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Research

Content-related solution quality in invention activities and worked solutions – promoting the professional vision of classroom management

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Abstract:

Invention activities and worked solutions are considered to be effective learning tasks. To date, limited research has been conducted regarding these tasks in teacher education and the process of solving these tasks. This study focuses on the solution quality of student teachers' task solutions. 149 students were randomly assigned to one of two experimental conditions: invention activity and worked solution. The latter group were given a set of categories; the former group had to invent their own categories to compare two constructed contrasting auditive cases with a focus on the subject classroom management. To determine whether it is more effective to compare cases with given categories (worked solution) or with self-generated categories (invention activity), we coded the 149 solutions regarding the content-related solution quality using qualitative content analysis. Students in the worked solution condition demonstrated a significantly higher content-related solution quality than those in the invention activity condition. Thus, it may be assumed that students of the worked solution gained a better conceptual understanding of classroom management through working on this task. Implications for the use of this task format in teacher education are discussed.

Keywords: Content-related solution quality, Invention activities, Worked solutions, Classroom management, Professional vision

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INTRODUCTION

In teacher education, invention activities and worked solutions have barely been researched although they have great potential for teacher students acquiring conceptual knowledge and transfer skills. An increasing interest has also been shown in these task formats in instructional research (Loibl et al., 2017). A large number of studies on these task formats have been conducted, generally in school-based learning settings, often in science and mathematics (Loibl & Rummel, 2014; Schwartz et al., 2011). In higher education, only a limited number of studies have been performed in teacher education (Glogger-Frey et al., 2022) and other domains (Holmes et al., 2014; Wiedmann et al., 2012).

Invention activities, in line with the problem-solving prior to instruction approach, are characterized by two sequential phases. First, learners are presented with contrasting cases, on the basis of which they are asked to solve a given problem. This activity aims to activate learners' prior knowledge, to raise learners' curiosity about the new topic, to promote learners' awareness of their own knowledge gaps and to enable visualization of deep features of the topic to be learned (Loibl et al., 2017; Wedde et al., 2021). Second, learners receive instruction on the new topic, which includes providing the canonical solution to the task (Schwartz et al., 2011).

Several studies have been conducted in which learners' task solutions were part of the evaluation. However, rather than these task solutions being analyzed in detail for their content, the studies investigated, for example, the matching number of items in the task solution with the canonical solution (Loibl & Rummel, 2014), the appropriateness of the task solutions (Glogger-Frey et al., 2022) or the students' answers depending on the topic to be learned (Wiedmann et al., 2012).

Presenting learners with contrasting cases may be used as a tool to foster student teachers' analytical competences, and hence their professional vision. Analytical competence is defined as the ability to perceive and evaluate the quality and learning effectiveness of observed classroom teaching (Plöger et al., 2020). In their study, Plöger et al. (2020) concluded that analytical competence consists of two dimensions, the content dimension, comprising pedagogical knowledge and content knowledge, and the formal dimension, referring to the 'complexity of information processing'. Drawn from this theoretical perspective, we divided the solution quality into two dimensions: analytical solution quality and content-related solution quality (Wedde et al., under review).

In another study, the analytical dimension of solution quality (see Figure 1) was assessed by addressing the question of how deep the student teachers' comparisons were on an analytical level (Wedde et al., under review). The present study focuses on the content-related dimension of solution quality, in connection with the question of what content-related quality the student teachers' task solutions demonstrate in terms of professional vision of classroom management. There were two experimental conditions. One experimental group compared two contrasting auditive teaching examples about classroom management, in line with a worked solution, on the basis of given categories. The other experimental group, the invention activity, compared the auditive teaching examples using self-generated categories.

To assess content-related solution quality, the solutions of 149 student teachers were coded in terms of their naming of categories relevant to classroom management. The purpose of the evaluation is to provide insight into what students compared in their task solutions prior to receiving instruction on classroom management. Additionally, the question is addressed as to whether it is more beneficial for the content-related solution quality for students to work with the invention activity or the worked solution. Thus, conclusions on the quality of solution quality have been drawn, taking into account the results of analytical solution quality, which are presented in a further study (Wedde et al., under review).

