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# Reflecting on teaching together and alone: preservice teachers' processes of knowledge construction in writing and discussion

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Understanding how preservice teachers (PSTs) engage with knowledge of educational sciences through reflective practice is critical to improving teacher education. This study investigates how PSTs construct knowledge when analyzing a complex classroom situation and explores how a reflective task format—individual essay writing or collaborative group discussion—shapes the types and quality of knowledge construction processes involved. Drawing on frameworks of reflective practice and epistemic cognition, we developed a coding scheme to identify five knowledge construction processes and three levels of implementation quality. Using data from a university-based teacher education course, we applied this scheme to PSTs' written essays and transcribed group discussions. Our findings indicate that collaborative discussions elicited a broader variety of knowledge construction processes and deeper levels of implementation, while essays involved more references to scientific literature but fewer exploratory hypotheses. These results suggest that different reflective tasks afford distinct opportunities for preservice teachers to mobilize and integrate educational sciences knowledge. The study highlights how the perceived relevance and applicability of theoretical content are shaped not only by individual cognition but also by the task design and social context of reflection. Implications for teacher educators include selecting reflection formats strategically to support meaningful engagement with educational knowledge in preparation for complex pedagogical reasoning.

## KEYWORDS

teacher education, preservice teachers, reflective practice, epistemic cognition, knowledge construction, pedagogical reasoning, teacher reflection, professional judgment

## Introduction

Becoming a successful teacher requires continuous learning opportunities that enable teachers to analyze and reflect on their instructional practice to expand their knowledge and make informed classroom decisions (Collin et al., 2013; Kavanagh et al., 2020). This knowledge includes both formal, research-based insights acquired through preservice teacher education and the practical understandings gained from prior experiences as students or teachers. To prepare teachers for this task of life-long professional learning, teacher education is crucial for

developing their ability to identify, understand, and apply standards for how to use and evaluate different forms of knowledge to explain complex pedagogical situations (Fives et al., 2017). Thus, teacher educators and educational researchers need insight into preservice teachers' (PST) processes of knowledge construction—across both theoretical and experiential domains—to foster high quality reflection on classroom situations and to help PSTs develop a solid foundation for making professional judgments in their future day-to-day practice. Frameworks that examine teachers' thinking related to the construction, evaluation, and use of knowledge can thus potentially offer valuable insights for teacher education and research (Buehl and Fives, 2016; Cramer et al., 2023; Lunn Brownlee et al., 2017).

This study investigates the processes PSTs employ when reflecting about a pedagogical situation and introduces a coding scheme that can enable educators and researchers to distinguish forms and qualities of these processes of knowledge construction. As reflective tasks in teacher education operate with different formats of reflection, we study PSTs' knowledge construction within tasks of two often-used formats: essay-writing and group discussion. The results may inform researchers and educators with regard to selection and analysis of reflective tasks in teacher education that aim to elicit and expand various kinds of knowledge and arrive at professional judgments for pedagogical practice.

## Theoretical background

### Reflective practice

*Reflective practice* is a longstanding ideal for good teaching. It involves a critical evaluation of one's perceptions, continuous learning, and the application of insights from reflection (Schön, 1983). However, 'reflection' has long lacked a universal definition (Collin et al., 2013). This ambiguity allows 'reflection' to encompass discovering ideas, solving problems, evaluating situations, and critiquing theories (Beauchamp, 2006). Recent literature has sought to sharpen the concept of reflection in teacher education. For example, Arendt et al. (2025) propose an integrated model that treats reflection as an input–process–output cycle: teachers start from pedagogical experiences (input), engage in processes such as describing, evaluating, and generating alternatives (process), and aim at professional development (output). In general, models of reflection emphasize that reflection differs from mere analysis through its reliance on self-reference and justification with professional knowledge.

In this article, we conceptualize one specific aspect of reflection in detail: the active construction of knowledge on teaching—encompassing both research-based knowledge acquired through formal teacher education and practical knowledge developed through personal experience in educational settings. We focus on university-based teacher education and regard reflective practice as a means to support PSTs' ability to apply their academically acquired knowledge base to the analysis and interpretation of classroom events (Fives et al., 2017). For example, PSTs can learn to describe and interpret pedagogical situations using conceptual frameworks, empirical findings, and disciplinary norms drawn from educational science coursework (van Es and Sherin, 2002). Approaches to foster PSTs' reflective practice often involve inquiry processes (e.g., Cochran-Smith and Lytle, 1999) or dilemma-like pedagogical situations (e.g.,

Caspari-Gnann and Sevan, 2022; Kavanagh et al., 2020) to equip future teachers with adaptable and informed decision-making skills.

### One lens to view PSTs' knowledge construction: epistemic cognition

Models of epistemic cognition (Chinn et al., 2011, 2014) have increasingly been applied to the complexities of teaching situations. For example, Lunn Brownlee et al. (2017) introduced the 3R-EC framework (Reflection, Reflexivity, Resolved Action for Epistemic Cognition), using epistemic cognition as the starting point for supporting a variant of teachers' reflective practice. The framework emphasizes the role of reflective thinking in fostering deeper understanding and transformation in teaching practices, thereby enhancing the overall educational experience for students. *Epistemic cognition* refers to "all kinds of explicit or tacit cognitions related to epistemic or epistemological matters" (Chinn et al., 2011, p. 141). In teaching, it pertains to the processes and mediational mechanisms employed when teachers engage in knowledge construction (e.g., Buehl and Fives, 2016). PSTs' epistemic cognition may influence their understanding of coursework and the resulting knowledge of teaching and learning (Lunn Brownlee et al., 2017). One notable framework is the AIR model (Aims, Ideals, Reliable Processes) by Chinn et al. (2014) and Chinn and Rinehart (2016), has been adapted specifically to teaching (Buehl and Fives, 2016; Lunn Brownlee et al., 2017). The AIR model suggests that in processing information, people set individual aims for the epistemic (i.e., knowledge) products they hope to generate. The framework then differentiates the values people place on these aims, their ideals for evaluating their success at arriving at their aims, and processes that can be considered reliable for achieving their aims (reliable epistemic processes). In contrast to the other dimensions of the AIR model, these processes are more directly observable in individuals' pursuit of knowledge aims. In studies that build on the AIR model, researchers identified reliable epistemic processes employed by teachers in classroom assessment (Barnes et al., 2020), in providing dialogic feedback (Rinehart et al., 2022), and in learning through professional development (Fowler et al., 2022).

However, theoretical literature on epistemic cognition assumes that effective performance requires not so much the use of one single epistemic process, but the use of an array of different processes depending on the questions at hand (Barzilai and Chinn, 2018; Chinn et al., 2014). Understanding which epistemic processes PSTs use—and when and how they use them—could offer insight into when and how educational sciences knowledge is perceived as useful or usable. For instance, selecting relevant theories, critically evaluating research, or integrating course content with teaching experiences are not just cognitive achievements but indicators of educational knowledge being valued and applied in meaningful ways.

