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Nudging dialogic pedagogical design of peer feedback towards exploratory collaboration: a four-year educational design research study

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ABSTRACT

Dialogical peer feedback is an important element of socio-cultural pedagogy design. However, many student teachers have unbeneficial experiences with dialogical – or collaborative – peer feedback. To advance the development of theory and pedagogical support practices for dialogical, collaborative, and exploratory peer feedback, this study combined theories of dialogical peer feedback, higher-level collaborative learning, and exploratory social thinking. Video data collected during a four-cycle educational design research study (conducted over four years in subject teacher education) were analysed to identify observable patterns in students' interaction modes. The research design involved yearly shifts in pedagogical support practices towards (a) feedback exemplars involving repetition and multiple presentational modalities and (b) demonstrations exemplifying dialogicality and the use of a feedback protocol. The results show that each yearly change in pedagogical design nudged students' interactions towards more dialogical and exploratory feedback across successive cohorts, while unilateral feedback and demonstrations of individual expertise became less common.

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Exploratory collaboration; dialogical peer interaction; patterns of interaction; social mode of thinking; video research

Introduction

Peer feedback tasks provide possibilities to practice two related but separate competencies: 1) assessing learning constructs and 2) formulating feedback observations (Bürgermeister, Glogger-Frey, and Saalbach 2021), which should result in peer learning and the implementation of corrective actions (Er, Dimitriadis, and Gasevic 2021). These competencies are elemental for student teachers' future performance as teachers. Yet, research on teacher education (TE) approaches to peer feedback teaching (Grainger 2020) and learning designs supportive of peer feedback dialogue (Cheng et al. 2023; Kollar and Fischer 2010) remains scarce.

Multiple approaches to peer feedback exist (Topping 2018, 2021), but research (e.g. Nicol 2014; Schillings et al. 2021) suggests that peer feedback benefits are likely to

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increase when tasks are carried out as a dialogical process. These benefits are likely to increase even more if participants engage in high-level cognitive and discursive processing, such as explaining, providing well-warranted arguments and counterarguments, questioning, and coherently integrating peers' suggestions into one's own product (Kollar and Fischer 2010). Thus, for high-quality peer feedback, students should engage in knowledge co-construction.

Students do not always welcome peer feedback tasks (Lynch, Mannix McNamara, and Seery 2012), and high-quality peer feedback is unlikely to emerge spontaneously (e.g. Sluijsmans and Prins 2006). High-quality peer feedback depends on student motivation and a willingness to share (Nicol 2014), but also on design decisions pertaining to pedagogical configurations at the course (Hattie and Timperley 2007; Winstone et al. 2017) and curriculum levels (Er, Dimitriadis, and Gasevic 2021; Sadler 2010). Besides mere 'teacher talking', students should be provided with practical examples and experiences of peer feedback (Topping 2018, 5). The provision of individual experiences is necessary as students' experiences and beliefs accumulated prior to TE form a change-resistant filter through which new knowledge is interpreted (Bryan 2003; Korthagen 1993). These filters are not necessarily supportive of pedagogies pursued by TE (Britzman 2003; Hong and Perez 2023). Thus, new experiences of peer feedback practices conducive to higher-level learning are needed.

In TE, the bar for learning designs should be even higher than it is elsewhere in higher education. For Finnish student teachers, it is insufficient to recognise features of subpar quality and suggest corrective actions. According to the Finnish Basic Education Act (Finlex 1998), pupil assessment should develop pupils' self-assessment capabilities in addition to guiding and encouraging learning. To achieve this, student teachers should be able to elaborate on how various characteristics of learning artefacts reflect the levels at which learning objectives (set locally) and assessment criteria (set in the national core curriculum) have been reached (Finnish National Agency of Education 2014). In other words, student teachers need to be able to recognise and verbalise in situationally sensitive ways how diverse characteristics of learning artefacts fall on a continuum of quality (cf. Sadler 2013). Therefore, this study focuses on learning designs that support high-quality peer feedback practices from the uniquely demanding perspective of TE.

Dialogical peer feedback has been advocated over information transmission for (at least) since 2010 (e.g. Cheng et al. 2023; Esterhazy 2018; Nicol 2010; Schillings et al. 2021), as have framings as collaborative learning (e.g. Er, Dimitriadis, and Gasevic 2021; Kollar and Fischer 2010; Lineback and Holbrook 2024; van Gennip, Segers, and Tillema 2010). These accounts situate feedback within a socio-constructivist paradigm, which – as Nicol (2014) pointed out – has been slow to influence feedback research, even though in learning research, the change from transmission to the socio-constructivist paradigm had already taken place in the 1990s. However, socio-constructivist feedback processes have not gained popularity (Carless 2019); consequently, no extensive research exists in this field. In TE, learning designs should provide holistic experiences (that differ from the information-transmission paradigm) and pedagogical support sufficient for producing beneficial student experiences.

Moreover, poor conceptualisations of feedback practices (Schluer and Brück-Hübner 2024) and dialogic peer feedback (Er, Dimitriadis, and Gasevic 2021) in research result in poor comparability between individual studies, effectively preventing the field from advancing through meta-analysis. To advance theory building, Er, Dimitriadis, and Gasevic (2021) presented their theoretical framework of three phases of collaborative

peer feedback: feedback planning, dialogue, and performing corrective actions. Similarly, Schluer and Brück-Hübner (2024) provided a feedback design taxonomy to promote comparability in peer feedback research. Furthermore, to emphasise the important link between the quality of dialogue and knowledge co-construction, Er, Dimitriadis, and Gasevic (2021) recommended exploratory dialogue (Mercer 1996) as a model for high-quality dialogue. To date, Kollar and Fischer's (2010) suggestion for stronger links to collaborative learning research has not been enacted in full by peer feedback researchers.

From these premises, this study has two-fold aims: to advance the theory building of peer feedback as exploratory collaboration and to develop pedagogical support for face-to-face exploratory peer feedback. The pedagogical support intends to be specifically suitable for TE purposes: not only to enhance the quality of students' interactions but also to develop student teachers' teaching skills.

Thus, with an emphasis on higher education, research on peer feedback and collaborative learning are explored, followed by an exploration of research at the cross-section of these concepts and related pedagogical support.

Background

Peer feedback

According to Topping (2018), peer feedback involves peer assessors providing information to assessees about the strengths and weaknesses found in the assessed learning artefacts. In TE, students' listings of artefact strengths and weaknesses should be complemented with justifications. Furthermore, peer feedback quality measures in TE have also referenced affective, cognitive, and metacognitive aspects (Zhang et al. 2024), have separated positive, negative, and constructive comments from questions (Sluijsmans et al. 2003), and have involved task goals, strategies for future learning, and weaknesses linked to advised strategies (Bürgermeister, Glogger-Frey, and Saalbach 2021).

