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Preservice mathematics teachers' beliefs about peer feedback, perceptions of their peer feedback message, and emotions as predictors of peer feedback accuracy and comprehension of the learning task

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ABSTRACT

Peer feedback is increasingly used to train assessment skills in teacher-training programs. However, studies investigating the roles of peer feedback providers' beliefs about peer feedback provision, their perceptions of their peer feedback message and their experienced emotions are still limited. This study aimed to explore how peer feedback accuracy and providers' comprehension of the learning task were related to these characteristics. Analysis of peer feedback provided by 53 preservice mathematics teachers revealed that peer feedback accuracy was predicted by cognitive-verification, cognitive elaboration and self-efficacy types of peer feedback. Providers' perceptions of their peer feedback message and anxiety also predicted peer feedback accuracy. No evidence was found that peer feedback related beliefs and perceptions predicted providers' comprehension of the learning task.

KEYWORDS

peer feedback; preservice teachers; mathematics education; beliefs; emotions

Peer feedback is now increasingly used in teacher-training programs as an activity that supports preservice mathematics teachers' active learning and assessment skills (e.g., Sluijsmans, Brand-Gruwel, Van Merriënboer & Bastiaens, 2003; Lavy & Shriki, 2014). However, despite the large body of research on the characteristics of the peer feedback message, researchers do not seem to agree on its relevant characteristics. For instance, Strijbos, Van Goozen and Prins (2012) identified peer feedback content in terms of its function (cognitive, metacognitive, affective and self-efficacy) and its style (evaluative/verification, informative/elaboration or general). Conversely, Van Steendam, Rijlaarsdam, Sercu and Van den Bergh (2010) measured peer feedback in terms of its accuracy (i.e., how correct and accurate are the comments and suggestions).

Due to possibly limited domain knowledge, peer feedback may include inaccuracies that are not necessarily represented by the type (function and/or style) of the peer feedback. Although it is argued that the frequency and immediacy of peer feedback – compared to teacher's feedback – can counter for the lack of accuracy (e.g., Topping, 1998), empirical evidence suggests that received peer feedback provided by high ability students is more likely to be implemented (Patchan, Hawk, Stevens & Schunn, 2013); probably because it is more likely to be accurate. Peer feedback accuracy is, also, equally important for the provider because benefiting from providing feedback on a peer's solution may rely on whether certain strengths and weaknesses are correctly identified in the peer's solution. This issue is very important for preservice mathematics

teachers who will have to provide accurate feedback to their students in the future. Yet, the type of peer feedback is still important as it can also influence recipients' processing of the feedback (i.e., performance; Gielen, Peeters, Dochy, Onghena & Struyven, 2010; Strijbos, Narciss & Dünnebier 2010; Gielen & De Wever, 2015).

Peer Feedback Content: Type and Accuracy

In their study, Gielen et al. (2010) addressed the importance of investigating the impact of both peer feedback *type* and *accuracy* on recipients' performance. They showed that the accuracy as well as a specific type of peer feedback (i.e., justification) positively predicted performance when included in separate models. By comparing models' fit, the authors concluded that justification seems to be more important for recipients' performance than peer feedback accuracy.

However, peer feedback content (i.e., type and accuracy) can also be influenced by providers' individual characteristics; a factor that is still widely ignored in peer feedback research. In the Interactional Framework of Feedback, Strijbos and Müller (2014) integrate the role of individual characteristics and context into two distinct feedback processes: (1) the composition of feedback, and (2) the processing of the received feedback. In this framework both the roles of the feedback provider and the feedback recipient, together with their individual characteristics (i.e., personal factors), in a specific context are equally acknowledged. This framework postulates that both the composition and processing of a feedback message are shaped by the providers' as well as the recipients' individual characteristics such as emotions, beliefs and domain knowledge. Accordingly, the processed (received) feedback message may be different from the provided feedback message because the individual characteristics of the recipients shape their interpretation of the feedback. Likewise, the individual characteristics of the feedback provider shape the way the feedback message is being composed.

Patchan and Schunn (2015) showed that the providers' level of domain knowledge influenced the type of peer feedback they provided. While high domain knowledge students' peer feedback included more criticism, low domain knowledge students' peer feedback was dominated by praise. High domain knowledge students are likely to provide more accurate peer feedback, and thus specific types of peer feedback provided by them might be related to accuracy. Cho and Cho (2011) found that initial writing skills positively predicted the amount of comments outlining weaknesses in peer's writing. Yet no study has investigated the relationships between peer feedback types and accuracy. Additionally, Strijbos et al. (2012) identified comments in peer feedback that expressed providers' concerns regarding their ability to provide peer feedback or to perform the task (i.e., self-efficacy peer feedback). It is unclear, however, whether this type of comment can reflect inaccuracy in peer feedback.