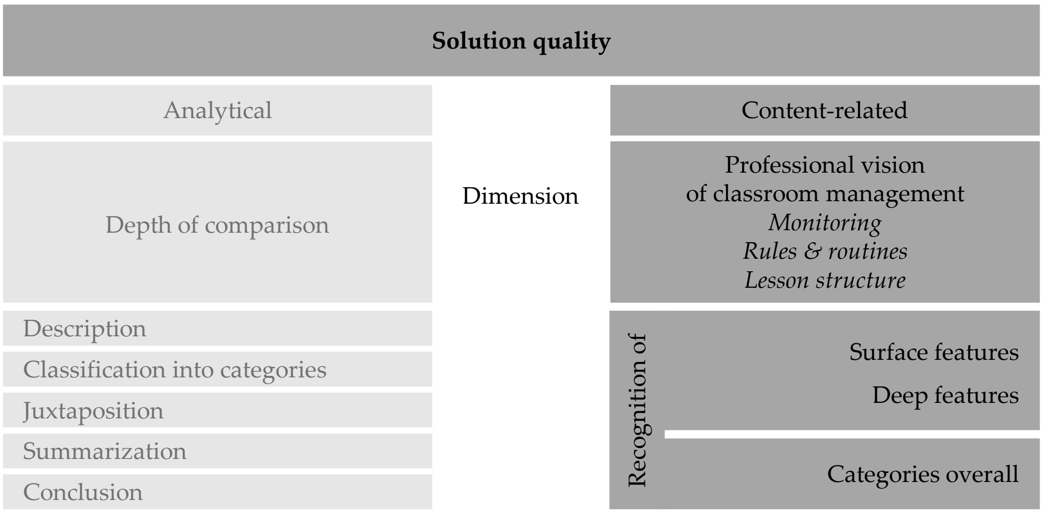

Figure 1. Construct of Solution Quality

Becoming a proficient classroom manager

From a theoretical point of view, classroom quality can be divided into emotional support, instructional support and classroom organization (Pianta et al., 2008). Emotional support relates to classroom climate and relationships within the classroom. Instructional support covers how teachers engage students' higher order thinking or the quality of teacher feedback. The dimension classroom organization reflects classroom management, the focus of this study.

Thus, we define classroom management as a teacher's actions in organizing a class and guiding classroom activities with the goal of maximizing active learning time and creating a classroom climate that facilitates academic and social-emotional learning (Evertson & Weinstein, 2006; Kunter & Voss, 2013). As key aspects for authentic relationships between students and teachers mutual trust and respect may be considered prerequisites for successful classroom management (Hammond, 2014). In addition to establishing a supportive and caring relationship with learners, the teacher is also responsible for organizing instruction to initiate effective learning processes and for preventing or responding appropriately to classroom disruptions (Evertson & Weinstein, 2006). Thus, classroom management is considered not only as behavioral but also as a support function of instruction (Martin & Sass, 2010). In particular, classroom management strategies focus on preventing disruptions. Consequently, classroom management has a significant positive impact on student achievement and promotes learners' social and emotional development (Kunter & Voss, 2013; Seidel & Shavelson, 2007).

Following Gold et al. (2020), classroom management may be categorized into three facets: *monitoring*, *rules & routines* and *lesson structure*. *Monitoring* includes the strategies withitness and overlapping (Kounin, 1970). Withitness refers to the teacher giving students the impression that they have an overview of everything occurring in the classroom. Overlapping describes the ability to engage in parallel actions in the classroom by maintaining an activity. Effective *monitoring* also involves praising students' positive behaviors and thus does not focus on negative behaviors. If classroom disruptions occur, the teacher can either ignore them or ensure that they are dealt with quickly, briefly and without a great deal of attention (Landrum & Kauffman, 2006; Simonsen et al., 2008).

Rules & routines are used for organized activities and for practicing routinized forms of learning (Emmer et al., 1980). The teacher should regularly recall established rules and note that different rules and routines are significant for different phases of instruction. *Lesson structure* refers to the design of transitions between different phases and activities as well as to managing instruction and activities. Kounin (1970) described the techniques smoothness and maintaining a momentum, meaning the ability of a teacher to organize and create smooth transitions and an activity flow. Further elements considered essential for an effective classroom management are clear instructions and presentations of the topics to be learned in terms of a structured learning environment and appropriate lesson planning including appropriate time management and transparency of the conducted lesson (Emmer et al., 1994; Evertson et al., 2006).

Young teachers often face difficulties in applying effective classroom management strategies. These difficulties also impact teachers' health (Chaplain, 2008). Thus, it is essential to foster student teachers' professional vision of classroom management as early as possible. With a professional vision of classroom management, teachers are able to perceive classroom management-related events in a timely manner and respond to the incidents in a situationally appropriate way (Gold et al., 2020). Thus, professional vision describes the ability to identify events that promote and hinder learning (noticing) as well as to interpret them in a theory-based manner (knowledge-based reasoning) in order to be able to react to them accordingly (Seidel & Stürmer, 2014; Sherin, 2007). These two knowledge-based interrelated sub-processes are part of a teacher's professional competence

(Sherin, 2007) and are considered learnable (Stürmer, Seidel, & Schäfer, 2013). Applying these two sub-processes requires teachers to possess conceptual and declarative knowledge (König et al., 2014; Stürmer, Könings, & Seidel, 2013). A teacher's professional vision is related to student learning (Kersting et al., 2012).

Teaching can be characterized by multidimensionality, simultaneity, immediacy, unpredictability, publicness and history (Doyle, 2013). Thus, teaching is a cognitively demanding activity, which is why novices and experts differ in their professional competence and professional vision (Berliner, 2001; Bromme, 2001; Carter et al., 1988). Empirical studies have shown that experts are able to draw on elaborated, networked and retrievable schemata as well as on specific case knowledge (Berliner, 2001; Borko & Livingston, 1989; Carter et al., 1988). Since novices are still developing these schemas and have yet to acquire specific case knowledge, they often have difficulties noticing important events in the classroom and distinguishing them from unimportant events. They tend to refer to superficial features instead of perceiving significant features related to teaching (Star et al., 2011; van den Bogert et al., 2014). Novices are more likely to perceive students' disciplinary behavior and demeanor, whereas experts refer to a learner's learning processes and actions that promote learning (Wolff et al., 2015; Wolff et al., 2017). Hence, developing a professional vision of classroom management necessitates student teachers gaining situational, i.e., case knowledge (Berliner, 2001), and declarative and conceptual knowledge about classroom management (Gold et al., 2020).