Concerns related to unilateral feedback have been discussed, for instance, by Adachi, Tai, and Dawson (2018) and Li et al. (2020). Transitioning from unilateral feedback to peer feedback as interactive (Zhang et al. 2024), active dialogue (Cheng et al. 2023), or collaboration (e.g. Er, Dimitriadis, and Gasevic 2021; Lineback and Holbrook 2024; van Gennip, Segers, and Tillema 2010) potentially eliminates some of these concerns. In fact, re-conceptualising feedback as dialogic was mainly due to concerns raised by research on higher education feedback (Steen-Utheim and Wittek 2017). Summaries of the benefits of dialogicality and collaboration in relation to concerns related to unilateral feedback were developed by, for instance, Steen-Utheim and Wittek (2017), van Gennip, Segers, and Tillema (2010), Er, Dimitriadis, and Gasevic (2021), Zhang et al. (2024), and Lineback and Holbrook (2024).

In TE, peer feedback implementation drawbacks include students' reluctance to criticise peers' work (Lynch, Mannix McNamara, and Seery 2012), and feedback experienced as short, overly positive, based on insufficient experience, and lacking sufficient advice for improvement (Bader, Iversen, and Borg 2024). This could signal students' mistrust towards non-expert (i.e. other-than-teacher) feedback. However, teacher feedback seldom unfolds as an active dialogue without power issues. Therefore, dialogical peer feedback has different benefits from expert feedback (Bader, Iversen, and Borg 2024; Er, Dimitriadis, and Gasevic 2021; Schillings et al. 2021). It allows discussions from multiple perspectives,

thus enhancing students' understanding of assessed work, learning tasks, and quality criteria (Bader, Iversen, and Borg 2024). It could stimulate elaboration, constructive comments, and feeling responsible for the feedback (Schillings et al. 2021). In other words, dialogical feedback supports students' agency – active participation in knowledge co-construction.

Yet, dialogicality or collaborative settings do not automatically remove obstacles for effective learning, as superficial feedback, resistance to critical thinking, and a lack of trust in peers' comments could still persist (Cheng et al. 2023). However, inhibition towards providing critical feedback and feedback quality issues was reduced by training and experience (Bader, Iversen, and Borg 2024; Lynch, Mannix McNamara, and Seery 2012), corroborating findings from other HE contexts (Li et al. 2020; van Zundert, Sluijsmans, and van Merriënboer 2010; Zong, Schunn, and Wang 2021).

Collaborative and exploratory practices

Collaborative learning has received multiple interpretations. One seminal definition by Roschelle and Teasley (1995, 70) recognises collaboration as 'a coordinated, synchronous activity' that results from 'a continued attempt to construct and maintain a shared conception of a problem'. In other words, learners share responsibility for the learning process while working towards shared goals (Roschelle and Teasley 1995). At times, collaborative situations (learning designs) have been conflated with collaborative interactions. However, not all collaborative situations result in collaborative interactions (Dillenbourg 1999). Collaborative situations refer to conditioning a collaborative interaction, for instance, a learning design in which peers can work together to reach a common goal. Meanwhile, collaborative interactions are characterised by interactivity, synchronicity, and negotiability (Dillenbourg 1999; cf. also Yang and Carless 2013). Here, interactivity refers to the extent to which one's interactions influence peers' cognitive processes. Synchronicity refers to a meta-communicative contract entailing mutual interest in others' contributions and a commitment to respond in a timely manner. Negotiability refers to participants arguing, justifying, negotiating, and attempting to convince instead of imposing their views (Dillenbourg 1999). Separating conditioned learning situations from actualised student interactions reflects this study's underlying concern: What pedagogical practices are necessary to elicit and support collaborative interactions within the context of a collaborative peer feedback task?

Dillenbourg (1999) suggests that achieving pedagogically beneficial collaborative practices requires research at the level of interaction categories as collaboration is too broad a concept. Amongst other aspects, he suggests noticing differences in symmetry of action, status, and knowledge. To examine the quality of collaboration observable in student interactions, this study employed Mercer's (1996) three modes of social thinking: exploratory, cumulative, and disputational talk. Er et al. also advocate for using these modes in collaborative peer feedback. Mercer et al. have centred longstanding research and pedagogical development around the idea that talk is a social mode of thinking (compiled, for instance, in the Thinking Together Project; University of Cambridge 2026). One strength of Mercer's social modes of thinking model is that it relies on concrete examples of productive and engaging language practices drawn from actual language

events. Beyond Mercer, such examples have been provided, for instance, by Isohätälä et al. (2018).

Exploratory talk manifests reasoning, underlying knowledge, and cognitive processes. It is characterised by sharing one's knowledge, ideas, and detailed reasoning, seeking various options to evaluate and comment, engaging critically but constructively with others' ideas, seeking agreement for joint progress, and, when necessary, challenging proposals with given reasons and alternatives – in other words, interactivity, synchronicity, and negotiability. Cumulative talk flows smoothly but uncritically, without disagreement, questioning, or challenges – that is, with surface-level interactivity but lacking in negotiability. Disputational talk is uncooperative and competitive (Mercer 1996).

Exploratory talk involves features of high-quality collaborative learning. Mercer's (1996) characterisations of the social modes of thinking resonate with Dillenbourgh's (1999) descriptions of interconnectedness, synchronicity, and negotiability. These two accounts appear to differentiate interaction categories based on the same features. Similar features – albeit identified from different starting points – were noted by Kollar and Fischer (2010). They suggested that certain collaborative processes have the potential to facilitate higher-level cognitive processing, which, in turn, is necessary for higher-level learning. Such facilitative processes involve explaining, questioning, providing well-warranted arguments and counterarguments, elaborating on feedback based on deep processing of evaluated learning artefacts and tailored to specific receivers, a thorough examination of suggestions, and coherent integration of others' suggestions into one's own learning artefacts (Kollar and Fischer 2010). This study assumes that exploratory talk approximates high-quality collaborative learning, which is well worth practicing in TE.

Peer feedback as face-to-face collaborative learning

Framing peer feedback as collaborative learning positions students to engage in actively collecting, hypothesising, analysing, and interpreting diagnostic data and identifying corrective strategies together. High-quality learning during peer feedback entails exploratory interactions rather than mere information transmission demonstrating the assessor's expertise. Scaffolding is mutual rather than unilateral (Zhu and To 2022), and both the feedback provider and receiver learn due to well-founded feedback (Gielen et al. 2010).