In sum, despite the immense attention to peer feedback accuracy or validity (for a meta-analysis see Li et al., 2016), few studies focused on individual factors related to the peer feedback composition process and peer feedback content, such as peer feedback providers' beliefs, perceptions and emotions.

The Role of Beliefs and Perceptions

Students' epistemological beliefs (i.e., beliefs about knowledge and knowing) and self-control beliefs are predictive of their learning (see Zimmerman, Bandura & Martinez-Pons, 1992; Muis, 2004) because these beliefs are related to students' motivation to engage in a specific learning activity (Bandura, 1977). In feedback literature, the importance of motivational constructs is emphasized both as a feedback outcome and as a moderator of feedback effects on learning (Kluger & Denisi, 1996; Duijnhouwer, Prins & Stokking, 2012).

Feedback studies investigating beliefs and perceptions revealed that several self-concept, (feedback) self-efficacy and motivational beliefs and perceptions were associated with individuals' reactions to the received feedback (for a review see Winstone, Nash, Parker & Rowntree, 2017). Most of the studies, however, focused on the recipients' perspective without paying much attention to the perspective of the provider.

In peer feedback research, students' peer feedback beliefs and perceptions are usually measured as outcome variables or to evaluate students' satisfaction with the peer feedback activity (e.g., Strijbos et al., 2010; Wang, 2014; Alqassab et al., 2018). The relationships between peer feedback beliefs and perceptions and peer feedback content (type & accuracy) or performance are rarely examined.

A recent study revealed that students' beliefs about the helpfulness of peer feedback positively predicted self-regulation and negatively predicted grade point average (Brown, Peterson & Yao, 2016). Similarly, Rotsaert, Panadero, Estrada and Schellens (2017) found that beliefs about the usefulness of peer feedback were positively associated with perceived accuracy and trust in themselves as a provider and in their peers as a recipient. It is still unclear, however, whether the same relationship can be found if the accuracy of the peer feedback comments is measured instead of general beliefs regarding the accuracy of peer feedback, and to what extent peer feedback providers' perceptions of their own peer feedback message match the accuracy of their peer feedback.

When it comes to the providers' perspective on peer feedback, epistemological and self-control beliefs related to peer feedback provision are central because these beliefs can influence providers' engagement and subsequently learning from this activity (Bandura, 1977; Muis, 2004). Additionally, qualitative studies revealed that students believed that they learn from providing peer feedback and engage in reasoning during peer feedback provision (Nicol, Thomson & Breslin, 2014), and also that the lack of sufficient domain knowledge influenced the perceived usefulness of received peer feedback (Wang, 2014). Thus, it can be expected that providers' perceived control and epistemological beliefs related to peer feedback will be linked to peer feedback accuracy and to learning from peer feedback provision. However, these assumptions have not been tested empirically.

Additionally, to our knowledge, no study has measured peer feedback providers' perceptions of their own peer feedback in terms of its quality, accuracy or usefulness, and examined the relationship between these perceptions and the accuracy of peer feedback they provide. Investigating preservice mathematics teachers' beliefs and perceptions about their peer feedback provision is important because research has shown that teachers' beliefs about teaching and learning in general predict their teaching practices (e.g., Brown, Harris & Harnett, 2012; Rubie-Davies, Flint & McDonald, 2012).

The Role of Emotions

Despite the important role of emotions in assessment and learning, research investigating emotions experienced during peer feedback reception and provision is limited. A number of studies investigated perceived emotions in response to peer feedback provision practices (Praver, Rouault & Eidswick, 2011; Vanderhoven, Raes, Montrieux, Rotsaert & Schellens, 2015). For instance, feeling of comfort during peer feedback provision was found to be related to anonymity (Vanderhoven et al., 2015). Students also reported being more embarrassed and nervous when they had to evaluate the work of peers using scores and written comments compared to giving scores without comments (Praver et al., 2011).

According to Pekrun and Stephens (2012), students experience emotions: (a) as a result of being cognitively involved in a task, and/or (b) when they encounter cognitive conflict. Cognitive conflict may trigger epistemic emotions such as curiosity, confusion, enjoyment, frustration or

anxiety. When preservice mathematics teachers have to provide peer feedback on a peer solution, they might experience curiosity to figure out how the task was approached, confusion when parts of the peer solution contradict their own understanding, and anxiety when they cannot provide accurate peer feedback.

In general, anxiety is negatively related to learning with complex or difficult tasks (Pekrun, 2011). In the peer feedback literature, students often report feeling anxious regarding peer feedback (e.g., Cartney, 2010; Cheng, Hou & Wu, 2014), and since peer feedback provision is a complex activity experienced anxiety is likely to be negatively related to peer feedback outcomes.

Whereas curiosity positively predicts shallow and deep learning strategies, confusion negatively predicts these strategies during mathematics problem solving (Muis, Psaradellis, Lajoie, Di Leo & Chevrier, 2015). To date, epistemic emotions experienced during peer feedback provision have not been explored. Likewise, how these emotions are related to peer feedback accuracy is open to investigation.