### Knowledge construction together and alone

Previous research also shows that processes of knowledge construction—and the ways in which PSTs activate, interpret, and apply educational science knowledge—may vary between individual and group formats (Csanadi et al., 2021; Kuhn, 2015).

In a study by Kuhn and Moore (2015), students engaged in a dialogic task used more of the available knowledge to counter positions opposing their own and also counted more on personal experience than students working on individual tasks. In the individual task, the students used more of the available information sources overall. This finding is corroborated by Csanadi et al. (2021), who found PSTs working collaboratively to engage more in the generation of hypotheses and in the evaluation of claims than those working individually. However, these findings are primarily derived from experimental studies and have not yet been supported by evidence from authentic, contextualized settings in teacher education.

## Qualities of preservice teachers' knowledge construction processes

Knowledge construction can encompass a range of activities such as identifying problems, generating hypotheses, or utilizing different sources of evidence and methods of analysis. Each of these processes play a distinct role in shaping PSTs' approaches to reflective practice. However, besides identifying different types of processes, linking the AIR model to teaching knowledge construction requires considering the processes' quality, that is, an estimation of how well generally reliable processes are implemented in a specific task (Rinehart et al., 2022). Procedures that are deemed reliable as a general principle, like using scientific educational literature to gain insight into classroom situations, can vary in proficiency and lead to different outcomes.

Teacher educators need to be able to assess how PSTs engage in processes of knowledge construction during common reflection exercises. Evaluating their understanding of complex classroom situations requires clear and reliable indicators to distinguish and evaluate the processes they implement. Such indicators also respond to calls for more reflective practice in teacher preparation (e.g., Alexander, 2017; Hartmann et al., 2021). As in many complex domains, reflective practice in teacher education involves connecting various sources of information to the specific context of the situation, using these sources to understand pedagogical practice in its complexity.

## Interconnection of knowledge construction processes

In addition to distinguishing different quality dimensions for individual processes, it is important to consider their interconnections. This aligns with research findings in teacher education that emphasize the role of integrating different sources of knowledge—e.g., past experiences, theoretical and research literature, testimony, observation, personal reflection (Harr et al., 2015; Renkl, 2022; Shulman, 1987). Effective integration connects different types of processes, creating a richer understanding. In contrast, processing sources merely sequentially without integrating them may be less effective (Hartmann et al., 2021). Knowledge integration might also comprise reflectively linking theoretical knowledge with personal teaching experiences (Kim and Klassen, 2018). For these reasons, combining knowledge construction processes could serve as another indicator of better process implementation (Chinn et al., 2014).

## Aims of the study

Our investigation has three main aims:

1. We aim to *create a coding scheme* that identifies and describes the types and qualities of knowledge construction processes used by PSTs during reflection on a complex pedagogical case vignette. This scheme will be applicable to analyzing essays and discussions from typical teacher education tasks.
2. We intend to *assess different qualities* with which PSTs implement these processes of knowledge construction. In a multi-layered analysis, we aim to explore how processes of knowledge construction are utilized in the context of PSTs' reflective practices.
3. In the context of university-based teacher education we sought to understand reflective practice implemented via two different modes—individual essay writing and group discussion. Investigating how these assignments *function as reflective opportunities in practice*, including their limitations, is central to understanding how teacher education fosters (or fails to foster) reflective judgment. We *analyze these two modes of—potential—reflection* to illustrate similarities and differences in the occurrence of different process types used by PSTs. Specifically, we *explore and compare* how often PSTs use scientific literature, make references to their own teaching experiences, and generate exploratory hypotheses to expand their knowledge of a pedagogical situation.

## Method

### Research context

This study was situated in a two-year Master of Education program for secondary school teachers in a mid-size university in Germany. The program includes a mandatory four-day course to prepare PSTs for their practical term, followed by a 5-month practical placement in secondary schools. The course aimed to familiarize participants with models of reflective practice (e.g., van Es and Sherin, 2002), helping them to question and analyze authentic pedagogical situations by connecting them to theory and research.

Case vignettes of classroom situations were presented in both video and written formats. The participants received guidance on using scientific databases. PSTs were tasked to: (a) identify essential characteristics of the situation, (b) formulate plausible explanations for what happened during the situation, (c) use professional literature to support their explanations, and (d) use their explanations to arrive at practical conclusions and alternatives for action.

PSTs concluded the course by choosing between writing an essay (EW condition) or working collaboratively in small group discussions (GD condition). All participants consented to data analysis and completed a short background questionnaire.

### Participants and procedure

Twenty-nine German PSTs ( $M_{Age} = 27.58$ ,  $SD_{Age} = 5.65$ , 69% female, 3.4% unreported gender) were recruited from two parallel

courses. Participants in the two conditions differed marginally with respect to group size (15 in the EW condition, 14 in GD condition), and gender (eight female in the EW condition, 12 female in the GD condition, one participant with unreported gender).

During the practical phase, PSTs observed experienced teachers and taught their first lessons. In the fourth month, all PSTs analyzed the same complex classroom vignette ([Supplementary material](#)), which was open to multiple interpretations. The PSTs analyses served as the primary data source for our study. Each participant began with an individual literature search to find educational sources relevant to the pedagogical situation.

In the EW condition, participants wrote essays summarizing their reflections and submitted their reference lists, explanations, and conclusions to instructors. In the GD condition, after the literature search, participants brought their reference lists to small group meetings of 4–5 members at the university. Guided by the same instructions as the EW participants, plus additional ones ([Appendices B, C](#)), they collectively discussed possible explanations. These 30- to 40-min discussions were recorded and transcribed using a clean verbatim transcription protocol. Afterwards, GD participants individually wrote a short conclusion essay with prompts identical to those in the EW condition.

## Comparability of conditions

Participants chose a reflection format (EW or GD) based on preference and motivation. To mitigate potential self-selection effects, we used background measures to check for differences between the conditions in areas we considered most likely to influence our results. Internal consistency, means and standard deviations for all measures described below are shown in [Table 1](#).

1. Educational knowledge: Assessed the PSTs' pedagogical knowledge in areas like motivation, diagnostics, classroom management, and individual support.
2. Need for cognition: Higher scores indicate a greater enjoyment of cognitively challenging tasks and a tendency to seek out and reflect on information.
3. Epistemic beliefs: Measured dimensions such as justification, certainty, and the reflective nature of knowledge to ensure that PSTs in both conditions had comparable epistemic orientations, which could potentially influence their use of different knowledge construction processes ([Lammert et al., 2022](#)).

Additionally, we compared the reference lists that the participants prepared for the task. Each student provided a list with three to 18 references, totaling 29 lists. These references consisted of common university textbooks, scientific articles, and practical teaching guides. We reviewed these lists for the number and type of sources selected to explain the pedagogical situation.

Analyses revealed no differences in responses to any of the standardized measures. Regarding the reference lists, we found that on average, participants in both conditions used a similar number of external literature sources ( $M_{GD} = 7.42$ ;  $SD_{GD} = 2.68$ ;  $M_{EW} = 6.87$ ;  $SD_{EW} = 3.8$ ), and similar types of literature, *t*-tests revealed no significant differences.

