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Engineering students' perceptions of teaching: teacher-created atmosphere and teaching procedures as triggers of student emotions

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ABSTRACT

The engineering education field has concentrated more on rationality and knowledge than on emotions, even though the latter are important in students' learning processes and in the engineering profession. This study examined engineering students' descriptions of the roles of teaching in their perceived emotions. A qualitative thematic analysis was conducted on data from interviews with 26 engineering students. The results show that students' emotions are influenced by their perceptions of 1) a teacher-created atmosphere, such as teacher interest, enthusiasm, emotions, and encouragement, and 2) teaching procedures, such as course arrangements, lectures, public performances, and active learning. The findings call for more attention to the nuances of student – teacher relationships in engineering classrooms, as they can affect the ways in which students experience teaching procedures, as well. These results can help engineering educators better understand students' teaching-related emotions and make instructional choices that enhance student emotions that are conducive to learning.

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Emotion; student – teacher relationship; classroom atmosphere; teaching methods; active learning

Introduction

Emotions have received increasing attention in educational research. While prior learning-related research has mostly focused on cognition and motivation (Beard, Clegg, and Smith 2007; Schutz and Zembylas 2016), the role of emotions in learning processes is now well recognised (Beard, Clegg, and Smith 2007; Pekrun, Elliot, and Maier 2009). Environmental and social factors play an important role in the emergence of emotions (Lazarus 2006; Schutz et al. 2006). For example, research has acknowledged that factors related to teaching can greatly impact students' emotions (Frenzel et al. 2009). In turn, emotions significantly influence the relationships between teachers and students (Quinlan 2016). Overall, scholars have called for more research on the effects of classroom instruction on students' emotions (Linnenbrink-Garcia, Patall, and Pekrun 2016; Pekrun and Perry 2014).

The importance of conducting research on emotions in higher education has been acknowledged because it differs from school contexts, where most of the educational emotion research has been conducted (Mendzheritskaya and Hansen 2019). In the field of engineering education, paying attention to emotions is valuable because of their significance – for example, when engineers engage with

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ethical aspects in their work (Roeser 2012) or solve emotion-provoking, complex, and wicked problems (Lönngren et al. 2020a). Emotions have also been strongly associated with other important aspects of the engineering profession, such as creativity (Chemi, Grams Davy, and Lund 2017) and collaboration (Järvenoja and Järvelä 2009). For example, Davis and Bellocchi (2018) found that emotions were particularly present when students collaboratively constructed objectivity in science inquiry.

However, the engineering education field has traditionally placed less emphasis on the role of emotions than on the role of content knowledge, rationality, and cognitive capacities, which also often guide teachers' actions (Kellam et al. 2018). Overall, previous research has connected teachers' disciplinary backgrounds to their teaching approaches. For example, Lindblom-Ylanne et al. (2006) found that the teachers from the so-called hard disciplines more often reported a teacher-focused approach, whereas teachers from soft disciplines were more often identified as student-focused. In engineering education, however, the development of teaching practices into more student-centred perspectives, especially those focusing on active learning, has received considerable attention (Lima, Andersson, and Saalman 2017; Streveler and Menekse 2017). Traditional methods have been challenged – among other reasons, because of their inability to provide graduates with the qualities required to respond to the new challenges of a society (Duderstadt 2008). Moreover, the engineering education field has lately seen a rapidly increasing interest in emotions, mostly following in the footsteps of science education (Lönngren et al. 2020b). Recent studies have focused on investigating, for example, engineering students' test anxiety (Karjanto and Yong 2013), emotions in entrepreneurship education (Rose et al. 2019), and experiences of well-being support mechanisms (Chadha et al. 2020).

This study aimed to examine how students describe their study-related emotions having been evoked by teaching during their study paths. Thus, the study fills a gap in the literature by providing a deeper understanding of the role of teaching in students' emotional experiences in the engineering education field, in which emotions have not been investigated as thoroughly as rationality and knowledge. Further, by focusing on student perceptions of teaching, this study addresses a general need in higher education research to explore in detail the various ways in which teaching affects student emotions. Based on student interviews, we used qualitative methods to better understand the complex nature of student emotions in the engineering education context. The findings can 1) help teachers and scholars recognise and understand students' teaching-related emotions and 2) help teachers make instructional choices that enhance student emotions that are conducive to learning – two aspects recognised as important goals of educational emotion research (Pekrun 2019). The study aimed to answer the following: How do engineering students describe their emotions being triggered by teaching?