Due to the importance of peer feedback providers' beliefs, perceptions and emotions and the lack of empirical studies investigating how these factors are related to peer feedback accuracy and to providers' learning, the current study sought to explore such relationships in the context of preservice mathematics teacher education. Peer feedback is increasingly used as a learning activity in mathematics education classrooms (e.g., Sluijsmans et al., 2003; Lavy & Shiriki, 2014).

Research Questions and Hypotheses

RQ1: What is the relationship between peer feedback accuracy and types of peer feedback?

H1: Based on previous findings (Cho & Cho, 2011; Patchan & Schunn, 2015), we expected a positive relationship of peer feedback accuracy with cognitive-verification and cognitive-elaboration peer feedback, and a negative relationship of peer feedback accuracy with self-efficacy and cognitive-surface peer feedback, because those who face difficulties in providing peer feedback may express that in their comments (i.e., self-efficacy), or would provide more cognitive-surface comments (Figure 1).

RQ2: What is the relationship between peer feedback accuracy and peer feedback providers' beliefs about peer feedback provision, their perceptions of their peer feedback message, and their experienced anxiety, curiosity and confusion?

H2a: Based on the findings by Rotsaert et al. (2017) and research on epistemological and self-control beliefs (Zimmerman et al., 1992; Muis, 2004), we hypothesized that peer feedback providers' beliefs about peer feedback provision and their perceptions of their peer feedback message would be positively related to peer feedback accuracy (Figure 1).

H2b: Since curiosity is positively associated with shallow and deep processing during mathematics problem solving, confusion is negatively associated with it (Muis et al., 2015), and anxiety is negatively related to performance on complex tasks (Pekrun, 2011), we hypothesized that peer feedback accuracy would be positively related to curiosity and negatively related to confusion and anxiety (Figure 1).

RQ3: What are the relationships between peer feedback providers' learning (measured by proof comprehension), their beliefs about peer feedback provision, and their perceptions of their peer feedback message?

H3: Based on previous findings that self-efficacy and epistemological beliefs predicted learning and performance (see Zimmerman et al., 1992; Muis, 2004) and the findings by Rotsaert et al. (2017), we hypothesized that peer feedback providers' learning (measured by proof comprehension) would be positively related to their perceptions of their peer feedback message and to their beliefs about peer feedback provision (Figure 2).

Figure 1. Conceptual model of the relationships between peer-feedback accuracy and peer-feedback types cognitive-verification, cognitive-elaboration, cognitive-surface and self-efficacy, peer-feedback providers' beliefs about peer-feedback provision, their perceptions of their peer-feedback message, and epistemic emotions curiosity, confusion, and anxiety.

Figure 2. Conceptual model of the relationships between proof comprehension and peer-feedback providers' beliefs about peer-feedback provision and their perceptions of their peer-feedback message.

Method

Participants

Fifty-three preservice mathematics teachers from a large university in southern Germany were included in the analyses (14 males, 39 females, mean age 24.40, $SD = 5.33$). The participants were recruited from a pool of 350 students through class announcements and advertisements posted in common areas including the library and café. To be eligible to participate, students had to be enrolled in undergraduate teacher education programs for high school (Gymnasium) or middle high school (Real Schule) with mathematics as one of their teaching subjects regardless of their year level in the program (typical program duration: 5-6 years). Out of the participants who specified their specializations, 73% were studying to become high school mathematics teachers, and 27% as middle high school mathematics teachers. The participants either studied mathematics together with school psychology (17%), or with another teaching

subject, including economics (22%), informatics (12%), languages (17%), sciences (17%), religion (5%), arts (5%) and sports (5%). Most of the participants (92%) had some prior experience with peer feedback in the form of peer tutoring in school. Participation was voluntary and the participants were compensated with €15 for their participation. All participants signed an informed consent before taking part.

Design

In a between-subject experimental design the participants were randomly assigned to one of two conditions: a near-correct peer solution condition (NCS, $n = 27$) and an erroneous peer solution condition (ERS, $n = 26$) using a block randomization procedure. Participants in the NCS condition provided peer feedback on a near-correct peer solution, and those in the ERS condition provided peer feedback on an erroneous peer solution.

Materials

Peer solutions

We used two fictional peer solutions to a geometry proof that the participants had to provide peer feedback on. The solutions were designed by an expert in the domain of mathematics education, based on prior research. The solutions were designed in such a way that both conditions had errors to comment on. The NCS only had minor notation mistakes and a weak warrant for one argument. The ERS had the same notation errors in addition to unwarranted claims and one missing step.

Measures

Peer feedback content: Type and accuracy

Peer feedback accuracy

This variable represents the number of accurate comments about the correct, incorrect or missing aspects in the peer solution that the preservice mathematics teachers provided peer feedback on.