Previous peer feedback research has touched on interactivity and the quality of dialogue in face-to-face situations. Focusing on the dimensions of engagement and equality, Lineback and Holbrook (2024) identified five patterns of interaction: collaborative, expert/novice, dominant/passive, dominant/dominant, and passive/passive. Of these, collaborative and expert/novice patterns involve active engagement in each other's ideas and a joint-problem space (Lineback and Holbrook 2024). Emphasising proactivity and (self- and co-) regulatory mechanisms, Zhu and To (2022) described seven feedback receiver roles: passive, respondent, verifier, explicator, negotiator, seeker, and generator. Of these, negotiators, seekers, and generators were found to be beneficial for high-quality engagement with and use of feedback (Winstone et al. 2017; Zhu and To 2022). Negotiators launched discussions between different perspectives, seekers actively requested critical feedback, and generators initiated revision strategies for their own work (Zhu and To 2022). When translated into activities, these roles approximate exploratory behaviour. Additionally, some face-to-face studies (e.g. Lineback and Holbrook 2024; Zhu

and To 2022) have referred to students' emotions but have not systematically probed them during feedback sessions.

In TE, collaboration simultaneously represents a learning method, a learning objective, and a pedagogical practice that student teachers should be able to facilitate when working with their own pupils. The same pertains to peer feedback. Therefore, framing peer feedback as collaborative learning could strengthen students' understanding of collaborative learning – and, by extension, feedback practices – as a pervasive pedagogical approach. Moreover, this framing could encourage students to see peer feedback as part of a shared effort to improve peer learning artefacts – that is, as a practice that promotes their agency and learning alike.

Considering the two above-discussed, separate but interrelated peer feedback dimensions – evaluating quality and communicating findings (Bürgermeister, Glogger-Frey, and Saalbach 2021) – the research appears imbalanced. Whereas ample attention has been directed towards the accuracy of students' assessments (e.g. Falchikov and Goldfinch 2000; Liu and Carless 2006) and peer feedback content (Gielen et al. 2010), little attention has been placed on elaborating on and explaining features demonstrating quality variations in learning artefacts and overall competencies for communicating diagnostic perceptions and judgements (Bürgermeister, Glogger-Frey, and Saalbach 2021) in a pedagogically justified manner (i.e. according to situational needs).

Another imbalance in feedback research concerns the paucity of attention paid to the role of emotions (Molloy, Noble, and Ajjawi 2019). Emotions play a fundamental role in learning (Pekrun 2024) and feedback (Värlander 2008). This is noted, for instance, in feedback frameworks such as learning-centred feedback literacy (Molloy, Boud, and Henderson 2020) and educational alliance (Telio, Ajjawi, and Regehr 2015). Kollar and Fischer (2010, 347) suggest that 'a comprehensive model on peer assessment should also incorporate motivational and emotional conditions, processes and outcomes'. In the context of collaborative learning, the regulation of emotions and motivations—two closely interrelated factors (Pekrun 2024) – has been approached from both intra- and inter-individual perspectives (Järvenoja et al. 2024). However, research on collaborative learning (e.g. Dillenbourg 1999; Järvenoja et al. 2024) emphasises the need to account for situational conditions (multifaceted and multilayered, static and dynamic) related to regulative activities. Therefore, identifying the role of motivational and emotional factors in situational variations in learners' emotional and motivational responses requires temporal analysis (Järvenoja et al. 2024). This poses a serious methodological challenge: The measurement should not interfere with the actual feedback activities, or, at least, should minimise interference. One solution has been to use physiological measures, such as electrodermal activity combined with video observation (e.g. Järvenoja et al. 2024), or heart rate variability together with experience sampling (e.g. Ketonen et al. 2023).

Pedagogical support for collaborative peer feedback

Providing peer feedback is not easy, and student teachers only learn about the knowledge they should apply. Pedagogical support is not tailored independent of curriculum-level issues and disciplinary cultures. In TE, formative and summative feedback need to be learned early on at both the conceptual and pedagogical levels. For instance, the Finnish National Core Curriculum for Basic Education (FNAE 2014) establishes objectives and focal areas for teacher

feedback and assessment, but the situational realities of teacher–student interactions need to be rehearsed – first with peers, and later during practicum periods. By comparison, in a context such as tutor–student feedback in medical education, beneficial results have been achieved through interventions that provide students with basic information about the aims of the feedback and support related reflective practices (Molloy, Noble, and Ajjawi 2019).

Feedback practices can build, validate, or challenge participants' identities (Molloy, Noble, and Ajjawi 2019). Several beneficial support practices have been identified by peer feedback research, including rubrics (which specify the qualities of the learning artefact to be evaluated) and scripts (involving procedural facilitation of the feedback process). Rubrics incited students to acquire more diagnostic information, which facilitated more tailored and grounded feedback (Bürgermeister, Glogger-Frey, and Saalbach 2021). Rare studies on procedural facilitation (such as feedback templates or guiding questions) have identified improvements in formulating feedback messages based on acquired diagnostic information (Bürgermeister, Glogger-Frey, and Saalbach 2021). Regulation scripts with questions guiding meaningful interaction and collaborative and regulated processes with shared goals elicited critical thinking and a climate of trust (Cheng et al. 2023). In TE, procedural facilitation focusing on learning strategies (particularly organisational and elaboration strategies) resulted in better quality feedback (Bürgermeister, Glogger-Frey, and Saalbach 2021). Furthermore, in medical education, supporting students' agency by guiding them in identifying their preferred feedback topics and focus areas – for instance, through self-evaluation prior to feedback sessions (Molloy, Noble, and Ajjawi 2019) – has yielded beneficial results.

The abovementioned results, obtained in online settings (e.g. Bürgermeister, Glogger-Frey, and Saalbach 2021) or through questionnaires and retrospective in-person student interviews (e.g. Cheng et al. 2023), provide valuable lessons. However, they do not address students' moment-to-moment, face-to-face interactions as they unfold. That is, these methodologies alone do not address the requirements of collaborative learning research, underlining the need for temporal analysis (e.g. Järvenoja et al. 2024) at the level of interaction categories (Dillenbourg 1999).

Aims and research questions

This study belongs to a four-year, four-cycle [C1–C4] educational design research (EDR) investigation addressing TE students' challenges in providing high-quality feedback during a face-to-face peer feedback task. Generally, EDR aims to develop both pedagogical and conceptual knowledge while systematically adjusting parts of the learning design from cycle to cycle (McKenney and Reeves 2013). Therefore, this study aims to advance the theory building of peer feedback as exploratory collaboration and to develop pedagogical support for face-to-face exploratory peer feedback in TE. Considering the abovementioned theoretical underpinnings of collaborative learning research, this study assumes that developing effective support practices for face-to-face peer feedback requires analyses of students' interactions as they unfold in such situations under conditions of changing pedagogical support practices. We do not aim to build a 'comprehensive model' (cf. Kollar and Fischer 2010) but rather to nudge the pedagogical design towards exploratory collaboration bit by bit, cycle by cycle. For instance, methodological solutions suitable for measuring emotional and motivational responses could not be integrated into these research cycles. Therefore, this study approaches peer

feedback as observable moment-to-moment interactions. The design element changed from cycle to cycle regarding pedagogical support – that is, instructions on peer interaction and evaluation criteria.