Student emotions in an academic context

The extensive literature on emotions reveals that scholars' understanding and definitions of the concept vary (Barrett 2006; Frijda 2007; Izard 2007; Scherer 2005), although most definitions encompass multiple components (Moors 2009). For example, Pekrun (2006) views emotions as psychological processes that include affective, cognitive, motivational, expressive, and peripheral components. Emotions can be defined as intense, short-lived episodes, which distinguishes them from moods, which are longer lasting and have a lower level of intensity of affective states (Linnenbrink-Garcia, Patall, and Pekrun 2016). Feelings, on the other hand, can be seen as private, mental experiences of emotions (Damasio 2000). Furthermore, emotions can be divided into state emotions, which are individual responses to changing environments, and trait emotions, which are more stable over time and reflect an individual's tendency to respond emotionally (Rosenberg 1998). Emotions directly associated with academic learning, classroom instruction, and achievement activities and outcomes can be called achievement emotions (Pekrun 2006; Pekrun and Perry 2014). Other types of emotions relevant to the educational context are epistemic emotions (triggered by

cognitive problems), topic emotions (related to the topic being learned), and social emotions (related to other people) (Pekrun 2017).

Zembylas (2007) identified three main types of approaches to studying emotions in educational research: psychodynamic approaches, which view emotions as individual experiences; social constructionist approaches, which view emotions as sociocultural experiences; and interactionist approaches, which view emotions as interactional and performative experiences and aim to overcome the dichotomy of the first two approaches. For example, the control-value theory of achievement emotions holds that learning environments and tasks have an impact on students' emotions through individual appraisals of their control and value and that emotions influence learning, especially through students' cognitive resources, interest and motivation, information processing, and self-regulation (Pekrun and Perry 2014). Thus, the theory is an example of a psychodynamic approach.

Research on emotions often classifies them based on their valence (positive/negative) or activation/arousal (activating/deactivating) (Linnenbrink 2007). Most studies in educational psychology have associated positive emotions with positive learning outcomes and negative emotions with negative outcomes (e.g. Dettmers et al. 2011). For example, Husman et al. (2015) found that engineering students' positive pre-emotions regarding an ethics class were associated with less physiological stress at the end of the class. However, the results have not always been straightforward (Pekrun and Perry 2014; Trigwell, Ellis, and Han 2012). Thus, the effects of valence and activation can not be considered straightforward processes. Moreover, in a study on engineering students' narratives, Kellam et al. (2018) found that there was a trajectory of emotions with varying valence and activation throughout their studies, including enjoyment in a pre-engineering phase, frustration with and doubt about core classes, and phases of more contentment and satisfaction later in their studies. Thus, the emotions in engineering education should be considered as a diverse and complex phenomenon.

Bellocchi and Turner (2019) posit that valence is a shift in the positive – negative polarity of emotions but criticise the division of emotions to merely positive and negative. They challenge the claim that pleasantness is experienced similarly by everyone and recognise also the sociocultural aspects by emphasizing that actions fuelled by varying emotions can lead to both negative and positive outcomes and emotions, depending on the viewpoint. However, they also challenge purely social constructionist approaches, recognising the biological basis of human emotional arousal and suggesting that the valence of emotions can be evaluated through the health outcomes to which they are related. Thus, Bellocchi and Turner's (2019) sociological perspective on emotions holds that the societal-level structural system (level of differentiation, individualisation, and mediation of actions) and the cultural system (emotion ideologies, emotion rules, and clarity of emotion labels) are crucial in emotional experiences. Depending on these systems, the level of self-reflexivity, the perception of the socio-cultural context, and the sanctioning responses of others vary and shape the initial bodily emotions through individual expectations of a situation. Thus, fulfilling expectations enhances the experienced positive emotional valences, while falling short of expectations produces negative valences. Therefore, individual defense mechanisms (such as attributions of the causes of negative emotions) and appraisals of situational emotions shape the experience of the valence of emotions. This is an iterative process whereby the experienced valence can change due to a re-perception of the sociocultural context, which can alter expectations, emotions, defense mechanisms, appraisals, and attributions. Studies have suggested that a socio-cultural context has an effect on how people value, promote and experience emotions based on their arousal. Westerners seem to prefer and experience high arousal emotions (such as enthusiasm) when Easterners promote and experience more low arousal emotions (Lim 2016).