Peer feedback type

Peer feedback was coded using the scheme by Strijbos et al. (2012). We identified the following types in this study: (1) cognitive-surface (comments on surface features of the peer solution like style and spelling), (2) cognitive-verification (confirming/disconfirming comments), (3) cognitive-elaboration (detailed comments that follow verifications or other elaborations in the form of correction, confirmation, justification, questioning or suggestions), (4) and self-efficacy (expressing confidence in own ability to provide peer feedback or to construct the proof).

Beliefs and perceptions related to peer feedback provision

Beliefs about peer feedback provision

These were measured using the Peer Feedback Provision Questionnaire (PFPQ; Alqassab et al., 2018) that consisted of three subscales: learning from peer feedback provision (LPF), confidence regarding peer feedback provision (CPF), and engaging in reasoning during peer feedback provision (RPF). The LPF scale consisted of 10 items (e.g., "I want to change my own work after providing peer feedback"; Cronbach's $\alpha = .80$); the CPF scale consisted of 17 items (e.g., "I believe

Table 1 Means and standard deviations for beliefs about peer-feedback provision subscales, for each peer solution quality.

Peer-feedback belief subscale	NCS		ERS	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
LPF	4.66	0.58	4.48	0.66
CPF	4.15	0.55	4.02	0.65
RPF	4.50	0.42	4.35	0.55

Table 2 Spearman's intercorrelations [95% confidence intervals], means, and standard deviations for perceptions of peer-feedback message (quality, accuracy, and usefulness) split by condition (i.e., peer solution quality). Means and standard deviations for combined perceptions.

Perception / Condition	1	2	3	<i>M</i>	<i>SD</i>
NCS					
1. Quality	—			3.80	1.98
2. Accuracy	.63*** [.32, .81]	—		4.98	2.39
3. Usefulness	.54** [.20, .76]	.53** [.19, .76]	—	5.43	2.29
ERS					
1. Quality	—			3.53	1.93
2. Accuracy	.55** [.21, .76]	—		4.78	2.56
3. Usefulness	.64** [.34, .82]	.65*** [.35, .83]	—	5.31	2.13
(combined) perceptions of peer-feedback message					
NCS				4.74	1.89
ERS				4.55	1.91

Note.

* $p < .05$

** $p < .01$

*** $p < .001$

that I have the competence to provide clear peer feedback"; Cronbach's $\alpha = .91$), and the RPF scale consisted of 13 items (e.g., "Providing peer feedback helps me to be critical about my own arguments", Cronbach's $\alpha = .76$). The items were rated on a 6-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = slightly agree, 5 = agree, 6 = strongly agree). The means (Table 1) for the three subscales were computed and used in further analyses.

Peer feedback providers' perceptions of their peer feedback

Participants rated the peer feedback they provided in terms of its quality, accuracy and usefulness using three items: "How confident are you about the quality of the feedback you provided?", "How confident are you that your feedback is correct?", and "How useful do you think your feedback will be for this student?" Each item was scored on a 10-cm visual analogue scale (VAS). The mean of the three items was computed after ensuring that they reliably belong to one scale (NCS: Cronbach's $\alpha = .81$; ERS: Cronbach's $\alpha = .81$; Table 2).

Epistemic emotions

Epistemic emotions experienced while providing peer feedback were measured with the short version of Pekrun and Meier's (2011) scale. This scale consists of seven emotions each measured by a single-word item (curious, surprised, confused, frustrated, excited, anxious and bored) and rated on a 5-point Likert scale ranging from *not at all* (1) to *very strong* (5). For the purpose of this study we analyzed responses to the items curious, confused and anxious.

Proof comprehension

Learning from peer feedback provision was measured by a geometry comprehension test based on Yang and Lin's (2008) model of reading comprehension of proof, consisting of sixteen open-

ended items created by an expert in mathematics education. The questions were assigned different weights depending on the complexity of the question (one or two points for each correct expected answer, and zero for missed or wrong answers). The test had a good inter-rater agreement (Krippendorff's $\alpha = .80$) and internal consistency (Cronbach's $\alpha = .82$; excluding 2 items with corrected item-total correlations $< .30$). Exploratory factor analysis supported a 1-factor solution, $\chi^2(104) = 126.15$, $p = .069$. Therefore, a total sum score of 52 points was computed for the items.

Basic knowledge

Participants' prior knowledge was measured using a basic knowledge test in geometry (Ufer et al., 2008). The test consisted of 49 true/false questions (scored as 1/0) about the areas of: properties of triangles, properties of a parallelogram, transversals and quadrangles (e.g., "For every parallelogram, the opposite sides are parallel: true/false"; Cronbach's $\alpha = .79$). This variable was used to control for participants' prior knowledge when investigating proof comprehension (i.e., RQ3).

