eta_p{}^2 = .51$, and the interpreting score, $F(1, 85) = 9.33$, $p = .003$, $\eta_p{}^2 = .10$. The number of unfocused comments decreased significantly from pretest to posttest, $F(1, 85) = 60.1$, $p < .001$, $\eta_p{}^2 = .41$. Thus, participants improved in all three components of PV, with very large effect sizes for noticing and unfocused comments and a medium to large effect size for interpreting.

There was no significant interaction effect between time of test and segmenting, Wilk's $\Lambda = .99$, $F < 1$, $p = .82$, or between time of test and self-explanation prompts on the professional vision scores, Wilk's $\Lambda = .98$, $F < 1$, $p = .64$. Thus, contrary to our Segmenting- and Prompts-Hypotheses, participants did not improve more when they trained with

segmented videos compared to non-segmented videos and with focused self-explanation prompts compared to open prompts.

Explorative analyses

Although participants generally improved from pretest to posttest, we found no significant effect of the different training phase conditions on improvement. Therefore, we were interested in whether there were any differences in participants' performance *during* training when the pre-service teachers were supported by segmenting and focused prompting. Table 4 shows the number of references participants made to the introductory texts' contents when commenting on the two training phase videos. Participants who commented on the segmented videos made significantly more references to the introductory texts than participants who commented on the non-segmented videos, $F(1, 85) = 40.3$, $p < .001$, $\eta_p^2 = .32$. Participants who received focused prompts outperformed those who received open prompts, $F(1, 85) = 12.2$, $p = .001$, $\eta_p^2 = .13$.

Moreover, there was a significant interaction between the factors segmenting and self-explanation prompts, $F(1, 85) = 4.67$, $p = .03$, $\eta_p^2 = .05$. When commenting on the non-segmented videos, both types of self-explanation prompts evoked a similar amount of references to the introductory texts. However, in the segmented condition, where participants' multiple comments were spread out between video segments, the focused prompts evoked significantly more references to the introductory text than the open prompts.

To gain more insight into how participants perceived working with the training intervention, we looked for statements about the different training elements in their feedback comments. However, as we did not primarily aim to investigate participants' experiences during the training intervention, we did not systematically collect specific qualitative data for this purpose (e.g., by standardized interviews). Thus, the following comments simply provide a glimpse into participants' experiences, which could motivate further investigation of process data in a more standardized manner (e.g., *cued retrospective reporting, CRR*; Bender et al., 2021).

Introductory texts

In both text conditions, many participants commented positively on the introductory text. For example, they said that the "input at the beginning of the second part was helpful" and "provided a focus for the video analysis". Moreover, participants positively highlighted the structure of the texts, for example, "The text was very clearly arranged. This way I could easily capture the most central aspects and apply them to the videos" and "The diagrams [included in the text] helped a lot in understanding and remembering important aspects". Additionally, several participants commented on the topic of small-group tutoring, for example, that they "gained interesting insights into a relevant topic for teachers" and that they "got some inspiration for future lessons". We conclude from these comments that the texts' structure and scope were appropriate for supporting participants in their analyses.

Video examples

Overall, participants perceived the video examples as helpful. They, for example, liked that the videos "were related to one particular topic" and that one "could compare the sequences". Especially those participants who had not worked with videos before, commented that the video examples "vividly showed the topic" and were "fun". However, several participants found it suboptimal that the videos were scripted. They said, for example, that "some situations seemed quite artificial" and that "real videos would have been more interesting". Regarding the length of the video examples, participants' opinions were quite heterogeneous. While some perceived the video length and study duration as just right, others commented that "the videos were too long" and it was "difficult to remember the video's content". Additionally, participants had differing views on the segmented videos. Some participants in the segmented condition liked "that the videos were segmented into small parts" because they "did not have to remember so many things". The posttest video, however, was "too slow and too much" in their opinion. In contrast, other participants did not like the segmented videos in the training phase. They, for example, commented that it was "way too much video material" and that they would prefer "less video sequences". Thus, although most participants found video examples in general helpful to work with, there are still relatively high expectations for the design of the videos (e.g., in terms of authenticity).