Student – teacher relationship and student emotions

Tormey's (2021) three-dimensional model of student – teacher relationships in higher education highlights the multidimensional nature of emotions in student – teacher relationships and goes beyond simple measurements of emotional valence. According to this model, teacher – student relationships depend on three dimensions: whether teachers and students feel warmth toward each other (affection/warmth), whether they feel trust in each other (attachment/safety), and whether they feel admiration or awe for each other (assertion/power) (Tormey 2021). Tormey showed that higher education students' emotional responses predicted how they perceived the quality of a course. Thus, he suggested that enhancing experiences of warmth, trust, and admiration in the classroom can also enhance students' overall experiences (Tormey 2021).

Teacher-focused research has examined how teachers' emotions impact both their own and their students' cognition, motivation, and behaviour (Sutton and Wheatley 2003). Studies have associated teachers' expressed enthusiasm with students' positive emotions (Frenzel et al. 2009), interest (Keller et al. 2014; Quinlan 2019), and motivation (Patrick et al. 2000). According to the control-value theory of achievement emotions, a teacher's enthusiasm can modify the motivational quality of the learning environment, thus, enhancing students' achievement values and motivation (Pekrun and Perry 2014). Furthermore, Becker et al. (2014) found that students' perceptions of teacher emotions predicted student emotions above and beyond instructional behaviour.

Meyer and Turner (2006) consider positive interactions and emotional encounters to be important for an engaging classroom climate that promotes motivation and learning. In a meta-analysis, Cornelius-White (2007) found that teacher variables such as positive relationships, non-directivity, empathy, and warmth, were associated with positive student outcomes. Similarly, in a meta-analysis of 99 studies on students from preschool to highschool, Roorda et al. (2011) found that, especially in higher grades, student engagement and achievement were positively associated with positive affective qualities of teacher – student relationships (empathy and warmth) and negatively associated with negative qualities. Youmans (2020) found that engineering students' experiences of their professors' expressed empathetic concern, mainly in the form of understanding, nonjudgment, and compassion, encouraged students to participate and actively seek help from a professor and enhanced their learning, motivation, and retention. Teachers who were not open to questions in class or made no exceptions on assignments reduced student motivation and discouraged engagement, even leading students to change their study plans and select other topics (Youmans 2020). Teachers' attitudes and actions also play an important role in breaking the 'chilly climates' experienced by underrepresented groups in engineering education (Friedrich, Sellers, and Burstyn 2008; Malicky 2003).

Teaching procedures and student emotions

According to the control-value theory of achievement emotions, environments and tasks that meet individual needs and are of relevant difficulty may enhance students' achievement values and motivation (Pekrun and Perry 2014). In a study on preservice science teachers' perceptions of high-quality learning experiences, classroom emotional climate, and emotional arousal, Bellocchi et al. (2014) found that long teacher monologues were related to decreased or negative emotional climates compared to dialogues. However, students still regarded monologues as high-quality experiences if the content was meaningful to them (Bellocchi et al. 2014).

According to Deci and Ryan's (2000) self-determination theory, a teacher can enhance students' motivation by ensuring that their basic psychological needs of competence, autonomy, and relatedness are satisfied. Autonomy refers to an individual's sense that their experiences and behaviours are self-determined, competence refers to feeling effectance and mastery, and relatedness refers to feelings of being socially connected (Ryan and Deci 2000, 2017). According to this theory, teaching that supports basic psychological needs is, foremost, autonomy supportive by offering choice and

encouraging self-regulation. In addition, experiences of competence can be supported by offering structure and positive informational feedback, and the need for relatedness can be supported by creating a caring environment (Ryan and Deci 2017). Research on higher education students has associated autonomy-supportive teaching with students who devote more effort to studying (Reeve et al. 2002) and exhibit increased perceived competence and interest/enjoyment and decreased anxiety (Black and Deci 2000). In control-value theory of achievement emotions, providing autonomy is recognised as a way to enhance positive student emotions, especially when it is matched with individual competence levels (Pekrun and Perry 2014).

Active learning teaching practices have also attracted research interest. Active learning is a concept seen from various perspectives (Hartikainen et al. 2019; Markant et al. 2016) but often refers to instructional activities aimed at activating students (Felder and Brent 2009; Prince 2004). For example, student-centred, activating teaching practices that elicit positive emotional experiences can promote increased involvement in learning, broaden thought processes and actions, and lead to emotional, cognitive, and behavioural changes and development (Naude, van den Bergh, and Kruger 2014). Villanueva et al. (2018) investigated engineering students' engagement using physiological arousal measurements and found that higher arousal levels (engaged learning) were more often associated with active learning activities than with traditional lectures. Active learning has also been associated with less boredom (Bieg et al. 2017), less anxiety (Rapp-McCall and Anyikwa 2016), and even less fear (Bledsoe and Baskin 2014).