Procedure

The study consisted of two phases during which participants were tested individually in a quiet room. In phase 1, preservice mathematics teachers received an introduction to peer feedback provision. Afterwards, they were presented with one fictional peer solution and were instructed to provide verbal peer feedback on that peer solution and their voices were recorded using an external voice recorder. In phase 2 they answered the epistemic emotions, the perceptions of their peer feedback, the peer feedback provision beliefs questionnaires, the basic knowledge test, and the proof comprehension test. In this phase, the preservice mathematics teachers were provided with a printed copy of the peer solution they had provided peer feedback on in phase 1 as the proof comprehension test asked specific questions related to each step of the proof and did not ask for reproducing parts of the proof. The entire experiment lasted between 90 to 120 minutes.

Analyses

We used beta regression models to analyze peer feedback accuracy (i.e., RQ1 & RQ2; Model 1) because it is in the form of proportions (Cribari-Neto & Zeileis, 2010). We used the Generalized Linear Model (GLM) to analyze the relationships between preservice mathematics teachers' comprehension of the geometry proof, beliefs about peer feedback and perceptions of their peer feedback message (i.e., RQ3; Model 2). Since the predictors were scored on different scales, they were all standardized and z-scores used in the analyses.

The beta regression models allow for nonlinearity and variable dispersions to account for skewness and heteroscedasticity by including precision parameters in addition to the parameters of the mean (Cribari-Neto & Zeileis, 2010). Precision estimation was included for all of the predictors in Model 1 which provided better model fit.

All analyses were conducted in R version (3.3.3). The beta regression models were conducted using the *betareg* package version 3.1.0 (Cribari-Neto & Zeileis, 2010). For all beta regression models, we used a bias correction to the Maximum Likelihood estimate (Grün, Kosmidis & Zeileis, 2012). For the beta regression models, we report the standardized coefficients and their 95% confidence intervals for the mean and the precision models. We also report the pseudo- R^2 suggested by Ferrari and Cribari-Neto (2004) for beta regression models, the log-likelihood, AIC and BIC. For the GLM we report the standardized coefficients (with their 95% confidence intervals), the McFadden and Nagelkerke pseudo- R^2 , log-likelihood, deviance, AIC and BIC.

In this contribution, we do not aim to investigate the impact of the quality of the peer solution on peer feedback accuracy and proof comprehension. Thus, the quality of the peer solution was included in the analyses as a covariate to control for variation in the dependent variables produced by peer solution quality.

Peer feedback coding

After transcribing the verbal peer feedback, the transcripts were segmented using the smallest meaningful segment as the unit of analysis rendering and acceptable percentage agreement between two coders (92.5% lower bound; 93% upper bound; see Strijbos, Martens, Prins & Jochems, 2006). The data was subsequently coded using the coding scheme adapted from Strijbos et al. (2012) with acceptable inter-rater reliability between two coders for peer feedback accuracy (Krippendorff's $\alpha = .76$) and peer feedback type (Krippendorff's $\alpha = .81$).

Results

Data Screening

Standardized skewness and kurtosis were determined for all variables and separately for each research condition. These values were within the acceptable range (± 3) for proof comprehension, peer feedback accuracy, all PFPQ subscales, for peer feedback providers' perceptions of their peer feedback, and the epistemic emotions curiosity, confusion and anxiety. Standardized skewness and kurtosis were outside the acceptable range for peer feedback types: cognitive-surface (NCS: $z_{\text{skewness}} = 3.60$; ERS: $z_{\text{skewness}} = 5.02$, $z_{\text{kurtosis}} = 6.61$) and self-efficacy (NCS: $z_{\text{skewness}} = 7.36$; $z_{\text{kurtosis}} = 14.63$; ERS: $z_{\text{skewness}} = 4.48$). One extreme univariate outlier ($z > |3.29|$) was identified for cognitive-surface peer feedback. The outlier was not caused by data-entry error and thus was retained. One extreme outlier was identified for basic geometric knowledge and adapted to the second lowest value as a result of which standardized skewness and kurtosis became within the ± 3 range. No multivariate outliers were identified.

Baseline Model

We included peer solution quality (NCS versus ERS) and proof comprehension as predictors of peer feedback accuracy and compared this model to the null model (i.e., an intercept only model). The two variables were included as regressors to the mean and to the precision of the model (Cribari-Netto & Zeileis, 2010). The model provided significantly better fit compared to the null model, $\chi^2(6, N = 53) = 37.58$, $p < .001$. Only proof comprehension was a significant predictor of peer feedback accuracy, $\beta = 0.59$, $p < .001$ (see Table 3). This model was used as a baseline model against which further models (for RQ1 and RQ2) were compared because we were interested in the relationships between peer feedback accuracy and other variables (e.g., peer feedback types, perceptions) after controlling for peer solution quality and proof comprehension. Thus, in the peer feedback accuracy model we included peer solution quality and proof comprehension as covariates and compared this model to the baseline model.