## Data sources

For our analysis, we used the explanatory sections of the essays and the GD transcripts, excluding participants' conclusions. To analyze transcripts, we isolated each participant's contributions by removing others' comments. This eliminated conversational context but provided insight into individual processes. Essays lengths ranged from 4,625 letters to 15,788 letters. Participants' individual contributions in the GD condition ranged from 2,799 to 10,159 letters.

Each participant was assigned a code linking their utterances in the transcripts to their reference lists and background information. In the EW condition, participants provided personal codes to match essays with other data sources.

## Data analysis

### Development of the coding scheme

We developed a coding scheme applicable to essays and group discussion transcripts regarding PSTs' knowledge construction processes, combining process types and implementation quality. We identified different process types based on qualitative studies in teaching ([Barnes et al., 2020](#); [Csanadi et al., 2021](#)) and other fields ([Barzilai, 2017](#); [Barzilai and Zohar, 2016](#)). We focused on how participants referenced different sources of knowledge, assuming they would link their understanding of the situation to relevant prior teaching knowledge.

Based on the extant literature we deductively identified three types of knowledge construction processes (process types 1–3) for inclusion in the coding scheme. However, we expanded the scheme to five categories based on inductive qualitative analysis of our data. See [Table 2](#) for example segments from each category.

1. *Referring to literature.* PSTs used scientific or practical teaching literature to support their claims or understand aspects of the situation.
2. *Referring to past experiences.* Participants connected aspects of the pedagogical situation with their own experiences, either as students or during their practical placements.
3. *Generating explanatory hypotheses about the situation.* Participants produced tentative explanations about the situation, similar to hypothesis generation or inference verification observed in previous studies ([Csanadi et al., 2021](#); [Barzilai, 2017](#)).
4. *Referring to details of the situation description.* Participants referred back to the situation description, using it as evidence for their claims, similar to the “re-reading” process in [Barnes et al. \(2020\)](#).
5. *Referring to current emotional experiences.* Participants commented on their emotional reactions, such as curiosity and surprise. Awareness of one's emotional experiences can be seen as an aspect of knowledge construction ([Chinn et al., 2014](#); [Barzilai and Zohar, 2016](#)).

Next, we assessed how well PSTs implemented these processes. Our assessment was based on an earlier paper in which the coding

TABLE 1 Control variables.

| Scale                                                                             | Sample items                                                                                                                                                                                                                                                                                          | GD    |      | EW    |      |
|-----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|------|-------|------|
|                                                                                   |                                                                                                                                                                                                                                                                                                       | M     | SD   | M     | SD   |
| Educational knowledge; Seifert et al. (2018)<br>(18 Items)                        | Which of the following objectives require measures of external or internal differentiation? <ul style="list-style-type: none"><li>• Learning processes of each pupil should be individualized. (internal)</li><li>• Classes should be as homogeneous in performance as possible. (external)</li></ul> | 12.84 | 2.52 | 12.87 | 2.45 |
| Need for cognition; Preckel (2016)<br>(19 Items, Cronbach's $\alpha = 0.83$ )     | I do not like thinking about things.<br>I enjoy thinking about a problem, even if I know that my thoughts will not change the problem.                                                                                                                                                                | 3.64  | 0.46 | 3.56  | 0.44 |
| Epistemic beliefs; Klopp and Stark (2017) (18 Items, Cronbach's $\alpha = 0.62$ ) | Scientific knowledge mainly originates from the opinions of the respective researcher. (Justification of knowledge)<br>In science, there is an unchanging core of knowledge. (Certainty of knowledge)<br>The assessment of knowledge changes with new findings. (Reflexive nature of knowledge)       | 4.11  | 0.52 | 3.92  | 0.52 |

principles were further described (Molitor et al., 2022). Our analysis revealed three levels of implementation quality<sup>1</sup>:

1. *Superficial*. PSTs used processes without reflection or distancing, mainly to confirm their initial judgments based on pre-existing beliefs. One particularly pertinent indicator was the frequent reliance on normative formulations.
2. *Evolving Analytic*. PSTs noted aspects of the situation factually and analytically, linking them to literature or experiences, but without questioning or qualifying interpretations or sources.
3. *Reflective*. PSTs compared, questioned, or weighed different sources of information and interpretations to explain the situation. This involved multi-perspectivity and potentially questioning initial assumptions and conclusions, representing the highest quality in our scheme.

The process types “referring to past experiences” and “referring to emotional experiences” capture the self-referential dimension identified as central in recent definitions of reflection (Arendt et al., 2025). Meanwhile, our three levels of process implementation—superficial, evolving analytic, and reflective—can be understood as indicators of depth of reflection. The variety and combination of different processes point to the breadth of reflection (Arendt et al., 2025).

Coding process

In both essays and GD transcripts, we excluded segments focused on procedural aspects of the discussion or on guiding the reader in the essays, as these did not contribute to knowledge construction. Despite instructions to focus on understanding the situation, participants often proposed alternative courses of action, especially in the group discussions. Since the analysis in this study targeted processes of description, analysis, and the

generation of hypotheses with the aim to construct knowledge on the situation—rather than developing purely outcome-oriented suggestions—we excluded such statements from our analysis. To analyze individual essays and GD transcripts in a comparable way, we treated the individual contributions to the discussion as individual texts.

While we adhered to standard qualitative content analysis methods for coding reliability and quantifiability (Chi, 1997), challenges with the data segmentation necessitated some deviations from standard procedures. First, different processes were often interwoven and unequally elaborated. As shown in Table 2, references to emotional experiences and references to the case vignette tended to be short, while references to past experiences and exploratory hypotheses ranged from single sentences to paragraphs. This made the raw count of coded segments less informative. To address this, we measured process elaboration using letter count instead of word count. The German language allows for long compound words which in some cases can take phrases of multiple words to express in English. We aimed to reduce distortions caused by such linguistic features and capture a more continuous measure of elaboration to consider the proportion of knowledge construction processes in participants’ texts. Our approach was similar to word count analysis in classroom discussions (O’Connor et al., 2017).

Second, processes of the same type were often not clearly separable. For example, literature references frequently mixed different sources. Therefore, we avoided uniform coding units and instead followed O’Connor and Joffe’s (2020) suggestions as described in Molitor et al. (2022). One author coded segments based on our scheme and a second author independently coded them to assess intercoder agreement. More than 50% of the data were double-coded, with high agreement for the low-inference process types ( $\kappa_{\text{process type}} = 0.92$ ) and acceptable agreement for the high-inference implementation quality ( $\kappa_{\text{process implementation}} = 0.68$ ). Disagreements were resolved through discussion.

These methodological adjustments allowed us to compare knowledge construction processes despite the different segment lengths and the difficulty of distinguishing processes of the same type from one another. It also allowed us to identify quantitative differences in process use in the two conditions.

1 For examples, see Table 2. For the categories referring to past experiences and generating explanatory hypotheses we included additional contextual information to allow for a better reconstruction of our quality assessment.