However, research has also shown that active learning activities may promote more negative emotions than teacher-centred teaching (Litmanen et al. 2012) and that students may experience more positive and fewer negative emotions in traditional than in active learning settings (Jacob et al. 2019). For example, active learning activities that involve randomly calling on students to answer questions can cause anxiety (Cooper, Downing, and Brownell 2018). Furthermore, although working on tasks collaboratively can satisfy students' basic psychological needs (Koch et al. 2017) or engage them in studying (Koch et al. 2017; Pekrun 2006), too demanding a social setting can also intensify students' negative emotions (Pekrun 2006). Students may also experience active learning negatively if they have expected more passive learning. For example, Nguyen et al. (2017) found that engineering students' expectations and experiences of the type of instruction correlated with their responses to instruction.

Methods

Research has shown that factors related to teachers and teaching are associated with students' emotions in multiple ways and are important for their learning. In the engineering education context, emotions are a diverse and complex phenomenon that also plays a key role when graduates enter the workforce. To gain a deeper understanding of the phenomenon, this study investigated engineering students' perceptions of teaching as a trigger of emotions in their overall study paths, which reflects more their trait than state emotions (Rosenberg 1998). The study aimed to address the following research question: How do engineering students describe their emotions being triggered by teaching?

Following Bellocchi & Turner's (2019) perspective, we view emotions as individual experiences but also as experiences that are affected by sociocultural aspects. In our analysis, we focused on emotional valence – not as an objective definition but rather as a concept that reflects students' own voice in the positive – negative polarity of their emotional experiences (Bellocchi and Turner 2019). We examined all kinds of student descriptions of emotions without restricting our analysis to only one kind of emotion, such as achievement, topic, epistemic, or social emotions (Pekrun 2017). In addition, reducing the investigation to a few discrete emotions could have limited the scope of students' experiences (Uitto, Jokikokko, and Estola 2015).

Previous research also encouraged us to employ qualitative methods to avoid exclusively quantitative method-driven designs (Douglas, Koro-Ljungberg, and Borrego 2010) and to gain a better

understanding of this complex, multilayered phenomenon (Schutz and DeCuir 2002). With a qualitative approach, we were able to access areas of the phenomenon that would have been inaccessible with quantitative methods (Koro-Ljungberg and Douglas 2008). Most psychological self-report studies on achievement emotions have employed quantitative methods (Postareff et al. 2017). In a review of the literature on emotions, Uitto, Jokikokko, and Estola (2015) found that, overall, the amount of research on emotions in the journal *Teaching and Teacher Education* had increased during the previous decade and that half of the 70 reviewed studies from 1985 to 2014 used qualitative approaches, often with self-report methods. Nevertheless, no studies had investigated the impacts of teachers on student emotions using qualitative methods (Uitto, Jokikokko, and Estola 2015).

Participants and study context

Twenty-six students from a Finnish technical university participated in this study in spring 2018. Their ages ranged from 19 to 48 years ($M = 23.8$, $SD = 6.066$; $Md = 21.5$). Most ($n = 16$, 61.5%) participants were male. In Finland, students are usually admitted to engineering programmes that include the right to study for both a bachelor's degree (180 ECTS) and a master's degree (120 ECTS), for which the estimated study duration is five years. The participants came from two courses. The first course was an engineering physics course that is mandatory for first-year students of all engineering programmes at the university and includes lectures, exercises, and laboratory work. In this course, the students ($n = 12$, 46.2%) were freshmen in information and knowledge management or industrial engineering and management majors. Their ages ranged from 19 to 25 years ($M = 23.8$, $SD = 1.712$; $Md = 21$). Half ($n = 6$, 50%) of them were male. The second course was an automation science and engineering course. In addition to weekly lectures and exercises, this course included one activating contact day. It is a bachelor's course that could be part of a student's major or minor studies. Thus, the participants from this course ($n = 14$, 53.8%) had more varied majors and represented all study years (first to fifth). Half of them came from electrical engineering, three from automation engineering, and the rest from other engineering majors. Their ages ranged from 20 to 48 years ($M = 26.0$, $SD = 7.555$; $Md = 23.5$). Most ($n = 10$, 71.4%) were male. The first course, engineering physics, lasted the entire spring semester. The second course, automation science and engineering, took place in the first half of the spring semester. The teaching methods in these two courses reflect quite well the regular teaching activities in the engineering field, as they include teacher-led lectures, laboratory work, and exercise or calculation sessions.