RQ 1: The Relationship Between Peer Feedback Accuracy and Types

According to the beta regression model (i.e., Model 1; Figure 1), cognitive-verification peer feedback ($\beta = -0.08$, $p = .032$), cognitive-elaboration peer feedback ($\beta = 0.18$, $p < .001$), and self-efficacy peer feedback ($\beta = -0.23$, $p < .001$) were significant predictors of peer feedback accuracy.

Table 3 Beta regression model analyses predicting peer-feedback accuracy from peer solution quality and proof comprehension (baseline model).

Predictors	β (SE)	95% CI	Precision	
			Std. Φ (SE)	95% CI
Intercept	-0.22* (0.10)	[-0.42, -0.02]	1.98** (0.18)	[1.62, 2.34]
Peer solution quality	-0.20 (0.10)	[-0.40, 0.01]	-0.17 (0.19)	[-0.54, 0.21]
Proof comprehension	0.59*** (0.11)	[0.38, 0.81]	0.07 (0.19)	[-0.31, 0.45]
Pseudo R^2	.47			
Log-likelihood (df)	25.77 (6)			
AIC	-39.40			
BIC	-27.70			
N	53			

Note. SE = Standard error; CI = Confidence interval; Φ = Coefficient for precision measures;

* $p < .05$,

** $p < .01$,

*** $p < .001$; Reported coefficients are standardized.

Table 4 Beta regression model analyses predicting peer-feedback accuracy from peer-feedback types, perceptions of the peer-feedback message, beliefs about peer-feedback provision, and emotions with peer solution quality and proof comprehension as covariates.

Predictors	Mean		Precision	
	β (SE)	95% CI	Std. Φ (SE)	95% CI
Intercept	-0.04 (0.08)	[-0.19, 0.11]	3.53*** (0.18)	[3.17, 3.86]
Cognitive-surface	-0.003 (0.08)	[-0.16, 0.15]	-0.53* (0.21)	[-0.95, -0.11]
Cognitive-verification	-0.08* (0.04)	[-0.15, -0.01]	-1.31*** (0.22)	[-1.73, -0.88]
Cognitive-elaboration	0.18*** (0.05)	[0.09, 0.27]	-1.70*** (0.23)	[-2.15, 1.25]
Self-efficacy	-0.23*** (0.02)	[-0.26, -0.19]	0.99*** (0.24)	[0.52, 1.46]
Perceptions	0.37*** (0.07)	[0.24, 0.49]	-0.45 (0.27)	[-0.98, 0.08]
LPF	0.07 (0.06)	[-0.05, 0.18]	-0.53* (0.26)	[1.04, 0.01]
CPF	-0.01 (0.07)	[-0.13, 0.12]	1.00** (0.32)	[0.36, 1.63]
RPF	-0.38*** (0.07)	[-0.52, -0.24]	0.52 (0.32)	[-0.10, 1.14]
Anxious	-0.27*** (0.04)	[-0.34, -0.19]	2.89*** (0.2)	[2.48, 3.30]
Curious	0.01 (0.04)	[-0.08, 0.09]	0.85*** (0.21)	[0.44, 1.26]
Confused	-0.03 (0.02)	[-0.07, 0.01]	0.36 (0.20)	[-0.04, 0.75]
Peer solution quality	-0.16*** (0.04)	[-0.24, -0.07]	-1.08*** (0.21)	[-1.49, -0.67]
Proof comprehension	0.37*** (0.05)	[0.27, 0.46]	0.21 (0.22)	[0.23, 0.64]
Pseudo R^2	.41			
Log-likelihood (df)	67.04 (28)			
AIC	-78.10			
BIC	-22.90	N = 53		

Note. SE = Standard error; CI = Confidence interval; Φ = Coefficient for precision measures;

* $p < .05$,

** $p < .01$,

*** $p < .001$; Reported coefficients are standardized.

This model provided a better fit than the baseline model, χ^2 (28, $N = 53$) = 82.54, $p < .001$ (see Table 4).

RQ 2: The Relationships Between Peer Feedback Accuracy, Peer Feedback Beliefs, Perceptions of the Peer Feedback Message and Emotions

The same beta regression model (Model 1) revealed that the peer feedback beliefs about engaging in reasoning during peer feedback provision (RPF) ($\beta = -0.38$, $p < .001$), perceptions of the peer feedback message ($\beta = 0.36$, $p < .001$) and anxiety ($\beta = -0.25$, $p < .001$) were significant predictors of peer feedback accuracy (see Table 4). The covariate peer solution quality ($\beta = -0.16$, $p < .001$) and proof comprehension ($\beta = 0.36$, $p < .001$) were also significant predictors of peer feedback accuracy (see Table 4).

Table 5 GLM models predicting proof comprehension from perceptions of the peer-feedback message and beliefs about peer-feedback provision with basic knowledge as covariate.