Two research questions (RQs) were pursued:

RQ1: What patterns in students' interactions emerged during face-to-face peer feedback?

RQ2: What changes in the patterns of students' interactions could be identified as the feedback support practices were changed from cycle to cycle?

Materials and methods

Ethical principles of research with human participants in the human sciences in Finland (TENK 2023) were duly followed. Due to the involvement of mobile gaze-tracking acquisition, C3 and C4 were approved by the Ethics Committee for Human Sciences at the University of Turku (decisions 40/2023, 703/06.01.01/2024).

Context

The context for this four-year EDR study involved an eleven-week course on a university-level TE subject. The course is mandatory for student teachers majoring in crafts (a mandatory subject in Grades 1–7 and an elective in Grades 8–9 within Finnish basic education). This master's-level clothing course followed an adaptation of studio pedagogy (Sawyer 2017) and project-based learning. This approach entails that informal peer evaluation and shared problem solving are essential parts of the project. Typical problems are open-ended, requiring substantial weighting between alternatives (Sawyer 2017). Much of the student work is done outside course contact hours without teachers present. Working in a university learning environment makes students' work 'public' (cf. Liu and Carless 2006), but this publicity often turns the project into a series of student-initiated collaborative encounters. This is typical of studio pedagogy adaptations.

The project assignment involved designing and constructing a material learning artefact – a demanding garment (e.g. a jacket, collared shirt, or winter coat). For the students, these garments represent learning artefacts and, more importantly, clothes that they have designed for themselves, expressing their personal values and identities and fulfilling their personal clothing needs (Härkki and Rönkkö 2023). These types of learning tasks have typically increased student motivation and interest in project results, likely improving their receptivity to forward- and action-oriented feedback. In the mid-course peer feedback task studied, students utilised a protocol (a rubric) to evaluate their peers' prototype garments. Instead of grading, the task targeted learning and actionable feedback involving suggestions for corrective actions. Thus, students were expected to participate in a peer feedback session, revise their prototype designs and then, construct their final garments based on the lessons learned from the prototype. Situating peer feedback in the middle of the course framed it as a forward-facing instrument designed to improve the learning artefact in collaboration with peers (rather than promoting 'what went wrong' discourse;

cf. Molloy, Noble, and Ajjawi 2019, 85). To tackle possible peer feedback quality issues (Gielen et al. 2010), students also received post-task feedback from the course teacher. The latter feedback focused on negotiating corrective actions regarding issues that were not noticed by peers or that exceeded their subject-specific knowledge.

Study design

All four cycles included an introduction to the protocol's criteria and subject-specific vocabulary and the expected interaction style. Each student participated in one EDR cycle. Due to the modest impact of the peer feedback on the final learning artefacts in the first cycle (Härkki and Rönkkö 2023), the introduction was changed from cycle to cycle (Table 1). Examples of interaction styles were provided to show students that, rather than dichotomous responses, the aspects they were asked to evaluate typically required careful examination of the garment. These aspects were subject to various viewpoints, and different corrective actions could be deemed equally suitable for addressing them. Thus, the examples were intended to communicate that frequently, no easy answers are available – or expected from students. Different instruction modalities were utilised and, in C3 and C4, combined to repeat the key messages.

To provide comparability through transparency, the mapping of the pedagogical elements common to all cycles (C1–C4) to the feedback design taxonomy by Schluer and Brück-Hübner (2024) is available in Supplemental Materials A.

Table 1. Design elements changed from cycle to cycle: introduction to feedback.

Cycle	Instructions provided during the studio class prior to the feedback on:	
	Protocol vocabulary and criteria	Style of interaction
C1	A structured presentation of the protocol.	A presentation and an example of “thinking aloud” (i.e. explication of all observations and related uncertain hypothesis, vacillations between various corrective strategies, etc.)
C2	A demonstration with a mannikin wearing an ill-fitting collared shirt	A presentation and an example of “thinking aloud” (similar to C1)
C3	A teacher-enacted garment analysis (i.e. a role-play exemplar of the feedback)	A presentation, an example of “thinking aloud” AND an illustration of active dialogue through role playing demonstrated negotiability and interactivity; this included questioning each other's opinions, sharing identifications of possible corrective strategies, expressing uncertainty when multiple options appeared suitable, etc.
C4	A demonstration with a mannikin followed by teaching dialogue employing a photo series of typical quality issues	“Thinking aloud” and an emphasis on active dialogue between the participants (similar to C3) AND a reminder of active participation in exploratory and shared investigations immediately prior to the feedback

Participants and data collection

During the first course lesson, 83 master's-level TE students gave their informed consent to participate in the EDR. Based on a course pre-survey, students were classified as having novice- or target-level subject-specific expertise. The peer feedback task required students to wear their prototypes so their peers could examine prototype fitness. The task was acknowledged as

potentially raising sensitive personal issues alongside more generic pressures (such as loss of face, embarrassment, or humiliation) related to peer feedback (e.g. Liu and Carless 2006). Therefore, the students were free to choose their pairs (cf. van Heerden and Bharuthram 2021). Even if occasionally resulting in pairs with unequal expertise, this was considered the only ethical approach. It also exemplified a socially sensitive pedagogical approach that was beneficial for these future teachers of teenagers.

Feedback sessions were reciprocal when permitted by students’ schedules. Reciprocity was assumed to increase familiarity with the feedback situation and the handling of such a task with the chosen peer – that is, to increase trust. Participants recorded their feedback sessions according to instructions provided at a location of their own choosing (C1) or at dedicated camera booths (C2). To provide more privacy, a small room with a full-body mirror was dedicated to recordings (C3–C4). Furthermore, during C3 and C4, additional mobile gaze-tracking data were recorded, which required the teacher to supervise the feedback. (However, analysis of the gaze data is not included in this study.) In total, video data with sufficient audio quality were acquired from 65 peer feedback sessions (Table 2).

Table 2. Acquired video data per cycle.

	Participants (consented/included)	Duration of feedback min–max (mm:ss)	Total volume of video data (minutes)
C1	20/17	1:14–17:30	86
C2	23/21	4:08–16:48	148
C3	23/16	8:11–30:38	260
C4	17/12	8:39–41:10	273

Analysis methods

This study utilised video-based qualitative content analysis (Härkki 2018) with a directive approach (Hsieh and Shannon 2005), using Boris video analysis software (Friard and Gamba 2016) for coding the video material. We now introduce our methodological choices and practical analytical steps (Table 3).