Procedure

This study was part of a larger research project investigating emotions in engineering higher education. Students were approached in the first lecture of each of the two courses. The first author introduced the study and asked students to participate in the first part of the data collection, which was related to the two courses (data not shown). After the data collection for the first part of the research, the participants were contacted via email and asked to participate in interviews to discuss their emotional experiences during their university studies. Overall, 26 of the 58 first-phase participants (44.8%) agreed to be interviewed. Thus, the sampling strategy used was criterion sampling, as all participants represented people who had experience in a phenomenon (Miles and Huberman 1994) – in this case, studying engineering at the institute in question. For this reason, it was possible to treat the participants from the two courses as a single sample. This was in line with our research aim, as our objective was not to generalise or compare student experiences but to better understand their overall emotional experiences in an engineering higher education setting. The sample was also based on convenience, as the students were already available to be contacted

and asked for an interview (Miles and Huberman 1994). The interviews were conducted at the end of the spring semester.

This study was conducted according to the guidelines of the European Research Council (2018). Permission for the research project was obtained from the higher education institution in question. All participants provided informed consent.

Instruments

Self-report research methods provide unique possibilities to approach emotions as subjective experiences, are easily applicable, and can provide rich data (Shuman and Scherer 2014). They are based on the premise that components of emotions can be mentally represented in the conscious mind and can be credibly reported by an individual (Pekrun and Bühner 2014). The data were collected using semi-structured interviews based on prepared questions discussed in a flexible order, which enabled the interviewer to encourage participants to elaborate on particular points and to cover the topics more discursively than when using structured approaches (Gibson and Brown 2009). The interviews, conducted in Finnish by the first author, lasted from 26 to 105 min, ranging mostly from 30 to 60 min. The interview themes were guided by Pekrun's (2006, 2017) control-value theory of achievement emotions but focused on students' overall experiences of attending engineering programmes. Four themes were explored. The first theme was related to study experiences (e.g. 'What are your experiences of the teaching and study methods during your studies?'). The second theme focused on study-related emotions (e.g. 'How would you describe the emotions that studying evokes in you?'). The third theme concerned aspects related to emotion regulation (e.g. 'What factors in the learning environment have made your learning experience pleasant/unpleasant?'). The fourth theme centred on teachers' emotions (e.g. 'Can you describe a situation in which a teacher's emotions impacted you in some way'?). The content of the themes and questions was planned by all authors to reflect the complex and multifaceted nature of learning in students' study paths and the role of emotions in them.

Analysis

The interviews were transcribed verbatim, and a qualitative thematic analysis was conducted, following the principles of Braun and Clarke (2006) and Braun et al. (2019). These principles emphasize a researcher's active role in the knowledge creation process, which aims to interpret the data by analyzing and reporting patterns instead of describing or summarising them (Braun et al. 2019). To search for semantic themes within the explicit meanings of the data, we concentrated on the participants' exact wording (Braun and Clarke 2006). The analysis was conducted abductively and aimed at constructing theoretical insights based on surprising empirical findings against a theoretical background (Timmermans and Tavory 2012). Abduction begins with the theory but is not engaged in the analysis, thus enabling data identification and new idea formation beyond the initial theory (Meyer and Lunnay 2013).

NVivo™ 11 software (QSR International, 2015) was used to perform the six phases of analysis (Braun and Clarke 2006; Braun et al. 2019). First, we read through the transcripts to familiarise ourselves with the data. Second, we formed initial codes related to students' descriptions of emotions, aiming to capture explicit meanings while remaining close to the participant's language (Braun et al. 2019) (e.g. 'It irritates me when a teacher is arrogant in a lecture'). This in vivo coding was based on the actual content of interview passages to help us respect the participants' voices (Saldaña 2013) and aimed to break down the data to reveal nuances. The same passage could be assigned more than one code (simultaneous coding) if it suggested multiple meanings relevant to our research question (Saldaña 2013).

Next, the initial codes were sorted into potentially overarching themes aimed at describing meaning-based patterns (e.g. 'Teacher's negativity increases negative emotions'). Theming the data included labelling the codes with extended thematic statements that identified what the data regarded or what they meant (Saldaña 2013). In the fourth and fifth phases, these candidate themes and their sub-themes were further reviewed and refined. Pattern coding was performed to identify similarities in the themes, and focused coding was performed to identify the most significant themes – for example, by creating diagrams of the themes (Saldaña 2013).