Use of contrasting cases in teacher education

From an empirical perspective, the effectiveness of training to promote professional vision among student teachers has been widely demonstrated, often using videos (Barnhart & van Es, 2015; Gold et al., 2020; Stürmer, Seidel, & Schäfer, 2013). These trainings have in common that learners first receive instruction before they analyze cases. Although it is known that the analysis of constructed videos promotes the acquisition and transfer of theoretical knowledge among student teachers (Anderson & Lignugaris/Kraft, 2006; Moreno & Valdez, 2007), few studies have been conducted on constructed video cases in teacher education. One advantage of constructed cases is that theoretical principles can be clearly outlined in the examples, which can also contrast specific behaviors related to a concept in the cases. This contrast can be particularly effective for novices, as it makes expert practices more recognizable by contrasting them with problematic teacher practices (Piwowar et al., 2018). By presenting a problematic case, students may also develop negative knowledge, i.e., knowledge of how something does not work (Oser et al., 2012).

A study conducted with student teachers to examine the effect of contrasting videos showed that the control group, who were only shown the same video case twice, demonstrated higher conceptual understanding than the student teachers who were shown two contrasting video cases with different instructional methods (Nagarajan et al., 2004). In an additional study, the researchers found that support in the form of guiding questions was beneficial in analyzing contrasting cases (Nagarajan & Hmelo-Silver, 2006). Another study used written physical education teaching examples to examine the effect of comparison. One group received "good" examples, another received only "problematic" examples and the third group received "problematic" examples in addition to the "good" examples. The third group achieved the best results in terms of lesson planning skills and the development of constructivist beliefs (Heemsoth & Kleickmann, 2018).

To date, no studies have examined the potential of auditive case comparison to promote the professionalization process of student teachers. Therefore, this study focuses on comparing two constructed contrasting auditive teaching examples. The following advantages are assumed for the use of constructed contrasting auditive teaching examples:

- A focus on the communicative actions of teachers: Through the auditive perception, the focus is particularly directed to the verbal level of classroom management. In this way, students first learn verbal strategies of classroom management before acquiring nonverbal strategies.
- A reduction of complexity: According to the cognitive theory of multimedia learning, to analyze audiovisual information such as classroom videos, learners process information through both the visual and auditory channels in working memory (Mayer, 2009). If auditive teaching cases are used, the information is mostly processed through the auditory channel. Proficient readers are also able to process information in the auditory channel first, but they are able to form a mental image from listening, which is then processed in the visual channel (Mayer, 2009). Although the modality principle in multimedia learning argues that limited capacity in working memory makes it more effective to present information using both the visual and auditory channels (Low & Sweller, 2009), this argument may not be fully transferable to student teachers acquiring analytical competence. The visual component in videos does not necessarily improve a novice's comprehension process, rather it adds another component to the complexity of the case to be analyzed. Novices may quickly suffer cognitive overload when analyzing videos as they cannot cognitively process the large amount of information they are confronted with in videos at the same pace as it is presented (Erickson, 2007). Thus, effective learning processes is more likely to be hindered. Similarly, Syring et al. (2015) showed that videos induced higher extrinsic cognitive load and cases presented as text induced lower extrinsic cognitive load among student teachers. Our studies showed that students experienced relatively low extrinsic and intrinsic cognitive load after comparing auditive cases (Wedde et al., under review, 2021). Therefore, to facilitate the competence acquisition process, auditive cases are used to direct student teachers' attention to essential information.
- More motivating than text: The use of text and video as cases has been studied in terms of motivational-emotional processes related to student teachers' learning.

Video cases were found to induce higher immersion and enjoyment among students during learning (Syring et al., 2015). Thus, for the present study, we assumed that auditive cases may be more motivating than cases presented as text at lower cognitive load since auditive teaching cases, for example, also raise learners' curiosity about the topic to be learned (Wedde et al., 2021). For example, it is easier to convey emotions via auditory media than via written case descriptions since emotions are transmitted more via the voice, volume and expressions of the person speaking (Häusermann, 2010).

- Contrast through design: The contrast between two cases is evident due to the variation of a concept’s deep features. Surface and less significant features can be held the same while significant features of a concept can be varied in constructed teaching examples to direct the focus to deeper features of a concept. This allows a concept’s features to be better illustrated and elaborated. Therefore, students may be able to clearly notice the contrast between the successful example, i.e., actions of an expert teacher, and the less successful example, i.e., actions of an inexperienced teacher (Piwowar et al., 2018). In our examples, deep features of classroom management, e.g., dealing with disruptions, were intentionally varied while surface features irrelevant for the task solution, e.g., the topic of instruction, remained the same. According to the expertise paradigm, experts are known to tend to categorize problems on the basis of deep features and novices to tend to categorize them on the basis of surface features (Chi et al., 1981).

While there have already been some evaluated trainings that specifically promoted student teachers' professional vision, only a few have focused on professional vision of classroom management (Barth, 2017; Gold et al., 2020). These research projects have in common that the professional vision of classroom management was surveyed or promoted using a video-based approach. The current project focuses on promoting professional vision of classroom management by comparing two contrasting auditive teaching examples. The comparison of contrasting teaching examples was investigated as a task format to promote the acquisition of a professional vision of classroom management among novices.