Self-explanation prompts

Contrary to the introductory text and the video examples, participants made relatively few comments about the self-explanation prompts. Moreover, only participants who had received the focused prompts commented about them. They perceived the focused prompts as supportive and stated, for example, that "the blue and green ovals provided guidance on what to focus on in commenting" or that "the ovals were helpful in structuring the comments". None of the participants commented that they did not like the format of the focused self-explanation prompts in general. However, one participant suggested providing a list of their previous comments, so they can make sure not to forget anything. To conclude, participants in general appreciated the additional support provided by the focused prompts.

Discussion

The aims of the present study were twofold: First, we investigated effects of a single-session training intervention on pre-service teachers' PV. We expected that the training intervention consisting of a short introductory text about small-group tutoring and exemplifying videos would foster pre-service teachers' ability to notice and interpret relevant tutoring strategies. Second, we applied two design principles from multimedia learning research to the training intervention to investigate differential effects of design. We hypothesized that both segmenting the video examples and using focused self-explanation prompts for analysis would lead to a higher increase of PV compared to non-segmented videos and open prompts through the course of a one-hour training.

After the training phase, the pre-service teachers noticed more relevant events in a video of small-group tutoring (e.g., the tutor reacting in a suboptimal way to a student's incorrect answer) and relied more on theoretical knowledge in their interpretations than

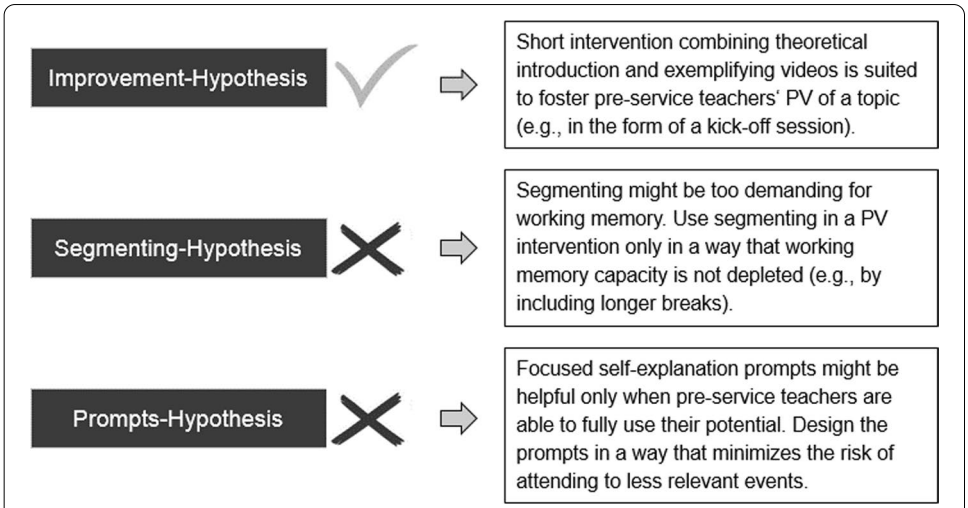

Fig. 5 Summary of the results and main implications

before training. Additionally, the number of unfocused comments (e.g., about classroom climate) decreased. Thus, the pre-service teachers improved on all PV indicators during the course of the study. Especially with regard to the interpreting component of PV, this finding is remarkable, as interpreting noticed events based on theoretical knowledge seems to be particularly challenging for pre-service teachers (Jacobs et al., 2010; Stürmer et al., 2016).

Contrary to what we expected, there were no differences in improvement between the different training conditions. Participants did not improve further in the posttest, when they analyzed training video examples that were segmented into meaningful units or when they received additional support for analysis through focused self-explanation prompts. During training, however, both measures supported the pre-service teachers in linking observations from the video to knowledge about tutoring strategies outlined in the introductory text. Thus, we may not speak of an effect *of* segmenting and focused self-explanation prompts but only *with* segmenting and focused prompts (Salomon, 1990).

The remainder of this discussion section consists of two main parts. First, we discuss four potential explanations for why the additional support measures may not have resulted in higher learning gains in the respective conditions. The first of these explanations concerns segmenting; the second focuses on self-explanation prompts; and the remaining two explanations might apply for both support measures. We conclude each section with implications for further research. Additionally, Fig. 5 summarizes our main findings and implications for each of the hypotheses.

