EMOTIONS IN PROBLEM POSING: A CASE STUDY ASSESSING STUDENTS' ENJOYMENT AND ANGER THROUGH FACIAL EXPRESSIONS

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In real life, problems arise and have to be posed before they can be solved. While interest in research on mathematical problem posing is growing, affective aspects, particularly emotions, have received little attention. To contribute to closing this gap, we examined (RQ1) whether students' enjoyment and anger differed across problem-posing activities and (RQ2) which events triggered these emotions during problem posing. We analyzed the problem-posing processes of two tenth-grade students by applying facial expression analysis to assess their emotions. Students expressed more enjoyment in problem evaluation compared with problem solving and more anger in problem solving compared with all other activities. Among various emotional triggers, enjoyment tended to occur when students set up and adjusted real-world conditions.

INTRODUCTION

One central goal in mathematics education is to enable students to apply what they have learned in their daily lives, for example, by solving problems that originate from the real world (Niss & Blum, 2020). Before problems can be solved, they first need to be identified and articulated. Therefore, the ability to pose a problem for a given real-world situation constitutes an important competency that students should develop. A significant influence on the outcomes of learning processes can be attributed to emotions, which can affect attention and performance (Pekrun, 2024). Although problem posing has the potential to support students' understanding of mathematics, little is known about affective aspects, particularly emotions, during problem posing (Cai et al., 2015; Cai & Leikin, 2020). To improve the teaching and learning of problem posing, a deeper understanding of cognitive and affective processes involved in the processes of problem posing is needed (Cai & Leikin, 2020). Addressing this gap, our aims were first, to analyze students' experiences of enjoyment and anger during problem posing by comparing emotional experiences across different problem-posing activities, and second, to identify emotion-eliciting events in order to better understand why emotions emerge during problem posing.

THEORETICAL BACKGROUND

Problem Posing

Problem posing has considerable potential for supporting mathematical learning and has increasingly become a focus of research in mathematics education (Cai et al.,

2026. In H. Krzywacki, M. Hähkiöniemi, E. Haataja, M.S. Hannula & P. Hästö (Eds.). *Proceedings of the 49th Conference of the International Group for the Psychology of Mathematics Education: Research Reports*, pp. 1299-1306. PME.

2015). Problem posing is defined as the reformulation of given problems and the generation of new problems that occur before, during, or after solving a problem (Silver, 1994). To characterize a problem-posing task, two core elements can be differentiated: the problem situation, which includes the context and data, and the prompt, which tells students what to do with the situation. Problem situations can be related to either real-world or intra-mathematical contexts and can be further differentiated according to their degree of structuredness (Krawitz et al., 2025). Unstructured problem-posing situations arise from a spectrum of contexts without an initial problem and may contain a little to a lot of information. Structured problem-posing situations present an initial problem and ask students to pose further questions, for example, by adding or changing conditions (Stoyanova & Ellerton, 1994). The process of problem posing can be described by the model proposed by Baumanns and Rott (2022) comprising five activities. The *situation analysis* refers to identifying relevant elements of the given situation and exploring possibilities for variation or generation. *Variation* includes modifying or removing given conditions without adding new ones, thus retaining the original structure. *Generation* includes adding new conditions or creating entirely new problems. *Problem solving* refers to solving a posed problem, often in a shortened problem-solving cycle. *Evaluation* includes judging the quality, solvability, or appropriateness of the posed problem.