Use of different tasks for comparative activities: Invention activities and worked solutions

Invention activities are considered an effective learning method for acquiring conceptual knowledge (Loibl et al., 2017), which, along with declarative knowledge, is the basis for professional vision (König et al., 2014; Stürmer, Könings, & Seidel, 2013). To date, there have been no studies that have investigated this learning format in teacher education, on the topic of classroom management, or with a focus on the comparison process. Schwartz et al. (2011) showed in their study with eighth graders that, by working with contrasting cases in an invention activity, the deep structure of the concept to be learned is more likely to be remembered and to be applied in transfer. Students who learned in the experimental condition with direct instruction tended to only recall surface features without acquiring conceptual understanding.

Inventions activities have been particularly studied in science, mathematics and school-based settings to evaluate their learning effectiveness. Most of the studies used contrasting cases that differed only in one feature (e.g. Loibl & Rummel, 2014). Worked solutions have often been contrasted with invention activities in research studies. There is evidence that worked solutions lead to better learning outcomes, especially for novices, due to lower cognitive load (Kirschner et al., 2006). In accordance with the assumptions of cognitive load theory, a lower cognitive load in the worked solution format is considered to be more likely to enable the acquisition of new knowledge than the higher cognitive load in the invention activity (Sweller et al., 1998). Our studies showed no significant difference between the two experimental conditions in terms of extrinsic cognitive load (Wedde et al., 2021); however, a significant difference was found between the two experimental groups in terms of intrinsic cognitive load, with invention activity students perceiving higher intrinsic cognitive load than the experimental condition of worked solution (Wedde et al., under review).

To date, studies have shown a mixed picture on the question of whether a high quality of task solutions also leads to better learning outcomes in the posttest or transfer. The assumption would be that learners who already found more deep features of the topic to be learned during working on the task would need to focus on fewer aspects during instruction. This approach would facilitate learning (Loibl & Rummel, 2014; Roll et al., 2011). Although the quality of the solution attempts differed significantly between the groups that worked with and without contrasting cases, the group with contrasting cases achieved a higher solution quality and better results in terms of conceptual knowledge. However, another finding of that study was that the quality of solution attempts of learners who worked with contrasting cases did not correlate with their posttest scores. In contrast, the quality of the solution attempts of the other experimental group, which worked without contrasting cases, correlated with their results in the posttest (Loibl & Rummel, 2014).

Research questions

This study examined the content-related solution quality relating to professional vision of classroom management. The aim is to clarify what the students of the two experimental conditions, worked solution (comparing by using given categories) and invention activity (comparing by using of self-generated categories), perceived and drew on when they solved the task of comparing two teaching examples without having received instructions on classroom management.

To fulfil the main research goal, the following research questions were drawn up:

1: In terms of classroom management, which categories are perceived from the two teaching examples by the students in the two experimental conditions and how often are these categories perceived?

2: How do the two experimental conditions differ in terms of naming *surface* and *deep features*?

3: How many categories do students refer to on average in their solutions?

4: Do students tend to mention categories from the successful (teaching example 2) or from the less successful auditive teaching example (teaching example 1)?

5: Is there a correlation between the content-related solution quality and the analytical solution quality?

The first research question is aimed at providing information about which categories were how often addressed on average by both experimental groups (RQ 1). The individual categories of the coding manual were additionally divided into *surface* and *deep features* to investigate the question of the extent the students already perceived deeper features of classroom management. The answer should indicate the teacher students' conceptual understanding of classroom management (RQ 2). Another aspect relevant to content-related solution quality is the average number of categories used in both experimental conditions (RQ 3). It was assumed that the students in the worked solution experimental condition would, on average, use more categories to compare the two auditive examples. Additionally, we asked whether students were more likely to identify aspects of classroom management in the less successful or in the more successful teaching example (RQ 4). Finally, the results on analytical solution quality were included (RQ 5) to allow conclusions on the overall solution quality to be drawn (see Figure 1).

METHOD

Sample

149 student teachers in the introductory phase of their studies at the University of Kassel participated in this study (65.8% female). This subsample was drawn from the total sample (N = 265). Only cases for which data on the content-related solution quality and analytical solution quality were available were selected from the total sample. The participants were randomly assigned almost equally to the two experimental conditions: 76 students worked on the invention activity (IA) (67.1% female; age: M = 22.3, SD = 4.85) and 73 solved the worked solution (WS) (64.4% female; age: M = 21.4, SD = 4.80).

Research design and treatment

The experimental study was conducted in an introductory lecture, accompanied by 15 tutorials, in educational science of the student teacher program during the winter term 2020/21. Due to the COVID-19 pandemic, the course was held online via video conferencing.

First, students in both experimental groups compared both auditive teaching examples in a tutorial session at the beginning of the semester. Second, during the lecture one week later, the students received instruction on the topic of classroom management as well as on the canonical solution to the assignment. Two auditive teaching examples in which excerpts from constructed lesson sequences were audible were used as contrasting cases. The auditive teaching examples were framed by a narrator and presented as podcasts. The first auditive teaching example represented a less successful application of classroom management strategies by a teacher, the second auditive teaching example a more successful case. One half of all students were given the IA as an assignment to compare the two teaching examples while the other half worked with the WS. As a first step of the assignment, both experimental groups listened to the two contrasting auditive teaching examples. Subsequently, IA students developed categories by which they could assess the quality of classroom management in both teaching examples. Using these categories, they were asked to compare the two examples. In contrast, WS students were given a set of categories to compare the two examples (i.e., managing transitions, rules, routines, communication by the teacher and managing disruptions).