Table 3. Analysis process.

Phase	Analytical steps: reasoning and decisions
Methodological choices	Multimodal data =>multimodal methods: video-based qualitative content analysis Limited study context =>theory development at local level =>theoretical base with suitable analytical power: Mercer (1996) and Dillenbourg (1999) =>initial coding scheme with operational definitions based on Mercer’s key concepts (exploratory, cumulative, and disputational modes of interaction) Unit of analysis supportive of analysis of collaborative dialogue => Dillenbourg (1999): pair work event detailed as “multimodal handling of an object of attention”
1st coding (with the initial coding scheme)	Events coded when possible; other events labelled with suggestive codes/subcodes
Decisions based on 1st coding =>Final coding scheme	No disputational modes in these data =>removal of this code Cumulative mode instances narrower than Mercer (1996) =>code description revised Events with suggestive codes and subcodes analysed =>a code “demonstrating individual expertise” added to the initial scheme and respective events representing unilateral information transmission (i.e. not collaborative) coded =>to satisfy all labelled findings, three subcodes reflecting symmetry of actions (Dillenbourg 1999) were added: maker-dominated, assessor-dominated, and no dominant activity (i.e. symmetric and equal participation)
2nd coding: All events given representative codes =>Finalised coding and coding scheme	
Selection of representative data excerpts and reporting of results	

The study data encompassed multiple layers of expressive modalities (e.g. speech, eye gaze, haptic interaction, and movement of head, hands, and body). Many such modalities resist straightforward interpretations, but they are interconnected and context dependent (Goodwin 2000). This requires an analytical method that preserves the richness and expressiveness of human interaction. Accordingly, the chosen method – video-based qualitative content analysis – was designed to yield descriptions and typologies grounded in multimodal data by limiting transcriptive action to sections and multimodal layers of interaction that clearly benefit from (or demand) transcription (Härkki 2018). This method, grounded in interaction analysis (Jordan and Henderson 1995), respects the character of multimodal interactions by encouraging the generation of multiple novel interpretations as the researcher becomes increasingly acquainted with the data.

The place of theory development within the study was then defined. According to the general principles of EDR, it can produce three levels of theory: local, mid-range, and high-level (McKenney and Reeves 2013). Due to the study's limited context (one course in one teacher education programme, repeated annually over four consecutive years, with each student participating in one peer feedback session), the targeted theory was limited to the local level and subject to further validation in other contexts. This limitation necessitated the selection of theories with sufficient analytical power to guide the content analysis process.

According to the literature review, studies of student peer feedback sessions rarely involve gaze data or fine-tuned analysis of multimodal data. However, we identified two established theoretical accounts that support meticulous differentiation between students' collaborative interactions within pedagogically designed contexts: Mercer's (1996) definition of talk as a social mode of thinking and Dillenbourg's (1999) notion of collaborative learning. Therefore, we chose to continue with directive content analysis (Hsieh and Shannon 2005), which aims to validate or conceptually extend a theory when prior research appears incomplete or open to supplementation. In this approach, existing theories can provide variables or relationships among variables to further development of the initial coding scheme, which is then refined based on the findings (Hsieh and Shannon 2005).

Mercer's (1996) idea that talk is a social mode of thinking was chosen as the starting point. Despite its primary association with spoken language (rather than multimodal interaction), it offers operationalisations that can be extended to inform analyses of multimodal interaction. To further advance the theory-based fine-tuning of the interaction categories, we chose Dillenbourg's (1999) criteria for situations (operationalised as symmetries of status and action) and interactions (operationalised as degrees of negotiability).

Due to peer feedback being approached as collaborative dialogue, a pair-work event was chosen as the unit of analysis (Dillenbourg 1999). An event was defined as the 'multimodal handling of an object of attention'. The object equalled a single protocol item (when students proceeded according to the protocol) or a single quality issue (in rare cases, when target-level students proceeded in an order of their own choosing from one quality issue to another). Moreover, material prototypes were often explored haptically where the assessor touched, tugged, dragged, or re-organised the donning of the garment, or the maker (wearer of the garment, the assessee) moved to feel the ease.

The first coding scheme iteration involved exploratory, cumulative, and disputational modes based on Mercer’s social mode of thinking. However, this initial scheme did not completely account for all features of the data. Therefore, some accommodations were necessary. None of the pairs engaged in disputational interactions; therefore, the code was removed from the scheme. Furthermore, the cumulative mode appeared as an extreme in which the suggested evaluations received very short confirmations, which facilitated straightforward coding but reduced description of the code. An additional mode representing unilateral information transmission (rather than dialogue) was identified and coded with the label ‘demonstrating individual expertise’.

However, these higher-level changes did not sufficiently represent the data’s observable features. To further fine-tune the categories, we added subcodes representing information about negotiability and symmetry of status and actions (Dillenbourg 1999); this indicated whether the maker dominated the interaction, the assessor dominated, or both students participated equally. Notably, domination was relevant only for the interaction modes of cumulative and individual expertise – not for the exploratory mode. The analysis process is outlined in Table 3 and the final coding scheme in Table 4. Related data examples are available as Supplemental Materials B.

Table 4. Final coding scheme for interaction patterns.

Codes and subcodes		Features of interaction
Codes for Social mode of thinking		
Demonstrating individual expertise [De]	Only one student speaks, the other stays silent Firm-sounding (not necessarily correct) conclusions Little (if any) emphasis on observations and reasoning	
Cumulative [Cum]	One student is active, but the other student provides only affirmative comments or minimal responses (e.g. “Yeah”, “Mm”) No disagreements or contesting reasoning/conclusions	
Exploratory [Ex]	Both participate actively and the interaction is negotiable (thus, no need for subcodes) Explicated noticing, analysing, weighting, suggesting, and concluding	
Subcodes for codes Demonstrating individual expertise and Cumulative		
Assessor-dominated interaction [A]	The student assessing the maker's garment dominates: Interaction is unsymmetrical and statements sound firm, leaving no room for negotiation	
Maker-dominated interaction [M]	The maker dominates: Interaction is unsymmetrical, leaving no room for negotiation	
No dominant activity [E]	Both students participate equally: symmetrical and negotiable interactions	

Results

The coding results are summarised in Table 5 and detailed at the level of pairs and cycles in Supplemental Materials C.

Table 5. Cycle-level summary results: interaction modes (average %), number of pairs engaging only in one mode, total number of pairs, novices, and target-level students.