In the final phase, the themes (e.g. 'The classroom atmosphere influences emotions') and their sub-themes were written in the report, and their ability to tell the story of the data was assessed. Coding was conducted by the first author, and the identified themes were discussed with the second author at various stages of the analysis. This facilitated the articulation of the codes and provided insights about the analysis (Saldaña 2013). Specific intercoder agreement was not sought because it is not in line with the thematic analysis principle of highlighting the researcher's active, subjective role instead of objective themes that simply emerge from the data (Braun et al. 2019).

Researcher positionality

The researcher's positionality guides the entire research process, starting from the framing of the research topic to communicating the research process (Secules et al. 2021). Our positionality is shaped by our experiences, which is one of the most frequently reported positionality types in engineering education research (Hampton, Reeping, and Ozkan 2021). Our experiences as educational researchers with no engineering background, for example, guided us in choosing a qualitative approach with appropriate analysis methods. Second, our position, along with other obvious characteristics, such as the researcher's gender and age, may have affected what our participants chose to share in the interviews (Secules et al. 2021). By acknowledging this, we aimed to highlight our status outside the teaching context to promote an atmosphere of trust. On the other hand, the practicalities of higher education, as well as the principal features of engineering education, are familiar to us, which helped us establish rapport with the participants. Furthermore, the researchers' perspective determines whether they view something as ordinary or worthy of attention (Secules et al. 2021). We aimed to recognize our viewpoint on the phenomenon and to be open to the students' descriptions of their experiences. On the other hand, as outsiders, we did not have an insider's expectations or firsthand experience of what it is like to be an engineering student, which probably helped keep our expectations in check.

Limitations

Certain limitations exist when studying emotional experiences using self-report methods. The methods are based on the idea that emotional experiences can be represented in the conscious mind. However, some emotional episodes may not be consciously experienced and, thus, cannot be reported. In addition, it may be difficult to determine whether students described their actual appraisals of past events or post-event reappraisals or attributions (Schutz et al. 2006). Prior research has criticized examining emotions after the experience as revealing more about individuals' beliefs about their emotions than about their actual emotions (Goetz et al. 2014; Robinson and Clore 2002) and as being influenced by other biases, such as other experiences (Pekrun and Bühner 2014). However, in this study, we were not seeking to reveal students' actual emotional states during specific events; rather, we wanted to investigate students' perceived emotional experiences in their overall study paths. Therefore, the possibility that not all emotional experiences were reported was not problematic, as many of students' most meaningful experiences were likely conveyed.

In addition, students' reappraisals of those experiences are central in building the meanings they assign to them. To help students recall experiences from many occasions, the interview structure was designed to approach the phenomenon from different perspectives. However, it was up to participants what they wanted to report, for example, due to social desirability. We acknowledged this and focused on building a comfortable interview setting where participants received all necessary information on how their responses would be treated confidentially. Another limitation relates to the differences in how people, even from the same culture, understand the semantics of emotion. The semi-structured nature of the interviews enabled discursive discussions during which students could report their experiences using their own language and terms, instead of interpreting terms according to previously determined variables.

Results

The thematic analysis showed that students' descriptions can be categorised into two main themes. One of these themes is related to a teacher-created classroom atmosphere. The other is related to teaching procedures.

Teacher-created classroom atmosphere and student emotions

The results indicated that students perceive the classroom atmosphere that a teacher creates as an important factor influencing their emotions. First, students recognised that teachers' expressed interest and enthusiasm on the topic had an effect on their perceived positive emotions, especially their own enthusiasm and interest. Conversely, students considered that, if a teacher seems bored or not interested in the subject, emotions of boredom, irritation or anxiety are triggered.

> Maybe it is more pleasant to listen to a teacher who is motivated and enthusiastic. If a teacher is totally bored and not actually interested in teaching, then that bores everyone else in the class. (Student25, male)

Second, students described that positive emotions shown by teachers had enhanced students' positive emotions. In addition, students reported having felt negative emotions in situations where a teacher had been angry, frustrated or tired.

> It was especially unpleasant when it was the second lecture, and there were maybe half of the students present, and then the teacher complained to us about students not showing up. That felt somehow wrong because we had done nothing wrong and had shown up but still ended up receiving all the negativity about others not showing up. (Student21, female)

Third, encouragement and positive responses by a teacher had led to perceived positive emotions of success, when a negative attitude, arrogance and disparagement by a teacher had caused emotions, such as irritation or shame.