TABLE 2 Example segments for each category in the coding scheme.

| Epistemic processes type                          | Implementation of knowledge construction processes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                                                                                                                                                                                                                                       |
|---------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                   | Reflective                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Evolving analytic                                                                                                                                                                                                                                                                                                                                                                                                                                 | Superficial                                                                                                                                                                                                                                                                                                                                                           |
| Referring to literature                           | This contrasts with controlling feedback, which is based on conveying a certain pressure on the learner to perform well. According to [reference to an empirical study], the latter does not promote but rather impairs intrinsic motivation [reference to a research article]. (EW)                                                                                                                                                                                                                                                                                                                                                                                                | But I would like to take a step back, because I also look at the text I found by [reference to a research article], because they make a very clear distinction between open and guided discussion. Guided means that I then also give feedback or ratification, that I classify it as right or wrong, that I give feedback, and open means that I do not give feedback, that I create free space. (GD)                                            | The very name “Visible learning” shows how much value [reference to a book] places on transparency in the classroom. He wishes for a balance between teacher-centered and student-centered learning that is characterized by mutual transparency. This transparency is achieved through evaluation, diagnostics, and feedback [reference to an empirical study]. (EW) |
| Referring to past experiences                     | I made another experience, a positive one [...]. I was in a Latin translation class and I did exactly what the teacher there always does, I imitated her style. Interestingly enough, in the first moment, in the class discussion, in the plenum, the translations are collected, [while] the teacher, in this case me or the other teacher before, actually does nothing other than writing down the sentences, so no comments, [...]. And what I noticed afterwards is that it works wonderfully for them, because [...]. (GD)<br><i>Context: This PST offers an alternative interpretation to how the other group members evaluate the teacher's behavior in the situation.</i> | But I have also noticed quite often that teachers collect answers, for example, and then only later react to them; so I would have understood that if she had first said “okay, okay,” just nodding everything off, and had then given it back in bundles, for example, because, um ... to improve her teaching. (GD)<br><i>Context: This PST contextualizes the teacher's behavior in the situation, offering a possible explanation for it.</i> | We are actually supposed to, well, in the practical semester at my school, we are actually often told that we should get away from the frontal teaching, that we should rather moderate. (GD)<br><i>Context: This PST argues that teachers are “supposed to” act a certain way, as they themselves were told to.</i>                                                  |
| Explanatory hypotheses                            | Maybe he just did not really understand the signals that were given by this nod, because you can also interpret this nod in a completely different way, just like you, uh, [participant's first name], said at the beginning, um, so this nod can be more like “Yes, thank you for your contribution.” (GD)<br><i>Context: This PST offers an alternative interpretation that contrasts with the other group members' understanding of the situation.</i>                                                                                                                                                                                                                           | Presumably, the teacher did not want to discourage students by hurriedly intervening, and wanted to value all of the students' contributions equally. (EW)<br><i>Context: This PST offers an explanation of the situation that builds on their previous arguments.</i>                                                                                                                                                                            | Thus, the task is incomprehensible. None of the students knows that the table is to be filled out independently after the class discussion and that it will also be collected. (EW)<br><i>Context: This PST offers a strongly evaluative explanation of the situation that acts to confirm prior assumptions.</i>                                                     |
| Referring to current emotional experiences        | At first, the teacher's behavior just made me angry, but then I became curious what could have led her to act like this. (Hypothetical example – no examples found in the data)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | I find it very exciting to find out how this effect can arise and I would like to investigate it at this point. (EW)                                                                                                                                                                                                                                                                                                                              | But I also really believe that the situation is not so negative. When I first read it, I did not perceive it as negative at all. (GD)                                                                                                                                                                                                                                 |
| Referring to details of the situation description | The way student B is described in this situation – his first answer, then his question to the teacher – allows for multiple interpretations. (Hypothetical example – no examples found in the data)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | In this learning situation, the teacher, by not giving feedback to Student A, invites the class to participate further and many students come forward for a response. (EW)                                                                                                                                                                                                                                                                        | Instead of naming the students “student A” and “student B,” they could have given them some nice-sounding names. (Hypothetical example – no examples found in the data)                                                                                                                                                                                               |

## Exploring knowledge construction processes in PSTs' reflections

Analyzing the coded data, we qualitatively explored differences in how participants articulated and interwove processes to construct an understanding of the situation. We first visualized the sequences of different process uses in the data of all cases. Segments that were not related to knowledge construction processes were marked as a residual category and were not considered in any of the analyses. We then explored one case from each condition (EW and GD) to illustrate the different ways that reflection unfolded.

Second, we investigated the differences between conditions regarding the variety of processes used and the quality with which they were implemented. To prepare our data, we first checked for differences between the total segment lengths of different knowledge construction types in both conditions. We found that the 15 essays contained on average 23 percent more letters than the 14 individual contributions in the transcripts. We standardized averages to 100 in both conditions to adjust for this difference, ensuring that the more extensive length of the essays would not influence our results.

We conducted multivariate analyses of variance (MANOVA) to compare the two conditions. We restricted our analysis of differences in the types of knowledge construction processes to the three deductively derived process types (referring to literature, referring to past experiences, generating explanatory hypotheses) as the two additional processes made up a minimal amount of the coded data and would not have allowed meaningful comparisons. As the assumption of multivariate normal distribution of the residuals was violated both regarding process type and to process quality (multivariate Shapiro–Wilk test:  $W_{\text{process type}}(29) = 0.85, p < 0.001$ ;  $W_{\text{process implementation}}(29) = 0.63, p < 0.001$ ), we used the more robust Pillai's trace as our test statistic (Meyers et al., 2017). To ensure the robustness of results, we confirmed our findings with Mann–Whitney  $U$  tests.

Although no *a priori* directional hypotheses were formulated, one-sided tests were applied following the MANOVA to further explore the observed group differences. This decision was made *post*

*hoc* to increase sensitivity to the direction of effects apparent in the data, allowing a more targeted examination of the results.