	Interaction mode Average (%)			Pairs with only one interaction mode				Students		
	Ex	Cum	De	Ex	Cum	De	Total	Number of pairs	Novices	Target
C1	25	26	49	2	0	1	3	17	13	4
C2	27	42	31	1	3	4	8	21	13	8
C3	61	29	10	5	0	1	6	16	12	4
C4	74	8	18	6	0	1	7	12	7	5
Total	44	28	28	14	3	7	24	66	43	23

Observable patterns in student interactions

The interaction modes resulted in different use types – that is, patterns. One-third of student pairs engaged in only one mode during feedback – a sole interaction mode that defined the tone and student roles for their entire session. Some pairs transitioned flexibly from one mode to another during their session. The number of transitions varied from 1 to 21, but on average, it was about 4 to 5. In these data, all combinations of interaction modes occurred.

Pairs with solely an exploratory mode often involved at least one target-level student. In general, target-level students engaged more frequently in the exploratory mode. However, three C3–C4 novice pairs had the exploratory mode as their sole interaction mode; thus, being a novice was not an obstacle to exploratory behaviour. However, no clear-cut interaction patterns based on mere skill levels could be identified. Instead, the event analysis provided broader explanations for the choices and changes between modes.

Demonstrating individual expertise

The absence of dialogue and reciprocity characterised this pattern. Typically, one student sequentially read the protocol items aloud and announced judgements. The judgements often sounded firm, even when the explicated analytical activity left doubts about how justified those judgements were. Characteristically, no evidence was found of stated judgements influencing peers' cognitive processing or forming a shared understanding.

Assessors often dominated interactions. Contrary to typical feedback settings, at times, makers dominated feedback. At the outset of some cases, assessors stated that makers knew the design and how the garment felt, suggesting that makers should take the lead. At times, makers assumed the lead from the outset and were unchallenged by assessors.

Three distinct patterns were identified. 1) Most often, this mode was utilised for protocol items of good quality. Then, a change in mode occurred when the assessor noticed an issue. 2) Sometimes the assessor sequentially read the protocol items aloud and judged each as 'Ok', leaving no room for comments. 3) At times, the maker dominated and provided explanations and judgements that were missing the obvious need for corrections.

Cumulative interaction

This mode entailed a minimum level of dialogicality and unchallenging replies: suggestions by the dominant student, confirmed by the peer. Two distinct patterns can be identified. 1) The assessor sequentially read the protocol items aloud and asked for the maker's judgement, which the assessor unquestioningly documented as the feedback. 2) The assessor made a suggestion and asked for the maker's opinion. This typically occurred when the assessor noticed an issue. Characteristically, no evidence of *both* participating in the analysis and reasoning was observable for either pattern, despite a (superficial) consensus.

Exploratory interaction

This mode involved open-ended questions that invited peers to participate in evaluation, hypothesis testing, and reasoning, typically both verbally and haptically. This interaction mode involved, for instance, dialogues related to where the feature under evaluation

existed in the quality continuum, testing possible corrective strategies, and scrutinising from multiple (physical and personal) viewpoints.

An example of target-level students' performance. (Note: In the examples, ... indicates a pause, * rearranging, + pulling, <grabbing, ~ stroking).

(C4-2, 2:28-4:17)

Assessor: Then, back width [*shirt back]. In my eyes, this looks perfect. This is [+yoke] rather tight ... shouldn't be any tighter [*back]. No drags and ... this back pleat gives space [*back]. And no bags, at least on the back [*sleeves and armhole seams]. How does it feel? Can you move?

Maker: [Bends her back and stretches her arms back and forth].

Assessor: [~yoke] Now when you do that, this seam is rather tight. Can you move your arms to the maximum position?

Maker: [Stretches her arms even further]. Yes, I can.

Assessor: [*pleat] The back looks neat. If these sleeves are loose like they should be [*shoulder], it drapes well.

Later, they reconsidered the shoulder area, this time from the side (5:06-8:26).

Assessor: As a matter of fact [+right sleeve], from the side, there *is* some bagging.

Maker: The sleeve does not fit properly; the lowest bit is kind of too low.

Assessor: Yeah. From the back, you cannot see bagging but from the side ... Likely, it can be corrected by raising the sleeve [students discuss and try two different ways to pin the sleeve higher on the shoulder]. How much should we raise the sleeve? [<shoulder] Is 1 centimeter enough?

Maker: I tried and raised the left sleeve 5 centimeters to get it to the shoulder bone.

Assessor: Ok [* and pins the sleeve again].

Maker: In the front look, the left sleeve has a better position while the right hangs lower, which makes the dress look ... kinda ... not carrying itself well. To my eye, it's disturbing.

Assessor: Understand.

Two patterns emerged. 1) Some students engaged in exploratory interactions throughout their feedback session, and 2) some only occasionally did so when an issue required a deeper and shared analysis. Still, exploratory collaboration was not a symptom of faulty garments. Rather, the students carefully discussed their observations and reasoning when the item was fine. They tested options and discussed what was meaningful, design-dependent, fine, or what required

corrective actions.

An example of novice performance (C3-3, 1:18–3:40):

Maker: Well ... Had I used a smaller pattern, it could have been too tight. Careful pinning really changes the fit.

Assessor: Donning is better with pins [~right sleeve, *sides]. This fits really well ... What if we take in 0.5 cm? [<side seams]

Maker: Maybe not ... if I didn't have the darts, *then* it could be too loose.

Assessor: [~shirt front]

Maker: Back fits better with the darts.

Assessor: Indeed ... Does bust ease feel Ok? [+shirt front]

Maker: The wear is comfortable there. If tightened, then it would not [tests ease by rotating arms vigorously].

Assessor: You have a T-shirt underneath. On purpose?

Maker: A possibility should exist.

Assessor: There is [+shirt front].

Maker: I've been thinking whether I want a slim-fit but ... not necessarily.

Assessor: Looks balanced [examines the back, ~* +horizontal and vertical lines, examines sides]. Looks good. Darts are really good [~dart positions], carefully sewn, balanced [*sides and front]. This appears to fit well.

However, exploratory interactions did not guarantee the identification of all – even obvious – correction needs or agreement on corrective strategies. At times, negotiations were relatively lengthy and were dropped if the maker did not appear eager to follow through.

Changes in student interaction patterns as support practices changed from cycle to cycle

Prior to the EDR study, the teachers' understanding was that many learning artefacts with obvious adjustment needs were not improved as expected, despite the mid-course peer feedback task. Therefore, C1 introduced the protocol criteria, vocabulary, and the orientation to think aloud (rather than merely talk). The immediate results were found wanting, as the protocol was not used consistently and many quality issues were judged as 'Ok' rather than identified as corrections. Demonstrating individual expertise was the most frequently utilised mode, on average, and three-fourths of pairs engaged in it at some point. Comparatively, one-third of the pairs did not have a single exploratory event.