Enjoyment and Anger in Mathematics Education

Emotions are an essential part of students' experiences in mathematics education and influence how they engage with tasks, process information, and perform. The Control-Value-Theory (Pekrun, 2024) provides a theoretical framework of how these emotions arise. Regarding achievement emotions, the Control-Value-Theory distinguishes the object focus (activity or outcome) and temporal relationships (past, present, or future) of events and related emotions. Additionally, two appraisal dimensions are central: perceived control and value. Perceived control refers to students' perceived influence over their learning activities and the outcomes of these activities. Value refers to the personal relevance associated with mathematical activities. Different combinations of these appraisals lead to distinct emotional experiences. For activities in present events, such as engaging in problem posing, specific events can trigger emotions by influencing learners' perceived control over the activity and the subjective value they attribute to it (Pekrun, 2024). High control and high value typically foster positive emotions, such as enjoyment, supporting persistence and deeper cognitive engagement (Linnenbrink-Garcia et al., 2016). By contrast, anger may arise from reduced control, for example, when challenges are difficult or impossible to manage and value is high (Pekrun, 2024). Positive emotions, such as enjoyment, are in general linked to intrinsic motivation and deeper learning strategies, whereas negative emotions, such as anger, may lead to disengagement but can, under certain conditions, also promote effort and persistence (Linnenbrink-Garcia et al., 2016). Traditionally, emotions are investigated by administering self-report measures such as questionnaires. However, self-reports are limited to conscious emotional experiences that can be verbalized. An alternative

and innovative approach is computer-assisted facial expression analysis, which can capture outwardly expressed emotions that may be experienced unconsciously. It enables automated real-time analysis of emotional experiences during work phases (Bishay et al., 2022).

The Role of Emotions in Problem Posing

According to Pekrun's (2024) Control-Value-Theory, the control and value appraisals of students in different problem-posing activities significantly influence students' emotions. To a large extent, their experiences of enjoyment and anger depend on whether the students consider the task to be of high value. If they do, perceived control will determine whether enjoyment (high control) or anger (low control) will arise. A high level of control could arise during variation and generation or evaluation activities when students use their knowledge creatively and make assumptions. Low control could arise during variation and generation or problem-solving activities when students may run out of ideas or might not know how to solve a problem mathematically.

On an empirical level, emotions have rarely been investigated in problem-posing research (Cai & Leikin, 2020). To the best of our knowledge, no study has explicitly focused on enjoyment and anger in problem-posing processes. Evidence stems from research on problem solving, which is closely related to problem posing and is considered part of the problem-posing process here. In problem-solving research, emotions are described as integral to self-regulation in problem solving with social interactions, such as joking or seeking peer support as central coping strategies (Hannula, 2015). Regarding affective aspects of problem posing, a case study by Schindler and Bakker (2020) showed that interactive aspects of problem posing, such as group collaboration, can positively influence students' negative emotions, such as fear. Furthermore, students were found to describe both positive experiences resulting from the freedom to make choices during problem posing and negative ones in terms of effort and difficulty (van Bommel & Palmér, 2021).

RESEARCH QUESTIONS

In this study, we focused on the following research questions:

RQ1: Do students' (a) enjoyment and (b) anger, assessed through their facial expressions, differ across problem-posing activities?

RQ2: Which events trigger enjoyment and anger during mathematical problem posing?

METHOD

Participants and Data Collection

Two 16-year-old, female students from a German middle school participated in the study. We refer to them by the pseudonyms Lea and Hanna. Both students had already been involved in varying and generating problems. They were given two problem-posing situations related to real-world contexts: first, the structured situation "shared apartment" (see Figure 1), and a second unstructured situation. In both cases, they were

first asked to read and understand the situation on their own and develop initial ideas and then pose easy and difficult problems working in pairs (see Figure 1). The entire process was filmed. The videos included their facial expressions, gestures, written solutions, and spoken language.

Figure 1. The "Shared Apartment" Problem-Posing Situation

Shared Apartment

Anna, Jan, Seymen, and Judy want to share an apartment. For this purpose, they have selected several apartment listings. Their favorite is a four-room apartment with 95 m^2 of floor space near the university. The rent for this apartment is 765.00 € per month, and the monthly utilities are 210.40 €.

How much should each of them pay?

a) Individually: Imagine yourself in the situation described in the "shared apartment" task. What other information could be important to answer the question? Collect as many different ideas as possible and write them down.
b) Partner: Compare your ideas with your partner's. Use these ideas to vary the task. Write down one easy and one difficult new task.

Data Analysis

We used content analysis to transcribe and analyze the problem-posing processes. The coding scheme was based on the problem-posing activities described in Baumanns and Rott's (2022) process model. We did not include the situation analysis activity, as it was addressed in the initial part of the problem-posing task through individual work and could not be reliably identified. In addition, we combined the activities of variation and generation due to their conceptual similarities, as they differ in whether an initial question is specified or not. Table 1 presents the coding scheme. All transcripts were coded by the first author. To test interrater reliability, 25% of the material was coded by a trained second rater. Agreement was very high ($\kappa = .90$).