## Results

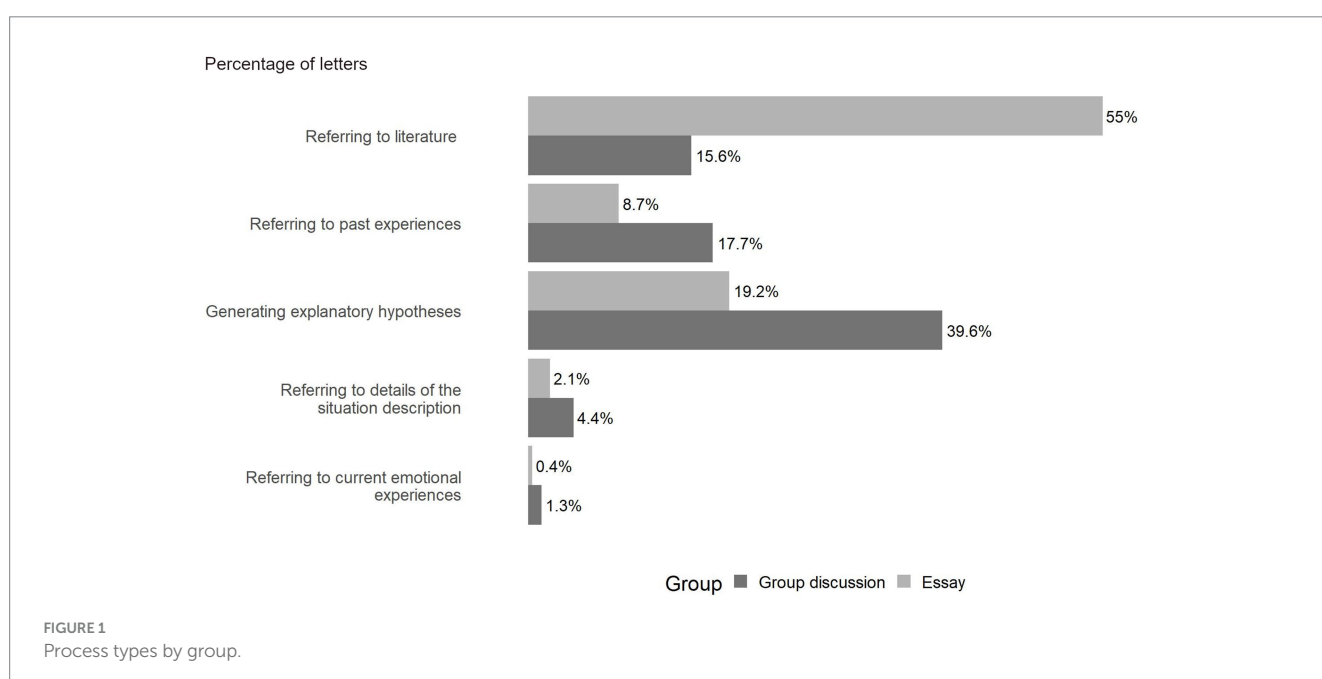
### Aim 1: viability of the coding scheme illustrated in two case examples

On average, we found 29 segments indicating knowledge construction processes in the essays and 32 segments in individual contributions to the transcripts. Over 50% of the total number of letters in essays were assigned to the category *referring to literature* (Figure 1). In transcripts, we coded almost 40% of the total number of letters as *generating explanatory hypotheses*. The two inductively added categories *referring to details of the situation description* and *referring to current emotional experiences* had considerably shorter segment lengths, only making up a small proportion (less than 6%) of the total number of letters used in both conditions.

Differences regarding process implementation quality are displayed in Figure 2. More than 70% of the letters used in the essays were coded as indicative of *evolving analytic* implementation. In contrast, the oral statements of the GD participants used more letters coded as *reflective*. Both conditions were similar in their use of *superficial* process implementations.

Two examples from EW (“Lisa”) and GD (“Tom”) conditions are displayed in Figures 3, 4. Selected for their sequential patterns with little deviation from their condition's norm, both exhibit characteristic behaviors for their respective conditions. Despite his slightly atypical lower number of reflective processes, Tom represents the GD cases especially well through his use of medium quality and varied processes, thus highlighting this aspect of our data on the GD condition.

EW participants often used the same kinds of processes throughout large text portions. When changing between process types, they would usually remain within the new process for several



sentences. Lisa began her essay by establishing a connection between her focus on feedback in the explanation of the situation vignette and her own past teaching experiences:

I decided to focus on giving feedback (especially up to the point where student B asks why student A's statement is wrong), because during teaching I became aware of the influence that positive reinforcement has on the learning climate. Praising good contributions often resulted in beaming faces and visible motivation of the students.

[...] Lisa went on to describe her emotional experience, in her case a feeling of interest, in this aspect of the situation:

This piqued my interest regarding the theoretical and empirical facts of the relevance of giving feedback, which I will discuss in more detail later.

She then explicated the focus on feedback by defining the term and delving into the literature on various aspects of feedback and

motivation. She did not use these sources to contrast any conflicting ideas on the issue, but correctly and transparently presented several theoretical distinctions and empirical findings:

[...] According to Locke and Latham's [...] goal-setting theory, the purpose of feedback is to ensure that the goal being worked toward in the classroom is transparent and thus learners can recognize their progress and maintain their efforts based on it [...]. Thus, feedback leads to transparency of what has been learned. Last, self-determination theory [...] makes it clear that due to the fact that everyone wants to feel competent, positive feedback creates some motivation. [...]

She concluded the explanatory part of her essay by returning to past experiences she connected to the situation described in the vignette:

[...] From my personal experience, I can say at this point that I feel that the topic of feedback is given enough space in the classroom. Often a nod or a short remark about the quality of the

Percentage of letters

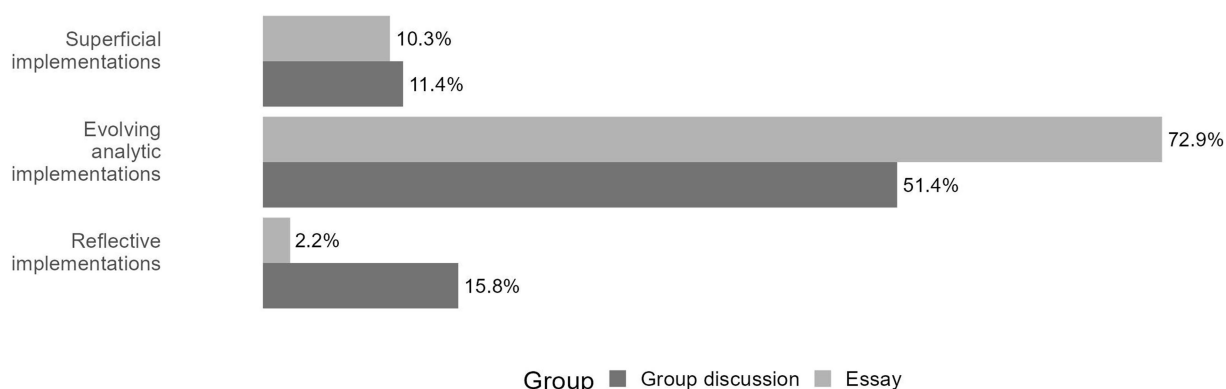


FIGURE 2  
Process implementation quality by group.

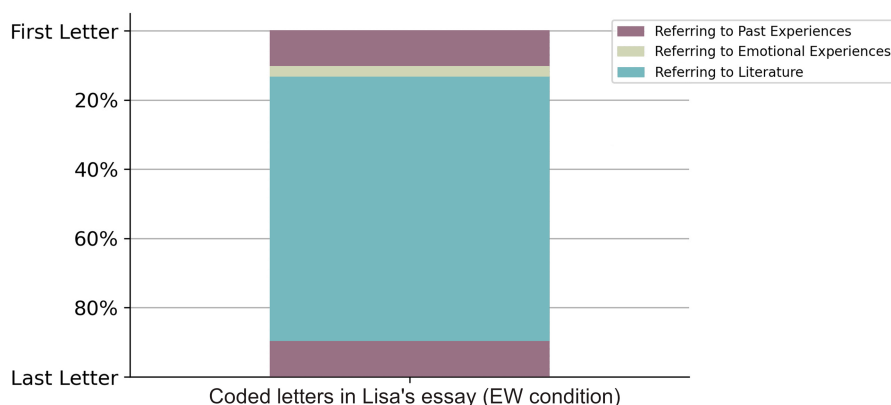


FIGURE 3  
Sequences of processes in an example essay.

students' statement is enough to increase motivation. If a teacher did not give clear feedback, in many cases that student would follow up and ask whether a student's statement was correct. [...]