> A teacher plays a big role. Even if the material is bad or the topic is difficult, if the teacher knows how to teach and is encouraging, it makes you want to attend and think about those difficult subjects. And if you get the answer wrong, then [a good] teacher does not make you feel bad, but instead says 'apparently this topic is difficult, maybe we should spend more time on this.' (Student2, female)

Teaching procedures and student emotions

Students described that teaching procedures had influenced their emotions. These descriptions were related to course arrangements, lectures, public performance and active learning tasks. First, the results showed that perceived inconsistencies regarding course arrangements, such as schedules, assessment, communication, and workload, increase students' perceived negative emotions. For example, negative emotions had arisen when the workload was experienced as too heavy compared with the value of the study credits. In addition, students reported feeling frustration and anger

when they had missed a lesson and had to make up for the work missed by completing tasks they felt were unfair.

> There was so much work involved compared to the study credits one gets from the course. Maybe that sort of added to the frustration. (Student25, male)

> And then I noticed that, in some instances, when you had to do a make-up assignment due to missing a lecture, there was no correlation to what others did in the lecture. I had to write a four page essay on the topic that I later heard the people in the lecture had discussed in small groups for five minutes and written down a few notes on. That felt a bit pointless. (Student17, male)

Second, the results illustrated that lecturing increased students' negative emotions. Emotions such as boredom were linked to teachers' monotonous lecturing, including not providing examples or demonstrations; a fast-paced or unclear lecture or writing too quickly on the blackboard also caused negatively experienced emotions.

> And then, if it is a really theoretical lecture that you don't really get a hold on because you would need to see a concrete example that is not provided in the slides or lecturing, then you get bored because you don't immediately see where you could apply it . . . and when a teacher just goes on and on with lecturing this very theoretical topic with no examples, then you mostly start thinking when am I going to get out of here and could I get some coffee and can I play with my mobile. Well, I play with my mobile, because I am most definitely not going to be able to concentrate on this. (Student2, female)

Third, students reported that performing in front of others also prompted emotions, such as nervousness when presenting their work to the public and shame when they answered a question incorrectly or made mistakes when displaying their answers on a blackboard. Performance situations were also cited as sources of anxiety, especially if a student was selected, rather than volunteering, to go in front of the class. On the other hand, nervousness during these situations had also decreased for some students as they got more practise in performing in front of the others during studies.

> And then there are the exercise sessions where you need to go and present your own results on a blackboard or something like that. Those have led to most anxiety, even if I had known for sure that I got it right. They have been the most distressing situations in studies. (Student14, male)

Fourth, students described having experienced a variety of emotions related to activating assignments that require active processing of the learning material and production of an end product (e.g. solving calculations, project work, collaborative work), which are from now on referred to as active learning tasks. Students connected positive emotions to three aspects of these tasks: actively working with a topic and seeing the result (enjoyment, pride), finalizing and returning a task (relief, relaxation, contentment, enjoyment), and succeeding in a task (joy, happiness, pride, enjoyment, enthusiasm).

> When we were at the laboratory and saw that the machine really worked, that the code we had made directed that machine in the right way, that made me feel really good. I was proud; it was great when it worked like it was supposed to. (Student14, male)

When faced with obstacles during active learning tasks, students experienced negative emotions, mostly frustration, anxiety, irritation, or disappointment. Students also mentioned feeling frustrated or irritated when they felt they did not receive adequate instructions or assistance to perform the task and experienced shame if they were embarrassed to ask for help.

> Sometimes, for example, in programming tasks when you don't get it right, even in the last possible return of the task and you just can't come up with what could be the problem and cannot interpret the feedback that the program is giving you, then that's when I'm just about to have a melt-down. (Student26, male)

> And then that last project was insanely difficult. Nobody was able to do it, not even the student assistants, and that was really frustrating because why would they give us so difficult tasks that they even themselves cannot solve? And then, yeah, that was frustrating and it made me a bit angry. (Student18, male)

Nevertheless, students conveyed that positive emotional experiences, such as enthusiasm and pride, were especially strong when they successfully completed active learning tasks after performing long, difficult work and overcoming obstacles. Emotions such as relief, contentment, and joy were also involved when students had first assessed the task as difficult but still succeeded. Thus, students' emotional experiences with active learning tasks can be considered something of an 'emotional roller coaster'.

> Well, I have felt enjoyment and pride at least when I have been able to finish a difficult task and if I get good feedback from it. And then, if I have been stuck in a task and then finally get it solved, that leads to enjoyment as well. When you face problems but then can solve them, that's when those kinds of emotions are enhanced. (Student4, male)

Participants expressed that positive emotions during collaborative active learning tasks were related to working with others to accomplish difficult tasks and sharing responsibility for the outcome. Students had also experienced situations where negative emotions had been either lessened or intensified depending on whether they had peers to share those emotions with or not.