Table 1. Coding scheme for problem-posing activities

Activity	Description
Variation and Generation	Development and formulation of possible problem(s) and determination of a question with or without reference to an initial question
Problem solving	Planning a more or less concrete approach for solving the posed idea or problem
Evaluation	Evaluation of possible problems using individual criteria
Other	All other sequences (e.g., activities not related to the task)

To answer RQ1, we analyzed Lea's and Hanna's facial expressions during their problem-posing processes using Affectiva AFFDEX 2.0 as integrated in iMotions 11.0

(Bishay et al., 2022). Affectiva detects faces in every video frame and identifies facial features that are assigned to specific facial expressions. These facial expressions are interpreted by a machine learning model that has been trained on large data sets of faces to estimate the occurrence of emotional expressions such as enjoyment or anger. The system aggregates these predictions at the frame level over time to create continuous emotion metrics (Bishay et al., 2022). The problem-posing activities of both students were used as units for analyzing the emotion data. The Affectiva metrics refer to each occurrence of a problem-posing activity and indicate the percentage of time of this occurrence that consisted of a specific emotion. We computed a univariate analysis of variance (ANOVA) to examine whether the percentage of time of measurable emotions differed between the problem-posing activities. To answer RQ2, we conducted a qualitative content analysis of the situations triggering enjoyment and anger. Therefore, we analyzed the video materials by focusing on the events that occurred before the facial expression metric indicated enjoyment or anger. We deductively distinguished two main categories: task-related emotions and non task-related emotions. For task-related emotions, we inductively developed subcategories. Intercoder reliability showed a substantial agreement ($\kappa = .85$).

FINDINGS

A total of 71.88 minutes of problem-posing processes were coded (35.94 minutes per person). To focus on emotions experienced during problem posing, we excluded every activity coded as *Other*. This exclusion resulted in 61.90 minutes of video material and 143 occurrences of problem-posing activities. An occurrence was measured as a problem-posing activity emerged. Table 2 provides an overview of the distribution of problem-posing activities regarding the number of occurrences, duration, means, and standard deviations for the emotions with respect to the percentage of time per activity (e.g., $M = 6.99$ means that students showed enjoyment for about 7% of the time during variation and generation).

Table 2. Descriptive statistics for problem activities

Activity	n	Total duration in minutes	Enjoyment		Anger	
			M	*SD*	*M*	*SD*
Variation and Generation	62	33.47 (54.07%)	6.99	11.94	0.07	0.43
Problem solving	24	9.18 (14.83%)	3.22	8.40	0.46	1.72
Evaluation	57	19.24 (31.08%)	10.80	15.37	0.01	0.05

For RQ1, the analysis revealed differences in enjoyment and anger across problem-posing activities (Enjoyment: $F(2, 140) = 3.14$, $p = .046$, $\eta^2 = .043$; Anger: $F(2,140) = 3.130$, $p = .047$, $\eta^2 = .043$). Post hoc comparisons showed that participants expressed more enjoyment during evaluation ($M = 10.80$, $SD = 15.37$) than during problem solving ($M = 3.22$, $SD = 8.40$) and more anger during problem solving ($M = 0.46$, SD

= 1.72) than during variation and generation (M = 0.07, SD = 0.43) or evaluation (M = 0.01, SD = 0.05).

For RQ2, the qualitative analysis included non task-related, non-visible, and task-related events. Non task-related events triggered emotions without a connection to the task, such as dropping a pen and subsequently laughing. Non-visible events referred to triggers in which either the emotion indicated by the facial expression analysis or its triggering event could not be identified in the video. Task-related events for enjoyment referred to six distinct subcategories. First, *setting up and adjusting real-world conditions* (16 events, 21%) comprised proposing ideas for the problem, e.g., including creative ideas on conditions or joking about possible but absurd assumptions.