Regarding process implementation quality, all of these examples were coded as *evolving analytic*, as they were clearly intended to construct an understanding of the situation and connected different sources but did not involve any form of questioning either the literature, the situation, or her own interpretations of the situation.

By contrast, participants in the GD condition not only used a wider variety of different processes, but also tended to switch more between different processes to argue for a specific understanding. Tom (Figure 4), mixed references to past experiences and explanations of the situation in his first recorded statement in the group discussion:

Well, I can also bring in my own experiences: It's a classroom discussion she tries to achieve here. And um, I was always told that a classroom discussion is, like, the masterpiece for a teacher. And you can see that it goes awry. Um, she leaves the students to a task that is not clearly formulated, she lets them make assumptions and she is also totally non-transparent about what is supposed to come out of it, she doesn't [...] And I've also experienced it that way: Classroom discussion I've tried to lead have gone totally wrong, simply because I've asked far too many questions that you could answer with yes, no or one word [...]

As these statements rested mostly on preconceived judgments, we coded them as *superficial*. Later, Tom would interweave ideas for

alternative courses of action, references to the situation description, and explanations of the situation:

But [as a teacher] you should announce that in advance, so that it's transparent and uh, still, even if it's not graded, it doesn't say [in the situation description] whether she makes a statement about it, whether it will be graded or not. If she just says, "I'm going to collect it now!" no matter if it's graded or not, if I were a student, I would feel totally pressured, because I have no possibility to change anything and also, it's not a valid measuring instrument at that moment.

In the course of the discussion, Tom connected aspects of the situation to literature and to experiences from his own forays into teaching. In some cases, he questioned his own or his fellow discussants' first interpretations of the situation and thus exhibited reflective processes. For example, when discussing in how the teacher in the pedagogical situation provides feedback to her students, he showed awareness of different possible interpretations of a detail of the situation:

... because when she nods, what does that mean—is that a form of feedback to the student, is it praise? I can't tell from [the description], it can be both in this context. [However,] these two should be clearly separated.

His explanation of this difference was cut short by another student. Overall, Tom remained mostly on the levels of *superficial* and *evolving analytic* process implementations: He used the information he had gathered from scientific literature for a straightforward

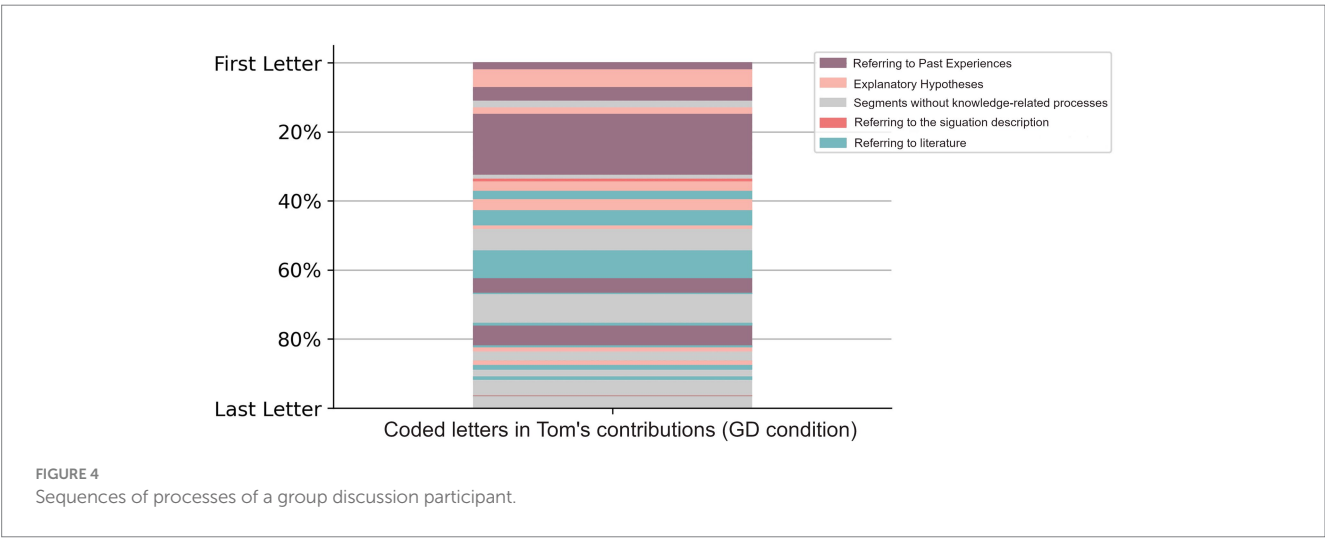


TABLE 3 Comparison of number of process types and number of switches between different process types.

| Indicator                                       | GD (n = 14) |      | EW (n = 15) |      | Difference |           |
|-------------------------------------------------|-------------|------|-------------|------|------------|-----------|
|                                                 | M           | SD   | M           | SD   | p          | Cohen's d |
| Number of Process Types Used*<br>(Min 2, Max 5) | 4.2         | 0.58 | 3.6         | 0.83 | 0.028      | 0.85      |
| Number of Switches*<br>(Min 1, Max 52)          | 23.4        | 11.4 | 14.7        | 10.6 | 0.042      | 0.79      |

\*p < 0.05.

explanation of various aspects of the situation but did not show any signs of weighing or questioning these explanations.

## Aim 2: differences in qualities of knowledge construction processes

Based on our qualitative results, we saw descriptively that participants in the GD condition use a wider variety of processes, both with regard to their total number as well as the number of times they switched between different kinds of processes. We explored these descriptive findings using *t*-tests. Regarding the number of different processes used in the two reflection formats, a two-tailed *t*-test showed a significant difference between the conditions (Table 3). On average, members of the GD condition used a larger number of processes. We found similar results when we looked at the number of switches between different process types.

While these results might point to a potential for a more comprehensive process enactment in the GD condition, we wanted to further explore differences between the two conditions. We therefore investigated whether the conditions differed regarding our ratings of process implementation quality. We tended to observe more processes of the highest implementation quality, called *reflective* in the GD condition. Using a one-factor MANOVA on the standardized number of characters in each process quality category, we found a statistically significant difference between the reflection formats for three degrees of process implementation [ $F(3, 25) = 10.765$ ,  $p < 0.001$ , partial  $\eta^2 = 0.564$ , Pillai's  $V = 0.564$ ]. Between-subjects effects show significant differences for *evolving analytic* processes and *reflective* implementation. This was confirmed by two-sided *t*-tests (Table 4).<sup>2</sup>

2 Mann–Whitney *U* tests were conducted for the variables *reflective* and *superficial*:  $Mdn_{GD} = 20.43$ ,  $Mdn_{EW} = 9.93$ ,  $U(14, 15) = 29$ ,  $z = 3.37$ ,  $p < 0.001$  and  $Mdn_{GD} = 17.93$ ,  $Mdn_{EW} = 12.27$ ,  $U(14, 15) = 64$ ,  $z = 1.8$ ,  $p = 0.08$ .