Predictors	β (SE)	95% CI
Intercept	27.00*** (1.17)	[24.70, 29.30]
LPF	-0.65 (1.65)	[-3.84, 2.54]
CPF	1.06 (2.16)	[-3.16, 5.30]
RPF	0.62 (2.00)	[-3.30, 4.51]
Perceptions	1.22 (1.71)	[-2.12, 4.56]
Peer solution quality	-2.56* (-2.68)	[-4.92, -0.20]
Basic knowledge	5.40*** (1.41)	[2.63, 8.16]
McFadden R^2	0.50	
Nagelkerke R^2	1.00	
Log-likelihood	-185.10	
Deviance (df)	3351.5 (46)	
AIC	386.20	
BIC	402.00	
N	53	

Note. SE = Standard error; CI = Confidence interval;

* $p < .05$,

** $p < .01$,

*** $p < .001$; Reported coefficients are standardized.

RQ 3: The Relationships Between Proof Comprehension, Peer Feedback Beliefs and Perceptions of the Peer Feedback Message

According to GLM performed on Model 2 (Figure 2) with basic knowledge as a covariate, none of the peer feedback beliefs – LPF ($\beta = -0.65$, $p = .693$), CPF ($\beta = 1.06$, $p = .625$), and RPF ($\beta = 0.60$, $p = .762$) – nor perceptions of the peer feedback message ($\beta = 1.22$, $p = 0.476$) significantly predicted proof comprehension (see Table 5). Comparing this model's fit to a model with basic knowledge only as predictor rendered no significant difference, χ^2 (8, $N = 53$) = 3.38, $p = .497$.

Discussion

This study aimed to investigate the relationships between peer feedback accuracy and the types of peer feedback provided by preservice mathematics teachers. We also explored how peer feedback accuracy is related to preservice mathematics teachers' beliefs about peer feedback provision, their perceptions of their peer feedback message and their experienced emotions. Finally, we examined the relationship between their proof comprehension, their beliefs about peer feedback provision and their perceptions of their peer feedback message.

The Relationship Between Peer Feedback Accuracy and Types

Peer feedback accuracy was positively related to peer feedback type cognitive-elaboration, but negatively related to cognitive-verification. Similarly, peer feedback accuracy was negatively related to self-efficacy peer feedback; H1 was partially supported. These findings suggest that accurate peer feedback is more likely to involve elaborations and less likely to involve comments regarding ability to provide peer feedback or to perform the learning task (i.e., self-efficacy peer feedback). These relationships are in line with previous studies that showed that high ability students - who are expected to provide accurate feedback - provided more criticism, and low ability students - who are expected to provide inaccurate feedback - provided more praise (Patchan & Schunn, 2015).

Although we hypothesized that cognitive-verification peer feedback would be positively related to peer feedback accuracy, we found a negative relationship. One explanation might be that this type of comment is the most common peer feedback that students provide (Gan & Hattie, 2014) regardless of the level of their domain knowledge (Cho & Cho, 2011). Thus,

cognitive-verification peer feedback tends to be inaccurate because students with low domain knowledge more often provide this type of feedback and/or their feedback is more often limited to this type, whereas those with higher domain knowledge tend to provide more cognitive-elaboration peer feedback (Cho & Cho, 2011).

Similarly, those who provided inaccurate peer feedback were more likely to use self-efficacy comments expressing their inability to provide peer feedback or to perform the task. This finding suggests that preservice mathematics teachers are aware of their ability/inability to provide peer feedback. This type of comment, although previously identified in peer feedback comments (Strijbos et al., 2012), but still widely ignored in peer feedback literature, seems to convey important information regarding provider's ability to compose the peer feedback message. What remains unclear, however, is how this type of peer feedback influences recipients' perceptions and utilization of the peer feedback message, and how it is related to provider's learning and engagement in the peer feedback provision activities.

The Relationships Between Peer Feedback Accuracy, Peer Feedback Beliefs, Perceptions of the Peer Feedback Message and Emotions

Our findings indicated that preservice mathematics teachers' perceptions of their peer feedback message were a significant positive predictor of peer feedback accuracy. In contrast, only the beliefs about engaging in reasoning during peer feedback provision were negative predictors of peer feedback accuracy (H2a was partially supported). In line with the findings by Rotsaert et al. (2017) regarding providers' perceived trust in their own ability to provide peer feedback, we found that peer feedback accuracy was positively predicted by providers' perceptions of their peer feedback message. However, although they found a positive relationship between students' beliefs about the educational value and beliefs about peer feedback accuracy, we found no significant relationships between peer feedback accuracy and preservice mathematics teachers' confidence regarding peer feedback provision beliefs (CPF) or learning from peer feedback provision beliefs (LPF), and a negative relationship with beliefs about engaging in reasoning during peer feedback provision (RPF).