In the second part, we take a broader perspective that goes beyond the particular support measures investigated here. We take a look at the basic idea of applying general design principles from multimedia learning to the teacher education context (especially in PV). Additionally, we discuss advantages and potential downsides of the single-session intervention format used in this study. Based on our findings, but also on

theoretical considerations, we formulate some implications for further research on the one hand and for teacher education practice on the other hand.

Explanation 1: Segmenting is tiring, resulting in depleted resources for working on the posttest

Explanation: Segmenting the videos supported pre-service teachers in their analyses on the one hand. On the other hand, with the repeated disruption of the natural flow of events, a reduction in authenticity might have come at the expense of segmentation. Additionally, in the segmented conditions, participants had to comment on the training phase videos seven times in total, whereas in the non-segmented conditions participants commented only twice. Thus, participants in the segmented conditions might have perceived the task as more demanding. When working on a task without breaks (massed practice), working memory resources get more easily depleted compared to spaced practice with breaks between tasks wherein resources can be restored (Chen et al., 2018). Although the segmented conditions seemed to provide such breaks at first sight (by switching the task of watching and commenting more often), the opposite might be the case. The required minimum time on task was the same for all participants; however, participants in the non-segmented conditions might not have used the entire time for commenting on the task. As it was more difficult for them to recall important events from the long video, they might have stopped commenting at some point and just waited for the timer to run down. In the segmented conditions, however, participants recalled more relevant events, so they really used the entire minimum time on task for commenting. Thus, participants in the non-segmented conditions might have had a small break between the training phase videos, allowing them to restore their working memory resources, while participants in the segmented conditions were active throughout the entire training phase and thus suffered more from fatigue and working memory resource depletion.

We did not find any significant differences in participants' cognitive load that would support this claim. However, in an open feedback box, 14 participants in the segmented conditions stated that they struggled with staying focused through the course of the study, while only four in the non-segmented conditions did. Thus, participants in the segmented conditions might have indeed benefited more from the training but did not show all their learning gains in the posttest, as they had less working memory resources left for completing the posttest task.

Ideas for future work: In further studies, not providing the posttest immediately, but rather with some delay (e.g., one week) after training might cancel the effects of fatigue and resource depletion. Additionally, when implementing a PV intervention with several alternating phases of video viewing and comment writing, teacher educators should make sure to schedule enough breaks so as not to overload learners' cognitive capacities.

Explanation 2: Focused self-explanation prompts were not focused enough

Explanation: Focused prompts should raise the quality of self-explanations, as they direct the learner's attention away from irrelevant aspects (Wang & Adesope, 2017). However, in this study, the design of the focused prompts might not have fulfilled its purpose. Participants who received the focused prompts indeed made more comments

about relevant events (i.e., strategies that were outlined in the introductory text) than those who received open prompts. However, they also commented more on irrelevant events—on average, eight comments compared to about five in the open-prompts conditions.

Participants might have misperceived the focused prompts as an invitation to be behaviorally active by clicking on as many options as possible, which is a risk of providing interactivity in learning environments (Atkinson & Renkl, 2007; see also *active responding theory*; Robins & Mayer, 1993). On the one hand, the provided text stems facilitated comment writing, but on the other hand, they might have lured participants into placing quantity over quality. Writing comments without provided text stems, however, required more effort, so participants in the open-prompts conditions might have been more selective in what events they perceived relevant enough to comment on. Thus, although participants in the focused-prompts conditions commented on more relevant events than participants in the open-prompts conditions, they still might have spent less time elaborating on them.

Ideas for future work: Further studies could investigate self-explanation prompts that provide even more guidance, thereby minimizing the risk of focusing on irrelevant aspects (e.g., drag and drop task with a list of relevant events already provided). Another option to increase guidance could be step-by-step prompts that explicitly guide the preservice teachers in commenting on observed events.