Instruments

Content-related solution quality

The categories of the content-related solution quality (see Table 1) were deductively developed on the basis of the theoretical concepts of classroom management and the two teaching examples as well as inductively on the basis of the students' task solutions. The categories were assigned to these three facets of classroom management: *monitoring, rules & routines*, *lesson structure*. These categories of the three facets were coded in the task solutions using qualitative content analysis by Mayring (2015). Qualitative content analysis is characterized by a systematic procedure that aims to assess or even evaluate the cases to be analyzed on the basis of selected categories (Mayring, 2015). Categories were coded using analytic scoring (Schipolowski & Böhme, 2016). For this purpose, the individual solutions were examined to determine whether the individual categories for teaching example 1 (TE1) and teaching example 2 (TE2) were identified. If a category was mentioned for one of the two teaching examples, the value "1" (mentioned) of this category was assigned to the respective teaching example.

The value "0" (not mentioned) was given if a category of an example was not addressed in a solution. This process assigned all categories to the respective teaching example. Due to the heterogeneity of solutions, they were coded consensually by two trained coders and, following the codings, agreement was reached in the case of non-matching values (Guest et al., 2011). Thus, this approach can also be considered reliable. From this agreement, sum scores were generated and the variables may therefore be considered interval-scaled.

Table 1

Facets & Categories of the Content-Related Solution Quality

Facet	SF / DF	Category	TE	**Description** This category means that …
Monitoring	SF	Communication & behavior of the teacher	TE1	… the teacher often appears annoyed and emphasizes the misbehavior of the students.
			TE2	… the teacher communicates in a friendly yet decisive manner and praises desirable behavior.
	DF	Dealing with disruptions	TE1	… the teacher does not manage to maintain a flow through her disruptive interventions.
			TE2	… the teacher is able to keep a flow through purposeful, undramatic actions.
		Support for students	TE1	… the teacher does not provide individual assistance.
			TE2	… the teacher offers individual assistance.
		group focus	TE1	… the teacher does not actively involve students during the lesson.
			TE2	… the teacher actively involves students during the lesson.
Rules & routines	SF	Existence of rules & routines	TE1	… there are little or no established rules & routines.
			TE2	… rules & routines are established.
	DF	Linking instructions and rules	TE1	… rules for individual instructional phases are not present.
			TE2	… rules are established for each instructional phase.
		Reminder of rules	TE1	… the teacher only reminds students of rules by admonishing them.
			TE2	… the teacher reminds of the rules at the beginning of the lesson.
		Applying routines	TE1	… the teacher does not apply routines and there is no routinized procedure.
			TE2	… the teacher applies routines and there is a routinized procedure.
Lesson structure	SF	Instructional structure	TE1	… the lessons seem rather disorganized.
			TE2	… the lessons seem very well-structured.
	DF	Clarity of content	TE1	… the lesson planning is not made clear and transparent.
			TE2	… the lesson planning is very clear and transparent.
		Repetition of content	TE1	… there is no reference back to the past lesson.
			TE2	… there is a reference back to the past lesson.
		Transitions	TE1	… there are no smooth transitions.
			TE2	… there are smooth transitions.

Note: SF = surface feature, DF = deep feature, TE = teaching example

In line with IA allowing students to identify more *deep features* of the subject to be learned (Schwartz et al., 2011), the categories were additionally grouped into *surface* and *deep features* (see Table 1). The *surface features* refer to behavioral and well audible features, such as the teacher's communication. It is assumed that the *surface* features have undifferentiated, less complex features of classroom management requiring a lower level of conceptual understanding. To address essential aspects of classroom management, the recognition of *deep features* is required, which implies a conceptual understanding. *Deep* *features* relate to students' instructional and learning processes or how the teacher interacts with students, such as the teacher's intervention during disruptions. Such aspects are likely to be more complex and more difficult to observe (Kunter & Voss, 2013). Each aspect of the *surface* features was summarized in a single variable, just as the aspects of the *deep features* were summarized in a single variable for each facet.

The individual categories of the three facets are named and described in Table 1. More superficial and easy audible features such as teacher communication and behavior, the existence of rules & routines and instructional structure were defined as *surface features*. All other features were assigned to the *deep features*. The descriptions show that the characteristics of TE1 represent more negative and less successful teacher actions and techniques of classroom management and that the successful implementation of the respective strategies are to be found for TE2. To assess the content-related solution quality, *surface features* and *deep features* and the number of categories mentioned by the students were evaluated.

Analytical solution quality

In another study about the solution quality of WS and IA, we constructed the analytical solution quality (see Figure 1), which represents the modeled comparison process. It consists of the following five steps: Description, classification into categories, juxtaposition, summarization and conclusion. The result of that study indicated that WS students demonstrated a significantly higher analytical solution quality than did IA students. However, the overall sample achieved only a low analytical solution quality (Wedde et al., under review).

Data analysis

For the categories and variables used, absolute and relative frequencies, means, sum scores and standard deviations were calculated. To examine the differences between the two experimental groups, independent-samples *t*-tests were performed with a defined significance level of α = .05. The experimental condition (IA or WS) represents the independent variable and the variables of the content-related solution quality the dependent variable. In addition, Pearson's correlations were calculated between the analytical solution quality, operationalized by the depth of comparison scale, and the variables of the content-related solution quality.