> Lea: "One of them has a pet and therefore needs, I don't know, a large room so that the animal can live there too. Then he needs to have more space." [Laughs]

For this category, 13 events (17%) happened in variation and generation, two (3%) in evaluation, and one (1%) in problem solving. Second, *formulating the problem* (9 events, 12%) included discussions and humorous remarks about how to formulate the posed problem such as debating which words or operators to use. Out of these events, six (8%) happened in variation and generation, including formulations in general, and two (3%) in evaluation, including discussions about whether something had been forgotten in the question. Third, *attempting a calculation* (3 events, 4%) included discussions about how the posed problem could be solved, which sometimes caused problems and resulted in self-conscious laughter (always in problem solving). Fourth, *asking questions or comprehension problems* (8 events, 10%) comprised events of confusion or questions, e.g., whether the partner had understood an explanation accompanied by self-conscious laughter. For this category, six events (8%) happened in variation and generation and two (3%) in evaluation. Fifth, *judging the difficulty of the problem as high or low* (11 events, 14%) included events in which the students noticed that the task was very easy or much too difficult to solve (always in evaluation). Finally, *evaluating the meaningfulness of the problem* (6 events, 8%) comprised discussions about whether the posed problem made sense in the problem-posing situation or whether the embedded numerical values were realistic (always in evaluation). For anger, six task-related events were identified. These most frequently involved *asking questions or comprehension problems* (3 events, 50%), happening in variation and generation twice (3%) and in problem solving once (1%).

> Lea: "Isn't ten multiplied by ten one litre?"
> Hanna: "No." [showing signs of anger]

In addition, single events of anger (1 each, 17%) were identified for *evaluating the meaningfulness of the problem* (in evaluation), *formulating the problem* (in problem solving), and *attempting a calculation* (in problem solving).

DISCUSSION AND IMPLICATIONS

For RQ1a, the results of the facial expression analysis showed that, for Lea and Hanna, evaluating the posed problems elicited more enjoyment than problem solving did. This finding may suggest that students experience evaluative phases as more rewarding and controllable (Pekrun, 2024), perhaps because they are able to contribute their own ideas, leading to the successful posing of the problems. By contrast, for RQ1b, problem solving was associated with more anger than variation and generation or evaluation activities. This finding may point to the cognitive and emotional demands of problem solving, such as dealing with uncertainty or frustration when mathematical solutions are not working out. In line with the Control-Value-Theory (Pekrun, 2024), such uncertainty might result in lower perceived control, thereby increasing anger.

For RQ2, the results revealed that enjoyment and anger were triggered by both task-related and non task-related events during problem posing. For task-related events, a substantial proportion of enjoyment was evoked by judging the difficulty of the problem and evaluating its meaningfulness, both of which occurred during evaluation. This finding suggests that the students enjoyed reflecting on the product of their own creative problem-posing process. These findings provide an explanatory link to RQ1a, clarifying why evaluation elicited more enjoyment than problem solving. By contrast, anger in problem solving was triggered by different events, including comprehension problems, formulating the problem, and attempting calculation. However, due to the low frequency of these events, no conclusions can be drawn.

Taken together, the results provide empirical support for applying Control-Value-Theory to problem-posing processes and refine it by highlighting activity-specific emotional dynamics. Consistent with prior work reporting both positive and negative emotions in problem posing (van Bommel & Palmar, 2021) and emphasizing the role of social interactions in problem posing and solving (Hannula, 2015), our study demonstrates how concrete interactional and cognitive events function as emotional triggers. Methodologically, using automated facial expression analysis allowed us to capture emotions continuously during problem posing, providing process-level insights that go beyond retrospective self-reports. From an instructional perspective, these findings suggest that problem-posing tasks should deliberately include phases that allow for creative decision-making and evaluation, while providing scaffolds during problem-solving phases to prevent prolonged loss of control. Future research with larger samples should examine whether these event-emotion patterns generalize across learners and task types and how they can be systematically integrated into process models of problem posing.

Despite these contributions, limitations include the case-study design, unequal frequencies of activities (especially problem solving), and the use of activities as the unit of analysis, which reduces the ability to capture intra-individual dynamics. Furthermore, while facial expression analysis is a promising automated approach, its validity should be examined further.

Acknowledgments

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