TABLE 4 Comparisons of process implementation.

| Process             | GD ( $n = 14$ ) |           | EW ( $n = 15$ ) |           | Difference |                  |
|---------------------|-----------------|-----------|-----------------|-----------|------------|------------------|
|                     | <i>M</i>        | <i>SD</i> | <i>M</i>        | <i>SD</i> | <i>p</i>   | Cohen's <i>d</i> |
| Reflective***       | 12.9            | 12.86     | 2.21            | 3.43      | <0.001     | −1.59            |
| Evolving analytic** | 41.88           | 16.57     | 72.87           | 21.8      | <0.01      | 1.15             |
| Superficial         | 9.26            | 7.52      | 10.3            | 18.8      | 0.845      | −0.072           |

\*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

TABLE 5 Comparison of process types.

| Process                             | GD ( $n = 14$ ) |           | EW ( $n = 15$ ) |           | Difference |                  |
|-------------------------------------|-----------------|-----------|-----------------|-----------|------------|------------------|
|                                     | <i>M</i>        | <i>SD</i> | <i>M</i>        | <i>SD</i> | <i>p</i>   | Cohen's <i>d</i> |
| Referring to literature***          | 12.72           | 6.57      | 54.97           | 32.4      | <0.001     | −1.77            |
| Referring to past experience        | 14.41           | 12.28     | 8.68            | 8.72      | 0.082      | −0.206           |
| Generating explanatory hypotheses** | 32.29           | 15.69     | 19.25           | 14.65     | <0.01      | 0.86             |

\*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

No significant differences were found for *superficially implemented* processes. Effect sizes for *evolving analytic* and *reflective* codes were large ( $d = -1.59$  and  $d = 1.15$ ).

## Aim 3: differences in process types

A one-factor MANOVA with the condition as the independent variable showed a significant difference in the standardized numbers of letters in the three dominant knowledge construction processes: *referring to literature*, *referring to past experience*, and *generating explanatory hypotheses* [ $F(3, 25) = 11.174$ ,  $p < 0.001$ , partial  $\eta^2 = 0.573$ , Pillai's  $V = 0.573$ ]. The between-subjects effects show significant ( $p < 0.05$ ) influences of the *referring to literature* and *generating explanatory hypotheses* variables (Table 5). This was confirmed by subsequent Bonferroni-corrected one-tailed *t*-tests. Standardized values for *referring to literature*, and *generating explanatory hypotheses* were both significant. In contrast, differences in *referring to past experience* were found to be non-significant. Since the normality assumption was violated in the variables *referring to literature* and *referring to past experience*, results were additionally confirmed by the removal of outliers and by Mann–Whitney *U* tests:  $Mdn_{GD} = 7.71$ ,  $Mdn_{EW} = 21.8$ ,  $U(14, 15) = 207$ ,  $z = 4.45$ ,  $p < 0.001$  and  $Mdn_{GD} = 16.93$ ,  $Mdn_{EW} = 13.2$ ,  $U(14, 15) = 78$ ,  $z = -1.18$ ,  $p = 0.252$ . Both *referring to literature* (Cohen's  $d = -1.77$ ) and *generating explanatory hypotheses* ( $d = 0.86$ ) showed large effect sizes, with participants in the GD condition demonstrating more frequent uses of these processes in comparison to the EW group.

## Discussion

This study introduced a coding scheme to assess PSTs' knowledge of construction processes when reflecting on a complex classroom situation. The scheme is applicable to two different modes of reasoning and reflection—individual (EW) and collaborative (GD). Based on previous research and theoretical literature, we identified several knowledge construction processes and coded the data to compare their implementation in the two reflection modes. Four of these processes involved references to the sources of knowledge used to understand the vignette and guide reasoning: referring to literature, own experiences, the situation, or to current emotional experiences. The fifth process involved generating tentative explanatory hypotheses for the situation.

In exploratory analyses, we investigated differences between the two conditions regarding process implementation. We found differences in the absolute numbers of processes used and the number

of switches between different process categories, both indicating a larger variety and comprehensiveness in the GD condition. This may cautiously suggest a more sophisticated performance in the GD conditions than in the EW conditions. Expanding on Rinehart et al. (2022), we included an evaluation of how knowledge construction processes are implemented, identifying and coding three process qualities. While we found no difference between the two conditions for *superficial* implementations, we found more *evolving analytic* implementations in individual reflections (EW) and more *reflective* ones in collaborative reflection (GD), indicating that weighing and relating of evidence and arguments is more prominent in group discussions. This corresponds to Kuhn (2015) and complements prior findings from educational psychology within teacher education (Csanadi et al., 2021). Our findings also resonate with the literature on epistemic cognition, which assumes that epistemic performance requires not so much the use of one single process, but the proficient use of an array of different processes depending on the aims at hand (Barzilai and Chinn, 2018; Chinn et al., 2014).

With regard to the types of processes in the two conditions, we found that in individual reflective essays, PSTs made more references to literature, whereas in collaborative reflective discussions, they generated more explanatory hypotheses for what happened in the classroom situation and why. In both cases, we found large effect sizes. There were no significant differences between EW and GD conditions regarding references to PSTs' own experiences. In addition to the processes deductively identified from prior research and theory, we inductively found two more knowledge-construction processes: *referring back to the situation* and *referring to emotional experiences*. These appeared in both conditions, but to a much lesser extent than the first three process types. However, they were valuable in understanding which sources of knowledge our participants used when they reflected on the pedagogical situation. From the perspective of reflection theory, these differences highlight distinct pathways to the extended understanding of pedagogical practice that Arendt et al. (2025) identify as the core outcome of reflection. Individual essays, with their stronger emphasis on literature, may foreground justification and align with academic norms of evidence use, whereas group discussions might elicit more self-referential and generative processes, involving the weighing of alternatives and self-integration.

Even though both essay writing and group discussion were designed and experienced as reflective tasks within the teacher education program, only a minority of participants in either format reached the highest quality level of *reflective* engagement. Comparing the two formats therefore provided insight not only into the endpoint of reflection but also into the developmental trajectories—and potential absence—of reflective processes that teacher educators may wish to scaffold more explicitly.

The patterns observed suggest that different reflection formats may afford different kinds of engagement with educational sciences knowledge. While the essay format elicited more frequent references to literature, it remains an open question whether these references reflect perceived usefulness or a sense of academic obligation. In contrast, the GD condition seemed to encourage more generative reasoning, where explanatory hypotheses were developed in dialogue with others. This pattern suggests that collaborative reflection may support the functional use of educational knowledge—i.e., its active integration into meaning-making and professional judgment—rather than its formal citation alone.