The significant relationship between preservice mathematics teachers' perceptions of their peer feedback message and peer feedback accuracy is consistent with the previous research on self-control beliefs (Zimmerman et al., 1992). The more accurate the peer feedback is, the more likely that the provider also perceives it as being of high quality, accurate and useful for the recipient. Although previous peer feedback research findings indicated that students expressed that they learn from providing peer feedback and engage in reasoning during peer feedback provision (Nicol et al., 2014), evidence from this study suggest that those who believed that they engage in reasoning during peer feedback provision tended to provide less accurate peer feedback. One explanation might be that pre-service mathematics teachers who are already capable of providing accurate peer feedback might not consider the relevance of engaging in reasoning during peer feedback provision because they already know how to perform the task. Future studies should investigate this issue.

Anxiety negatively predicted peer feedback accuracy, while the epistemic emotions of curiosity and confusion were not related to peer feedback accuracy (H2b was partially supported). Consistent with previous findings that the epistemic emotion of anxiety is negatively related to performance on complex tasks (Pekrun, 2011), the accuracy of peer feedback was negatively related to anxiety. It appears that anxiety during peer feedback provision is detrimental to the accuracy of the peer feedback message. Since anxiety is frequently reported by students during peer feedback activities (e.g., Cartney, 2010; Cheng, Hou & Wu, 2014), the effects of such emotion should be further investigated in future studies.

The Relationships Between Peer Feedback Providers' Proof Comprehension, their Beliefs about Peer Feedback Provision and their Perceptions of their Peer Feedback Message

After controlling for basic knowledge, preservice mathematics teachers' beliefs about peer feedback provision and perceptions of their peer feedback message did not predict their comprehension of the proof (H3 was not supported). Unlike epistemological (Muis, 2004) and self-control beliefs (Zimmerman et al., 1992) that predict performance, these types of peer feedback related beliefs did not predict learning from peer feedback provision in our study. This might be due to the complexity of the peer feedback provision process that is shaped by the characteristics of the provider and the recipient and the representations they possess of each other (Strijbos & Müller, 2014). Thus, learning from peer feedback provision cannot be simply explained by the providers' beliefs and perceptions. This finding challenges the findings of peer feedback studies that rely purely on measuring students' perceived learning or perceived usefulness as outcome measures of peer feedback (e.g., Nicol et al., 2014; Wang, 2014), and indicates the need to further investigate the roles of peer feedback related beliefs and perceptions more systematically in relation to more objective outcome measures (i.e., performance).

Limitations

Although our study shed light on several influential factors that are widely ignored in peer feedback research, it also had its limitations. First, we only investigated the relationships between peer feedback accuracy and preservice mathematics teachers' beliefs about peer feedback provision, perceptions of the peer feedback message and emotions. Investigation of the relationships between these individual characteristics and different types of peer feedback was not possible due to the small sample size in relation to the number of the different types of peer feedback.

Second, we used fictional peer solutions and although this allowed for a stronger control of the effect of peer solution quality on the variables of interest, it does not necessarily represent the natural settings when a solution is produced by a peer in the classroom. Nevertheless, fictional scenarios have been shown to invoke reactions comparable to real situations (Robinson & Clore, 2001). Third, verbal peer feedback was analyzed which might differ in its content compared to written peer feedback (Van Den Berg, Admiral & Pilot, 2006). Thus, we recommend that our study should be treated as exploratory and the findings replicated in future studies.

Practical implications

As the cognitive-elaboration peer feedback type seems to positively predict peer feedback accuracy, combined with the negative effects of self-efficacy and cognitive-verifications types of peer feedback, this suggests that when implementing peer feedback in teacher education we have to pay more attention to the accuracy of the provided peer feedback. Even the basic type of peer feedback (i.e., cognitive-verification) that represents the majority of students' comments (Gan & Hattie, 2014) is likely to be inaccurate, possibly limiting its usefulness for the recipient and the provider. Self-efficacy peer feedback that most of the time designates provider's inability to provide peer feedback or to perform the task seems to reflect a true effect and can indicate a need for support. Instructional support in the form of domain-knowledge and peer feedback scaffolds (e.g., Alqassab, Strijbos & Ufer, 2018) may help in training preservice teachers to provide more accurate and advanced peer feedback types (i.e., cognitive-elaboration).

Preservice mathematics teachers' perceptions of their peer feedback message were positively related to peer feedback accuracy, whereas anxiety was negatively related to peer feedback accuracy. Accordingly, it is important to use peer feedback activities in which preservice mathematics teachers can feel a sense of control (Cheng & Warren, 1997) and regard errors as learning opportunities (Borasi, 1994). A sense of control will be beneficial as students are likely to

experience anxiety when they think that they lack control over their performance (Pekrun, 2006). Therefore, careful design of peer feedback activities that ensure perceived control over the activity may reduce experienced anxiety. This can be achieved, for example, by involving them in defining assessment criteria (e.g., Sluijsmans et al., 2003) or using anonymous peer feedback activities (Vanderhoven et al., 2015) when peer feedback is first introduced and proceeding to non-anonymous activities once students are more experienced (Rotsaert, Panadero & Schellens, 2018).

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