RESULTS

The first research question, concerning which categories students perceived and how frequently they were perceived from the two contrasting teaching examples, is covered first. Table 2 lists the frequencies of the three facets including the individual categories.

Table 2 shows that, for TE1, the WS students most frequently referred to the *monitoring* categories. For TE2, the WS students frequently referred to the *rules & routines* categories in addition to the *monitoring* categories. Although the WS group was provided with categories to compare, they were not used by the entire experimental group to compare the two examples: transitions (TE1: 66%, TE2: 58%), existence of rules and routines (TE1: 70%, TE2: 68%), communication and actions of the teacher (TE1: 82%, TE2: 82%), dealing with disruptions (TE1: 77%, TE2: 55%). The individual given categories were used slightly more often for TE1 than for TE2.

For TE1, IA students also frequently referred to *monitoring*. In particular, they mentioned categories such as communication & behavior of the teacher (49%) and dealing with disruptions (36%). As in TE1, *monitoring* was also frequently discussed by students in the experimental condition IA for TE2. However, the students were less likely to address dealing with disruptions (26%), yet over half of the experimental condition continued to address communication & behavior of the teacher (53%). Other categories that some IA students addressed for comparing the two teaching examples were existence of rules & routines (TE1: 30%, TE2: 33%), instructional structure (TE1: 16%, TE2: 22%) and clarity of content (TE1: 14%, TE2: 26%). It is noteworthy that IA students addressed these categories more frequently for TE2 than for TE1.

Table 2

Frequencies of the coded Facets and associated Categories of Classroom Management

Facet	SF / DF	Category	**Teaching example 1** Less successful classroom management strategies						**Teaching example 2** Successful classroom management strategies					
			WS		**IA**		**Overall**		**WS**		**IA**		**Overall**	
			n	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Monitoring	SF	Communication & behavior of the teacher	60	82	37	49	97	65	60	82	40	53	100	67
	DF	Dealing with disruptions	56	77	27	36	83	56	40	55	20	26	60	40
		Support for students	3	1	2	3	5	3	25	34	18	24	43	29
		Group focus	7	10	7	9	14	9	8	11	9	12	17	11
		total	**126**	/	**73**	/	**199**	/	**133**	/	**87**	/	**220**	/
Rules & routines	SF	Existence of rules & routines	51	70	23	30	74	50	50	68	25	33	75	50
	DF	Linking instructions and rules	1	1	3	4	4	3	14	19	3	4	17	11
		Reminder of rules	9	12	1	1	10	7	28	38	7	9	35	23
		Applying routines	10	14	4	5	14	9	46	63	10	13	56	38
		total	**71**	/	**31**	**23**	**102**	/	**138**	/	**45**	/	**183**	/
Lesson structure	SF	Instructional structure	13	18	12	16	25	17	12	16	17	22	29	19
	DF	Clarity of content	9	12	11	14	20	13	24	33	20	26	44	30
		Repetition of content	2	3	1	1	3	2	18	25	5	7	23	15
		Transitions	48	66	5	7	53	36	42	58	8	11	50	34
		total	**72**	/	**29**		**101**	/	**96**	/	**50**	/	**146**	/
		total	**269**	/	**133**	/	**402**	/	**367**	/	**182**	/	**549**	/

Note: SF = surface feature, DF = deep feature; WS: *n* = 73, IA: *n* = 76, Overall: *N* = 149

The assignment of all categories to *surface* and *deep features* will be used to examine how frequently students addressed these different features of classroom management (RQ 2). In addition to the absolute and relative frequencies (see Table 2), sum scores were calculated for the *surface* and *deep features* for each facet (see Table 3): WS students named more *surface* and *deep features* on average than IA students (except for the *surface feature* of *lesson structure*). However, the entire sample remained low in *surface* and *deep features* recognition in their task solutions.

Overall, there was a high significant difference with regard to addressing the *surface features* of *monitoring* ($t(138.76) = 4.85$, $p < .001$, $d = 0.80$) as well as those of *rules & routines* ($t(147) = 5.54$, $p < .001$, $d = 0.83$). There was no significant difference between the two experimental conditions for the recognition of *surface features* for *lesson structure* ($t(147) = -0.36$, $p = .72$). The WS experimental group addressed *surface features* on *monitoring* and *rules & routines* more often than the IA group. Regarding *lesson structure*, there was little difference between the experimental conditions.

For the *deep features*, highly significant differences associated with a strong effect were shown between the two experimental conditions for *monitoring* ($t(147) = 4.28$, $p < .001$, $d = 1.16$), for *rules & routines* ($t(127.21) = 7.86$, $p < .001$, $d = 0.86$) and for *lesson structure* ($t(147) = 7.10$, $p < .001$, $d = 1.12$). Overall, for the *deep features*, the WS students on average addressed more *deep features* for the three facets than did the IA students. However, the WS students also remained in the bottom third of the score for addressing *deep features*.