Differences in conditions may stem from the more diverse perspectives that arise during a group discussion (Kuhn, 2015). Further, discussions may expose participants to alternative ideas, questions, and possibilities. As suggested by Gregory (2007), the goal of a discussion in terms of dialogue types may shift from inquiry to information-seeking, to persuasion based on the needs of the individuals participating in the discussion. Thus, the frequency of switches between processes may reflect shifts in goals throughout the discussion. In contrast, when participants worked individually to write about the vignette, they were able to focus only on their own thinking and then reflected on the sources they relied on to inform their analysis. This individual mode may prompt closer alignment with formal academic expectations, including the use of educational sciences literature, even if this does not always translate into deeper epistemic engagement. Future research could explore how group composition or dialogue types influence the use of different kinds of knowledge-generating processes.

## Limitations

Conceptually, teachers' knowledge construction involves processing both their own teaching decisions as well as their students' learning (Buehl and Fives, 2016). Our study focused on PSTs as *learners* about different aspects of *teaching*. We chose this limited focus because we assume that teachers' knowledge construction regarding their teaching role should better be studied in the environment of practicing, in-service teachers rather than on the basis of the mostly hypothetical reflections of PSTs still enrolled in university programs. To address this issue, different research designs would be necessary.

Our small sample size limits generalizations to a broader PST population and precluded an examination of possible biases from the slight gender imbalance. Moreover, self-selection bias may exist, as PSTs chose their preferred reflection condition. Although we compared the two groups on several measures, we cannot rule out that unobserved differences (e.g., talkativeness or discussion affinity, writing self-efficacy, comfort with public reasoning) may have influenced both format choice and process use. Our design privileges ecological validity over causal identification; results should be interpreted as descriptive of authentic practice under choice, not as causal effects of format. Interpreting results is further complicated by possible methodological biases associated with the two reflection modes (EW and GD). While GD transcripts may be regarded as proximal indicators of ongoing processes, individual reflective essays might represent final *products* rather than the *processes* of reflective engagement. Before writing an essay, PSTs might have engaged in several steps of knowledge construction that may be invisible in their written essays. Thus, the GD transcripts may more directly reveal underlying processes compared to essays.

Additionally, essay-writing evokes a more academic mindset that peer discussions (Kuhn, 2009). PSTs might feel obligated to use more scientific sources and express arguments in a more sophisticated way. However, this might not necessarily reflect its perceived practical utility. As previous research has shown, PSTs often struggle to connect abstract concepts from educational sciences to concrete teaching actions unless these connections are explicitly scaffolded (Zaragoza et al., 2021). In our study, we were unable to collect think-aloud

protocols for the participants in the EW condition that might have revealed earlier phases of reflective thinking. The GD task is also intrinsically multi-layered: it integrates written artifacts (prepared notes/bibliographies) with oral deliberation, and participants may alternate between these modes during the session. These modality and task-structure differences likely contributed to the observed process profiles and should be considered when interpreting between-format contrasts. To replicate and extend our findings, we suggest incorporating different kinds of individual process data such as annotated outlines, planning notes, or concept maps.

GD transcripts also posed challenges in identifying individual participants' knowledge construction processes. We adopted an individual-contribution lens to align modalities (one essay  $\approx$  one individual's contribution set), but we acknowledge that this choice ignores within-group clustering. Even though we segmented discussions into individual utterances, participants' arguments build on others', making them not fully independent. This might be problematic when several participants engaged in similar knowledge construction processes but only one of them demonstrates these explicitly. In this case, we would only count this process as part of the engagement of one individual PST. Our data suggests that this is not a general pattern, as there were proportionally more codes in GD transcripts than in the essays. Still,  $p$ -values in GD/EW contrasts may lead to over-interpretation. We emphasize converging patterns and effect sizes, and were cautious when drawing inferences from these results. To address selection and dependence concerns while preserving ecological validity, follow-up studies should prioritize: (a) random assignment to EW/GD or within-subjects cross-over designs; (b) designs that hold preparatory work constant across formats; and (c) analyses that model clustering when using group-embedded data.

As noted in the Methods section, character counts were used to approximate elaboration across German written and spoken language; this choice has limitations (e.g., sensitivity to transcript conventions). While proportional reporting reduces scale dependence, different metrics (words, speaking time) may capture distinct aspects of production. Our core claims center on relative profiles (which processes and qualities are foregrounded) rather than absolute quantities. Another limitation of our analysis approach is that the use of one-sided tests was data-driven rather than theory-driven. Consequently, the findings should be interpreted with caution and considered preliminary.

Despite these limitations, our study's results remain significant due to the authenticity of our comparative approach within real-world teacher education contexts. Alternative methodologies might offer more direct comparability but would sacrifice the naturalistic setting crucial for understanding reflective processes in actual practice. Our findings highlight trade-offs in research design and underscore the value of understanding reflective practices as they naturally occur.

## Implications and outlook

Achieving continuous reflective practice in teaching requires a deeper understanding of PSTs' knowledge construction processes. We consider our study and coding scheme a starting point to assess types and implementation qualities of knowledge construction processes directly linked to the explanation of

complex pedagogical situations likely to occur in school practice. In doing this, we offer insight into how to identify and evaluate PSTs' process enactment on ecologically valid tasks and into how different reflective tasks might support or constrain PSTs' tendency to integrate different forms of knowledge into classroom reasoning. This may help educational researchers and teacher educators, and, in the long run, teachers' classroom practice. Educational researchers might adapt the coding scheme for various settings and reflection formats.

Teacher educators can use our findings to select reflection formats depending on their courses' specific aims. If the aim focuses on applying a theoretical approach or an empirical finding to a pedagogical situation, an individual task like essay-writing might be preferable. However, if teacher educators aim to elicit a combination of various processes, linking educational science knowledge with experiential knowledge, a peer discussion might be more appropriate. Our results suggest that well-structured peer discussions where students are required to come with a prepared reference list support more elaborate process implementations and unfold a larger array of processes without distracting from epistemic focus. This underscores the need for teacher educators to explicitly teach PSTs how they are supposed to implement aspects of professional reflection in elaborate ways. Such specificity is crucial for understanding complex classroom situations and influencing professional judgment and decision-making in meaningful ways to become reflective practitioners (Schön, 1983)—that is, professionals who can interpret complex teaching situations through a thoughtful integration of theory and evidence from educational science with their context-specific judgment.

## Data availability statement

The datasets presented in this article are not readily available because of a high risk of participant de-anonymization. Requests to access the datasets should be directed to [marcus.kindlinger@uni-muenster.de](mailto:marcus.kindlinger@uni-muenster.de).

## Ethics statement

Ethical review and approval were waived for this study because, according to the German legislation on research involving human subjects, ethical approval is only required when sensitive data are collected, when physical interventions are performed, or when subjects could be harmed. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

## Author contributions

UH: Writing – original draft. MK: Writing – original draft. KT: Writing – review & editing. A-LM: Writing – review & editing. HF: Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The authors declare that Gen AI was used in the creation of this manuscript. Generative AI was used solely for language editing, improving grammatical and lexical clarity. All intellectual content, research design, and data analysis were conducted solely by the authors.

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## Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/feduc.2025.1668962/full#supplementary-material>

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