Explanation 3: The transition from high support to no support is difficult

Explanation: The third explanation applies for both segmenting and focused self-explanation prompts. Throughout the training phase, participants in the segmented conditions immediately commented on short segments that already structured the information and highlighted single events. In the non-segmented conditions, however, participants practiced recognizing relevant events in a steady flow of information, keeping their thoughts in mind until the end of the video. The posttest video was non-segmented and required from the participants exactly what was practiced in the non-segmented conditions. Similarly, participants in the open-prompts conditions practiced writing their comments freely and structuring them themselves—which was also required in the posttest—while participants in the focused-prompts conditions never practiced writing a comment from scratch.

According to the concept of *Transfer Appropriate Processing* (*TAP*; Morris et al., 1977), learners perform best when the activity required in an assessment task resembles the activity that had to be performed during training. In our study, participants in the non-segmented and open-prompts conditions were already familiar with the posttest task and thus, they had an advantage over those participants who received support during training (through segmenting, focused prompts, or both). This advantage in the posttest might have compensated for the differences that were present during training.

To facilitate transfer, one could alter the assessment task to make it more similar to the training task. However, when teaching in a real classroom, teachers can neither stop a situation to immediately think about an event, nor receive scaffolds that help them access their theoretical knowledge about teaching and learning. Thus, in the long-term,

PV interventions should ultimately prepare pre-service teachers to analyze classroom situations without support.

Ideas for future work: While segmenting and focused self-explanation prompts are applied to single elements of a learning task (i.e., one video example or one analysis task), the structure of the whole course should also follow instructional design principles. For a PV course aiming toward the long-term goal of pre-service teachers being able to notice and interpret important events without support, the *Four Components of Instructional Design (4C/ID)* approach for training complex skills (van Merriënboer & Kirschner, 2018) suggests transitioning from high support during the early phases of training to no support during the final phase of training.

The intervention presented in this study was designed as a single session that can be flexibly integrated into existing courses in teacher education (e.g., as a kick-off intervention). However, to facilitate application of the skills learned in this supported environment, one could add an additional fading phase in which support is gradually reduced step-by-step. In terms of the self-explanation prompts, fading from focused prompts (e.g., fill-in-the-blanks) to open prompts (e.g., open questions) has shown to be effective in other learning domains (Berthold et al., 2009). For segmenting, of course, one opportunity for fading could be a stepwise increase in segment length. However, the task of segmenting classroom video is not trivial, so it might not be possible to segment a classroom video into segments of the desired length (Hennessy et al., 2016). Another option for fading the support of segmenting could be to separate the two types of support that segmenting provides—highlighting the structure of the information and providing more processing time. To apply fading, one could first withdraw the additional processing time between segments, but maintain the support of highlighting structure, for example, by temporarily darkening the screen at meaningful times (Spanjers et al., 2012). Further studies could investigate whether the beneficial effects of segmenting and focused self-explanation prompts during training could translate to the posttest when the intervention is designed according to 4C/ID, meaning that the task is not changed all at once, but rather support is slowly faded out.

Explanation 4: Large effects of the intervention itself overshadowed smaller effects of specific support measures

Explanation: Overall, participants improved to a substantial degree in their PV during the training intervention (large effects for noticing and unfocused comments, medium effect for interpreting). We interpret this large improvement as being a result of our intervention design, which followed established guidelines for using video in teacher education (Kang & van Es, 2019). Thus, the combination of a theoretical introduction into a topic and analysis of corresponding video examples might already have been enough to exploit the major advantages of video. However, additional support measures (i.e., segmented videos and focused self-explanation prompts) had no additional effects on participants' improvement.

While video is considered a valuable tool to foster (pre-service) teachers' PV (Gaudin & Chaliès, 2015), it is still not used extensively in initial teacher education (Christ et al., 2017). For this study, almost half of the participants (43%) indicated that they had not yet worked with video of any form in the course of their studies. Moreover, the topic of

small-group tutoring was relatively new to the participants. The large improvement in PV stemming from a gain in theoretical knowledge and practicing with video examples might have overshadowed smaller differential effects of the additional support measures segmenting and focused self-explanation prompts.