Table 3

Descriptive Statistics of the Surface and Deep Features

		WS	IA	Overall
Facet	**Features**	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Monitoring	Surface	1.64 (0.67)	1.01 (0.90)	1.32 (0.86)
	Deep	1.90 (1.11)	1.09 (1.20)	1.49 (1.22)
Rules & routines	Surface	1.38 (0.81)	0.63 (0.85)	1.00 (0.91)
	Deep	1.48 (1.00)	0.37 (0.69)	0.91 (1.02)
Lesson structure	Surface	0.34 (.67)	0.38 (0.67)	0.36 (0.67)
	Deep	1.96 (1.28)	0.66 (0.93)	1.30 (1.29)

Note: For surface features, 0 to 2 points can be scored for each of the three facets; for deep features, 0 to 6 points can be scored for each of the three facets. WS: $n = 73$, IA: $n = 76$, Overall: $N = 149$

In total, the WS students used considerably more categories in their comparison (RQ 3, see Figure 2). On average, WS students mentioned 3.68 ($SD = 1.43$) categories TE1 and 5.03 ($SD = 2.13$) for TE2. In contrast, IA students used fewer categories for their comparison: They mentioned on average 1.75 ($SD = 1.60$) categories for TE1 and 2.39 ($SD = 1.83$) categories for TE2.

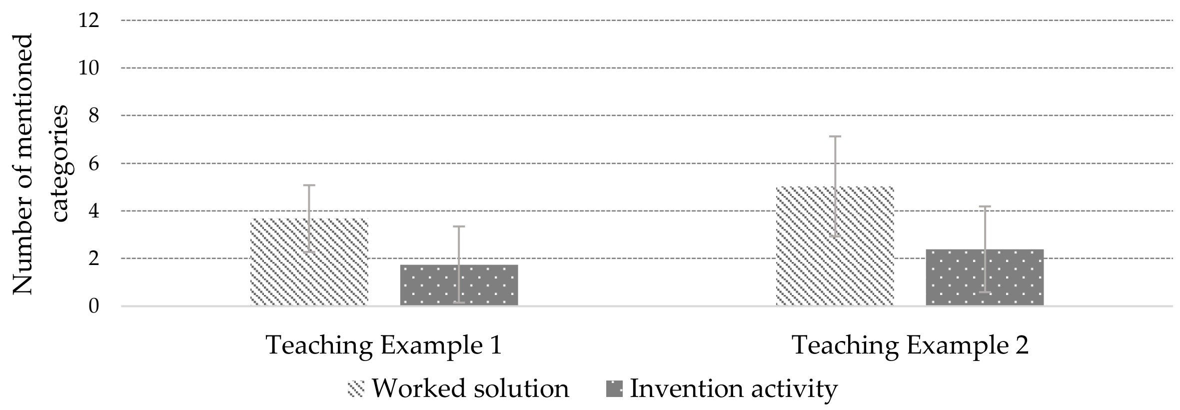

Figure 2. Mentioned Categories per Experimental Condition for both Teaching Examples

For the fourth research question, both experimental groups identified more categories for TE2 than for TE1. There was a significant difference with a strong effect between the two experimental conditions in terms of the number of categories used for TE1 ($t(147) = 7.76$, $p <.001$, $d = 1.52$) and for TE2 ($t(147) = 8.1$, $p < .001$, $d = 1.98$).

Research question 5 investigated to what extent the analytical and the content-related solution quality were interrelated. For this purpose, Pearson correlations were calculated with the variables depth of comparison scale, the number of categories mentioned, as well as the *surface* and *deep features*. There were highly significant strong positive correlations (one-tailed) between the variable depth of comparison and the number of categories named and the *surface* and *deep features* for the overall sample (see Table 4). The greater the depth of comparison, the more aspects were mentioned in the comparison. In addition, more *surface* and *deep features* were named. The correlations between the individual variables of the content-related solution quality (number of mentioned categories, *surface* and *deep features*) were highly significant medium to strongly positive.

Table 4

Intercorrelations between the Variables of Analytical and Content-Related Solution Quality

Variable	1	2	3	4
1. Depth of comparison	-			
2. Number of mentioned categories	$.65^{***}$	-		
3. Surface features	$.53^{***}$	$.80^{***}$	-	
4. Deep features	$.60^{***}$	$.93^{***}$	$.54^{***}$	-

Note: * $p < .05$, ** $p < .01$, *** $p < .001$; For the depth of comparison and the variables of content-related solution quality, the correlations were tested one-sided. The correlations between the variables of content-related quality were tested two-sided.

DISCUSSION

The purpose of this study was to assess the content-related solution quality of IA and WS by evaluating student teachers' task solutions. Overall, it appeared that WS students referred most frequently to *monitoring* categories for TE1 and similarly frequently to *monitoring* and *rules & routines* categories for TE2. The IA students most frequently addressed *monitoring* categories in both teaching examples. For the *surface* and *deep features*, the WS and IA were found to differ highly significantly at a strong effect with respect to all facets of the *surface* and *deep features* except for naming the *surface features* for *lesson structure*. For the most part, the experimental group WS named more *surface* and *deep features* than the experimental group IA. Similarly, it was evident that both experimental groups used more categories for TE2 than they did for TE1. However, WS students overall mentioned more categories than IA students. For the overall sample, the relationship between the analytical and content-related solution quality was medium to strong. A study by Plöger et al. (2020) already indicated that analytical competence consists of two dimensions; the formal dimension, i.e., the ‘complexity of information processing’, and a content dimension, i.e., pedagogical knowledge and content knowledge.