For C2, the protocol was demonstrated with a mannikin wearing a shirt with typical fit issues, and thinking aloud was emphasised more. This time, protocol use was more consistent. The cumulative mode superseded individual expertise as the most frequent mode (on average), and only half of the pairs engaged in demonstrating individual expertise. However, slightly more than one-third of the pairs did not have a single exploratory event. Simultaneously, a new mode emerged to accompany maker- or assessor-dominated cumulative modes: equal participation, in which students took turns initiating and leading interactions. Thus, dialogicality increased at the level of question–answer pairs, but deeper and longer engagement in shared reasoning was lacking. Together, all of these results indicated a small increase in dialogicality – a positive turn.

For C3, the protocol criteria were deconstructed through a role play by the teachers, the thinking-aloud instructions were complemented with an emphasis on active dialogue, and the teacher was present during feedback. Protocol use was consistent, and the pursued change in student interactions occurred: The exploratory mode became the most frequent interaction mode, resulting in increased shared analysis and reasoning. Three-fourths did not engage in individual expertise at all. As the sole mode, only one pair had individual expertise, and five pairs had exploratory mode.

For C4, the mannikin demonstration was followed by a teaching dialogue and a series of photographs illustrating various adjustment needs. Likewise, in C3, the teacher was present during feedback. At the beginning of the feedback, she emphasised active participation in exploratory and shared investigations. Again, the exploratory mode was the most frequent mode, on average, and for half of the pairs, it was the sole mode. More than half did not engage in individual expertise at all, and only one pair did not have a single exploratory event.

To summarise, throughout C1–C4, the volume of dialogicality and exploratory interactions increased. Exploration became the most frequent interaction mode (on average), more pairs had the exploratory mode as the sole mode, and fewer pairs engaged in the individual expertise mode. However, as several changes were introduced in each cycle, it is impossible to differentiate their effects. For instance, teacher presence during C3–C4 could have encouraged some students to engage more deeply with the task. Contrarily, this could have increased the pressure felt by others, diminishing reasoning and problem solving. Beyond the instructional changes, the student population changed. Half of the participants in C2 and C4 were target-level students – a higher proportion than in C1 or C3. However, the largest change towards dialogicality and the exploratory mode occurred in C3, when protocol usage and the anticipated feedback style were demonstrated through roleplay, and the teacher participated in feedback sessions.

Discussion

This study aimed to advance the theory building of peer feedback as exploratory collaboration and develop pedagogical support for face-to-face exploratory peer feedback in TE.

During the four EDR cycles, the pedagogical design of peer feedback was developed towards active dialogue and collaborative interaction (Dillenbourg 1999) as exploratory talk (Mercer 1996). To develop pedagogical support for face-to-face exploratory peer feedback, two RQs were pursued. Video data were analysed for student interaction patterns that emerged during face-to-face peer feedback (RQ1), and changes in

interaction patterns were contrasted against cycle-to-cycle changes in feedback support practices (RQ2). Guided by principles of collaboration research (e.g. Dillenbourg 1999), student pairs' interaction events were qualitatively analysed with Mercer's (1996) social modes of thinking as directive theory.

In these data, Mercer's (1996) disputational mode (open disagreement) was not observable. Instead, individual expertise was identified, characterised by the unidirectional transmission of information. No evidence of students forming a *shared* understanding of the learning artefact's quality was observed. Rather, the quality judgements could be understood as demonstrations of the assessor's expertise to which the assessee was to submit. This could have reflected students' prior experiences of feedback roles in unilateral feedback or, for instance, their eagerness to finish quickly (during a busy part of the academic year). Conversely, as students' understanding of high-quality garments was only just developing, they could have felt uneasy (cf. Bürgermeister, Glogger-Frey, and Saalbach 2021) and reluctant to engage in evaluative dialoguing. A student engaging in this mode could have adopted the position of a superior expert but felt the absolute opposite. Furthermore, students' underlying motivations could have changed during the feedback sessions as encountered problems proved easy or too difficult. From the perspective of collaborative learning research, unearthing students' underlying motivations in a methodologically satisfactory way requires complementing observational data with a broader methodological arsenal and temporal analysis targeting student emotions, motivations, and general well-being.

The individual expertise mode was utilised in three patterns: the sole interaction mode (dominating the whole feedback session), a maker taking a dominant position (turning feedback into a unidirectional presentation), or mostly when an assessor deemed a protocol item to represent good quality (often commented on as 'Ok'). Several possible interpretations can be derived. The protocol involved two options (Ok vs. Adjustment needs), which (maybe together with a dichotomous understanding of quality and feedback in general) could have legitimised this brevity. However, for some, deeming items 'Ok' could have appeared more tempting than 'Not Ok', as 'Not Ok' would have required further activity to find corrective strategies – an activity requiring knowledge, skill, and material resources, which is (understandably) not always easy, especially for novices.

The cumulative interaction mode was more dialogical, yet minimal and unchallenging responses provided no evidence of negotiability. This resembles the dominant/passive mode in Lineback and Holbrook (2024) and the respondent role in Zhu and To (2022). The first pattern in this mode (assessors utilising the protocol to interview makers to comment on designerly decisions, such as aesthetics, fit, or functionality) partly resembled expert behaviour. Notably, in garment fit analysis, some features cannot be judged solely by external observation (e.g. proper ease, placement of certain seams, or bodice length). However, reducing the feedback solely to interviews diluted the idea of providing one's opinion to a peer. In the other pattern (makers confirming assessor suggestions), interactivity influencing peers' cognitive processes remained questionable.

While the above two modes lack characteristics of Dillenbourg's (1999) collaborative interactions, the third exploratory mode represented collaboration resembling Lineback and Holbrook's (2024) collaborative pattern. The proactive receiver roles (explicator, verifier, negotiator, generator, and seeker) identified by Zhu and To (2022) were also identifiable in these data as recognisable types of activities rather than permanent roles.

Typically, most of the analysis, weighting, and suggesting occurred through touching and rearranging garments, which makers could observe through a mirror. When counting haptic activity, this mode shared features typical of higher-level learning (cf. Kollar and Fischer 2010). However, exploratory interactions were not always carried to fruition to establish shared agreement on what needed to be corrected and on corrective strategies.

Students often transitioned to this exploratory mode to analyse issues in combination with the other two modes for protocol items appearing as 'Ok'. This can be understood as the efficient use of time and peers' expertise (only when necessary to justify quality judgements). However, a more informative and conducive practice for learning (i.e. more befitting for student teachers) includes observable garment analysis and grounding judgements based on diagnostic data (cf. Bürgermeister, Glogger-Frey, and Saalbach 2021). For instance, explaining whether the analysis covered the left, right or both shoulder seams and explaining where on the quality continuum (e.g. acceptable, good, excellent) the seam features resided. Moreover, disclosing one's chain of reasoning changes feedback from telling to explaining, which could invite others to participate in reasoning and identifying corrective strategies. Critiquing peers' work and demonstrating one's expertise turns towards collectively finding better solutions.