Similarly, in a meta-analysis on simulation-based learning in higher education, Chernikova et al. (2020) found a large beneficial effect of simulations in general but only minor additional effects of extra scaffolding measures within simulations (e.g., checklists or step-by-step guidance). Both simulations and video analysis can be seen as new, interesting, and "refreshing" (as some of the participants in the present study stated) ways of learning. According to the *novelty effect* (Clark, 1983), learners encounter new and unfamiliar media or technologies (such as video or simulations) with increased motivation and effort, which results in high learning gains especially in the beginning of training. However, this initial increase of motivation decreases with time, and beneficial effects of the medium itself disappear when learners get more familiar with the new media and technologies. In sum, the large overall improvement we found in this study could be explained by the fact that both video analysis and the topic of tutoring were relatively new to the participants and the combination of a theoretical introduction and corresponding video examples already provided high support. This overall improvement might have overshadowed smaller differences between the training phase conditions.

Ideas for future work: Further studies should investigate whether specific support measures in video-based interventions show their full potential when participants are already used to working with video in order to avoid novelty effects. Moreover, in the present study, the introductory text might have already contributed a great deal to the pre-service teachers' PV improvement. Thus, further studies could investigate a topic more familiar to the participants, so that an introductory text serves more as a reminder instead of providing new knowledge. Reducing the impact of the introductory text on participants' improvement might make subtler effects of video design and prompt type more visible.

Limitations and further studies

Beyond the suggestions in the preceding sections, we want to propose additional ideas for future work that arise from some of this study's limitations. In this study, we assessed learning outcomes only within an immediate posttest. Thus, participants had already worked on video analysis for an hour and might have been tired and not fully focused. With this limitation in mind, it is remarkable that we did find such a strong increase in performance. However, this increase could also be due to short-term effects. Thus, further studies using a delayed posttest could investigate whether such a condensed training intervention is also suited to induce lasting effects on pre-service teachers' PV.

To enhance comparability between pretest and posttest, we used videos that were based on the same scripts but played by different actors. Although they were not identical, we cannot rule out potential effects of repetitive practice due to exposure to the same scenes twice. However, pretest and posttest were separated by about a week and participants watched different videos in between, so we assume that pure repetitive practice played a minor role, if any. Nevertheless, in further studies, an additional control group that does not receive the intervention might help to disentangle effects of the intervention from pure effects of repetitive practice.

Implications for research and practice

Considering that PV is a complex skill that takes years of training and experience, this study's single-session intervention on the very specific topic of small-group tutoring interactions may seem limited in both duration and scope. However, we argue that such single-session PV interventions nevertheless provide a valuable tool for teacher education research and practice. First, short interventions allow systematic investigation of single training elements. With relatively little time and money spent, the effectiveness of different video types, instructions, or additional support elements can be experimentally compared. In the present study, we investigated the design principle of segmenting as well as two types of self-explanation prompts. However, this study procedure could be also used as a template for examining effects of other design principles from multimedia learning (e.g., the signaling principle; van Gog, 2014) to determine those principles that bring the most benefit to the context of teacher education.

Another potential research question to investigate with such a study template concerns the different facets of pre-service teachers PV. One could, for example, compare whether different interventions have different effects on their noticing, interpreting, and decision-making. Moreover, teacher educators could use such a condensed video-analysis program for assessing major deficits in their students' PV, so they can tailor further instruction to the specific needs of their students. Thus, single-session interventions provide a practical research tool to investigate both the effectiveness of PV training elements and the quality of pre-service teachers' PV components on a micro level (Farrell et al., 2022). Insights gained on the micro level can then be used to inform decisions about the curricular embedding of video analysis in teacher education (Blomberg et al., 2013).

Second, despite its short duration, the intervention investigated in the present study significantly improved biology pre-service teachers' PV of tutoring interactions, probably because the development of complex skills such as PV follows a power-law of practice, predicting a steep increase in performance in the early phases of learning (Newell & Rosenbloom, 1981). Hence, single-session interventions could offer a complement to longer PV interventions such as the video clubs (van Es & Sherin, 2021). One major advantage of such a condensed intervention format lies in its potential to be embedded flexibly into various course formats at various stages of teacher professional development. At university, single-session PV interventions provide an opportunity to integrate practice examples—for example, in the form of a kick-off session—into courses focusing on educational theories, instructional design, or even subject matter, and thus answer the call of teacher educators and researchers to overcome the theory–practice gap in initial teacher education (McDonald et al., 2013).