From the results of this study, it may be concluded that the WS students demonstrated a higher quality of content in their solutions. Thus, first-year student teachers achieve a higher quality in terms of content-related solution quality when they receive more support during working on the WS task. This result is consistent with previous studies showing, for example, that support in the form of guiding questions is more goal-oriented when analyzing and interpreting contrasting cases (Nagarajan & Hmelo-Silver, 2006).

Studies on professional vision have shown that novices are more likely to relate to students' disciplinary behavior (Wolff et al., 2015). This finding was also reflected in our results, in that students in both groups most often referred to the teacher's *monitoring*, and thus, for example, to the teacher's dealing with disruptions. That the other two facets were perceived less may also be a result of them being less noticed in auditive cases. However, importantly, our results showed that the students were not able to perceive many of the key events and thus they did not perceive significant features of effective classroom management. The finding corresponds to research on professional vision of novices, who are often not able to distinguish significant from less significant features (Star et al., 2011). It clearly shows that, for the implementation of task formats using the problem-solving prior to instruction approach, it is necessary to implement the instruction as well. During the instruction, any missing declarative and conceptual knowledge that is not present in the problem-solving phase must be introduced (König et al., 2014; Stürmer, Könings, & Seidel, 2013).

In further studies, students could compare contrasting cases, focusing on classroom management a second time after instruction. These further studies would permit a cross-check on the extent to which students then also include the other two facets, *rules & routines* and *lesson structure*, in their task solution. Interestingly, studies that assessed the professional vision of classroom management through a video-based online test showed that, before an intervention, novices perceived the *monitoring* facet less than the other two facets (Junker et al., 2021; Weber et al., 2018). That finding may indicate that the auditive teaching examples particularly bring into focus the *monitoring* facet. This facet is also reflected in the way the teacher communicates. Certain strategies are brought into focus more through the visual channel, others through the auditive channel. To reduce the complexity of an analysis and to practice only the analysis of certain strategies, videos or purely auditive examples could be selected accordingly. If monitoring strategies are to be focused on, auditive examples could be compared. To analyze lesson structure strategies or rules and routines, videos could be used in addition to auditive lesson examples. However, this approach requires verification in further studies.

By comparison, the fact that both experimental conditions used more categories for TE2 shows that the students are better able to perceive aspects of classroom management on the basis of a successful rather than a problematic teaching example. This finding indicates that the students lacked the necessary knowledge to determine which aspects of professional teacher action regarding classroom management were not implemented in the less successful implementation.

Knowing that strategies have not succeeded or are not being implemented requires knowledge about those strategies. Hence, the students probably had no negative knowledge about classroom management (Oser et al., 2012). Due to the successful illustration in TE2, the students could identify successful aspects of the teacher's actions. By comparing the two examples, at best, students conclude for their own teaching practice which classroom management strategies are effective for professional teaching. Yet, one of our studies showed that the students did not draw any conclusions from their comparisons and even, in rare cases, merely summed up which example showed the more successful implementation (Wedde et al., under review). The observation that WS students scored higher in terms of using both *deep features* and *surface features* shows that the support in WS helps students to discover *deep features* of classroom management during the comparison process. However, it was also found that the entire sample recognized few *deep features* on average, suggesting that, as novices, they generally have difficulty distinguishing significant from insignificant features and in perceiving the important events in class in their multiplicity (Star et al., 2011; van den Bogert et al., 2014). Thus, it can be assumed that the students have only a poor conceptual understanding of classroom management.

Explaining all important *deep features* during the subsequent instruction in the second phase of the IA requires reviewing the extent to which the solution attempts of WS and IA differ from each other. The evaluation indicated that the WS group already discovered some *deep features* of classroom management through the problem-solving phase. In contrast, the IA group perceived fewer *deep features* during this phase. It may be assumed that WS students have a facilitated learning process for acquiring conceptual knowledge during the instruction because they have fewer features to add to the concept of classroom management (Loibl & Rummel, 2014; Roll et al., 2011).

Although our evaluations of content-related solution quality found that support in form of the WS led to better results in the students’ solutions, it is yet unclear whether this would also lead to better learning outcomes (Loibl & Rummel, 2014; Wiedmann et al., 2012). This question will be answered in a further study. The first-year student teachers' solutions indicated that WS is the preferable learning format in terms of comparing constructed contrasting auditive lesson examples. In the future, it would be useful to examine how these results can be replicated among students in higher level semesters or even among beginning teachers.

This study contributes to the sparse research on invention activities and worked solutions in teacher education. In particular, contrasting cases could be an innovative task format to initiate skills related to professional vision. Evaluating task solutions at the content level is essential to understanding what aspects of effective classroom management students initially focus on when comparing contrasting cases. Professional vision is commonly assessed using standardized video tools. We added value by evaluating non-standardized analyses, allowing us to reflect the range of classroom management strategies students notice. Furthermore, our study supports earlier findings (König et al., 2014; Stürmer, Könings, & Seidel, 2013) that analyzing teaching scenes requires professional knowledge.

Overall, this study provides valuable insights for teacher education research. It appears that, during the problem-solving phase, support in the form of a worked solution is more effective than an invention activity. The worked solution supports students in relating to the significant strategies of classroom management and focuses on learning-related events. It remains to be verified to what extent this result can be replicated after instruction.

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