In exploratory collaboration, understanding quality criteria and comprehending feedback content (Grainger 2020) alongside translating feedback into actionable strategies (Er, Dimitriadis, and Gasevic 2021) are not separate tasks to be complemented by feedback receivers, as students collectively analyse the learning artefact's quality and reason about how to improve the artefact. Students get a second opinion on their work while explaining and justifying their decisions – an opportunity they value (Bader, Iversen, and Borg 2024). Therefore, exploratory collaboration has the potential to tackle several concerns related to peer feedback practices.

Together, the changes in interaction patterns from C1–C4 indicated increased sharedness and collaboration. However, the proportion of novices changed from cycle to cycle, which could explain part of the change in interaction modes and patterns – especially if it is assumed that novices are less willing to engage in longer evaluative interactions. Subjecting one's performance to evaluation while only learning subject-specific practices entails emotional risks and requires sufficient motivation, self-confidence, and a sense of agency (Yang and Carless 2013) as well as trust (Molloy, Noble, and Ajjawi 2019; Nicol 2014; van Gennip, Segers, and Tillema 2010). Considering the study's pedagogical aim, the results from C1 and C2 remained dissatisfying. However, in C3 and C4, the share of exploratory collaboration among both novice- and target-level students was larger than in C1 or C2. Being a novice was no obstacle to exploratory collaboration, as some C3 and C4 novices analysed garments in detail and demonstrated the skills to describe features of good quality. For TE students, *recognizing and describing* instantiations of good quality is an important skill.

Isohätälä et al. (2018) noticed that task designs *permitting* collaboration can result in scarce spontaneous argumentation (even among familiar participants), which, especially from C1 and C2, aligns with our results. Doubts about one's epistemic authority (Tai et al. 2018) and various socio-emotional factors (Isohätälä et al. 2018; van Gennip, Segers, and Tillema 2010) can pose serious challenges to active participation. This study assumes that framing peer feedback as collaborative exploration aiming at the betterment of the scrutinised learning artefact and the shared building of expertise (rather than

demonstrating individual expertise) could mitigate at least some of these challenges – especially when combined with the possibility of choosing one’s partner for peer feedback.

Due to several simultaneous changes between cycles, no conclusions on causalities can be drawn. Subject-specific knowledge and interaction – both necessary for productive feedback – were supported. Nonetheless, after these four development cycles, we find that our EDR is far from complete. The limited study context suggests that theory-wise, our EDR cannot contribute to anything broader than local theory (McKenney and Reeves 2013) or yield comprehensive models (called for by Kollar and Fischer 2010). However, our results do show that mere rubrics do not guarantee good performance (Bürgermeister, Glogger-Frey, and Saalbach 2021). Considering the study’s pedagogical aim, both cycles C3 and C4 provided satisfactory results, suggesting that pedagogic support via a role-play exemplar, demonstration followed by a teaching dialogue with photographs of issues, and teacher presence in the feedback were beneficial for the quality of the feedback dialogue. In other words, *exemplifying* the pursued exploratory dialogue, *repetition* of vocabulary, and examples of quality issues provided in *several presentational modalities* appeared beneficial for supporting exploratory collaboration.

Study limitations

Rather than a large-scale learning context, this research targeted a single TE course in which students constructed material learning artefacts, and teachers had resources to instruct small groups and individual students (although this is a constantly diminishing resource). The sample size (one course in one teacher education program, repeated annually over four consecutive years, with each student participating in one feedback session) poses limits to deriving conclusions and generalisations. Therefore, the findings of this study are limited to the local level theory and subject to further validation in other contexts.

Additionally, novice students were likelier to withhold their consent to participate. Depending on the cycle, 30–60% of the participants were novices. Regarding sampling validity, this could be considered satisfactory. Regarding pedagogical implications, this is challenging, as these students could potentially benefit the most from support practices.

Factors such as students’ motivation, agency, and the self-regulation of their learning, but also their feelings of psychological safety, can cause behavioural variations, which were not studied. Drawing conclusions about the role of such factors in student feedback performance requires a broader methodological arsenal than video and mobile gaze tracking, which can only produce observational data. Thus, further studies are needed that integrate, for instance, heart rate variability and experience sampling data with observational video data.

The course syllabus (and, consequently, the EDR implementation) did not provide students with opportunities to participate in multiple teacher-supervised feedback sessions and repeatedly receive feedback on their performance. This could be considered a serious limitation of the study. This lack of contact hours and opportunities to practice and receive guidance on such an important skill poses more serious challenges to student learning. Conversely, the studied setting reflects the central character of EDR; it is conducted in ecologically valid contexts within the constraints of

real-world pedagogical designs and resources (McKenney and Reeves 2013). Moreover, the disciplinary context of this EDR (a masters' level teacher education program) includes several compulsory courses and practicum periods examining topics such as feedback and assessment. Those courses support students in constructing theoretical and pedagogical knowledge and in developing their initial teacher identities through tools such as self- and peer-reflection. Thus, the task of equipping student teachers with adequate feedback skills or regulative skills transcends this specific course. In the future, the TE program could consider including topics such as inter- and intra-personal emotion regulation while using multiple strategies (Methlagl and Vogl 2024).

Conclusions

Peer feedback is an important pedagogical component of socio-constructivist and participatory learning designs (Carless 2019; Kollar and Fischer 2010), knowledge and personal experience of which are important for student teachers. This study enhances the line of research promoting dialogical and collaborative peer feedback by compiling specific peer feedback research with research on collaboration, higher-level learning, and the exploratory mode of thinking.

Methodologically, this four-cycle EDR design in TE involved face-to-face peer feedback, which facilitated the analysis of feedback providers and receivers as a single unit: peers influenced by each other's actions. This setting is rarely researched in TE (or elsewhere in higher education) and involved temporal analysis of observable data – students working with material learning artefacts – that are typical for design and craft but also for STEAM subjects.

This study suggests that framing peer feedback as exploratory collaboration has the potential to mitigate many concerns that prior research has related to peer feedback. Peer feedback as collaborative exploration aiming at identifying improvement needs and strategies for the learning artefact and shared building of participants' expertise could be more motivating and less straining for students than 'more traditional' peer feedback as a demonstration of individual expertise. Moreover, TE courses should provide student teachers with sustained opportunities for guided practice in assessing learning constructs and formulating their observations as constructive and situationally sensitive feedback. For the peer feedback experience to unfold positively, feedback tasks need to be carefully designed to involve the necessary discipline-specific pedagogical support practices. By providing tentative suggestions for such support practices, this study could inspire researchers and teachers interested in collaborative and exploratory peer feedback in any TE subject.

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Author contributions

CRedit: **Tellervo Härkki**: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

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