In the later stages of teacher professional development, where teachers have limited time for continuing training in addition to their daily classroom practice, having condensed PV training formats available might also be particularly helpful. The intervention used in the present study was tailored to the particular prerequisites of pre-service teachers in the early stages of teacher education (i.e., limited prior knowledge, little to no classroom experience). However, support measures that are beneficial for novice learners sometimes have no effect or even negative effects for more proficient learners (see *expertise-reversal-effect,* e.g., Lee & Kalyuga, 2014). Thus, we cannot assume that this particular intervention, which contains a high level of support (e.g., tailored introductory texts, short video clips instead of whole lessons, and focused analysis questions), would be appropriate for expert teachers

with higher levels of theoretical prior knowledge or more classroom experience. We recommend considering the particular needs of the target group (pre-service teachers, beginning teachers, or experienced teachers) when designing PV training interventions.

Conclusion

In this study, a video-based training intervention that followed research-based recommendations for aligning theory and practice (Blomberg et al., 2013; Kang & van Es, 2019) effectively fostered pre-service teachers' PV of tutoring interactions. Additional support in the form of segmenting the videos and focused self-explanation prompts for analysis increased performance during training. However, this advantage during training did not result in higher learning gains assessed with a video-analysis task without supports. Further research is needed on how this additional support is best implemented to obtain an effect not only *with* but also *of* segmenting and focused self-explanation prompts. We conclude that short PV training interventions provide both a valuable research tool for investigating the effectiveness of design elements of video-analysis tasks on a micro level and a practical template for fostering the integration of theory and practice at various stages of teacher professional development.

Appendix

See Table 5.

Table 5 Example of a segmented video (brainstorming video) and corresponding key concepts from introductory text one could recognize

Segment	Duration	Content	Key concepts from introductory text
1	3:28 min	T begins the session by collecting the students' associations on the term "blood" (example answers: "Body", "Heart", "Dracula"). T then asks the students to eliminate those answers that are not relevant to the biology context (e.g., "Dracula"). T then states the circulatory system as the topic of the session	Group focus (PPK; student-centered) Elicitation of prior knowledge (PPK; student-centered)* Diagnosis of misconceptions (PCK; student-centered)* * *although quite superficially*
2	1:48 min	T asks if someone has already heard about the circulatory system and could explain how the blood flows through the body. Two students utter the "back-and-forth"-misconception, one student (S3) utters the "two-cycle"-misconception	Elicitation of prior knowledge (PPK; student-centered) Diagnosis of misconceptions (PCK; student-centered) Reacting to incorrect answers (PPK; student-centered & instructive)
3	2:31 min	T sits down near S3 who holds the "two-cycle"-misconception and asks her to explain in detail how she imagines these two cycles. He then asks her how the oxygen would come to the legs if there were two completely separate cycles. While T focuses on S3, the other students lose interest and start doodling and chatting. T finishes his explanation for S3 with the question "Did you understand that?"	Diagnosis of misconceptions (PCK; student-centered) Initiating cognitive conflict (PCK; student-centered) Group focus (PPK; instructive) Assessment of understanding (PPK; instructive)
4	0:24 min	T turns to the rest of the group again, students stop chatting and doodling. T then puts a schematic diagram of the circulatory system onto the whiteboard and asks S3 to show the other students how she imagines the blood to flow	Group focus (PPK; student-centered & instructive) Checking for modifications (PCK; student-centered)

Abbreviations
CE: Communicative Event; PCK: Pedagogical Content Knowledge; PPK: Pedagogical-Psychological Knowledge; PV: Professional Vision.

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Authors' contributions
AR, MF, MM, TS, and WR constructed the study design and materials used during study collection. MF and MM realized data collection. AR and MM analyzed and interpreted the data. MM wrote the original manuscript draft. All authors contributed in revising the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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