> And then the practice classes are nicer because you get to figure a task together with a group and also take a shared responsibility on a solution that you are presenting to others. I think that's what makes it more pleasant. (Student24, female)

> But then on the other hand, it was fun because it included a lot of group work, and that's why there was a kind of shared rage that helped us push it all through. That was kind of fun to experience, as well. (Student21, female)

Emotional experiences linked to peer collaboration included nervousness about working with strangers, shame when needing to be supported by others, and irritation and anxiety when group members did not complete their parts of the assignment, were passive at meetings, or did not attend meetings. Negative emotions also arose when a mismatch of ideas with peers occurred, when others had difficulty completing the task, or when a group member acted like a boss.

> When we have been working on a group project, and someone shows that they couldn't care less and do not take care of their job, that hinders my motivation and makes me irritated. And then there are surprisingly many of those . . . who are first promoting that now we agree on a meeting and get this started, acting like a boss . . . but then are themselves the last ones who take care of their part. That kind of unnecessary, I don't know what that is, kind of a need to show to others but then taking care of their duties the last. Wanting to be all bossy, that makes me, I don't like it. It makes me irritated and feel negative about the whole task we are working with. (Student23, female)

Discussion

In this research, we studied engineering students' descriptions of their perceptions of emotions evoked by teaching. We used a qualitative data collection method (semi-structured interviews) and thematic analysis to approach this complex phenomenon. Our analysis focused on students' descriptions of emotional valence associated with their experiences of teaching. The results are summarised in Table 1. The emotions can be mostly characterised as achievement emotions related to learning, instruction, and achievement, but the descriptions also included other types of emotions, such as social emotions related to teachers and other students (Pekrun 2017). Overall, the results indicate that engineering students' experiences of their learning environments are important for the arousal of emotions (Lazarus 2006; Schutz et al. 2006) and that teaching triggers emotional responses from students (Frenzel et al. 2009).

The findings suggest that two teacher-related features require engineering educators' attention. First, the efforts that teachers put into a classroom atmosphere appear to be important to students, as previous studies have also shown (e.g. Cornelius-White 2007; Meyer and Turner 2006; Roorda et al. 2011; Youmans 2020). For example, the results indicate that a teacher who expresses interest and enthusiasm can increase students' positive emotions, interest, and enthusiasm. These results support previous research that has linked teachers' expressed enthusiasm

Table 1 Students' perceptions of the effects of a teacher-created classroom atmosphere and teaching procedures on their emotions.

Main theme	Subtheme(s)		Perceived emotions
Perceived classroom atmosphere created by a teacher as a trigger of students' perceived emotions	A positive atmosphere created by the teacher enhances positive emotions	A teacher's interest and enthusiasm enhance positive emotions	(+) e.g., enthusiasm, interest
		A teacher's expressed positive emotions enhance positive emotions	(+)
		A teacher's encouragement and positive responses enhance positive emotions	(+) e.g., emotions related to success
		A bored or disinterested teacher increases negative emotions	(−) e.g., boredom, irritation, anxiety
	A negative atmosphere created by a teacher triggers negative emotions	A teacher's expressed negative emotions increase negative emotions	(−)
		A teacher's negative attitude increases negative emotions	(−) e.g., irritation, shame
Perceived teaching procedures as triggers of students' perceived emotions	Perceived inconsistencies in course arrangements trigger negative emotions		(−) e.g., frustration, anger
	Monotonous lecturing triggers negative emotions		(−) e.g., boredom
	Public performances in class trigger negative emotions		(−) e.g., nervousness, shame, anxiety
		Active learning enhances positive emotions	(+) e.g., enjoyment, joy, happiness, enthusiasm, pride, relief, relaxation, contentment
		Facing obstacles and not getting help during active learning increases negative emotions	(−) e.g., frustration, anxiety, irritation, disappointment, shame
	Active learning tasks trigger perceived emotions	Collaborating in active learning tasks enhances positive emotions	(+)
		Problems in collaboration during active learning increase negative emotions	(−) e.g., nervousness, shame, irritation, anxiety

Note. + = positive emotion, − = negative emotion.

to students' positive emotions (Frenzel et al. 2009) and interest (Keller et al. 2014; Quinlan 2019). The perceived valence of teacher emotions as negative or positive also affects students' own perceived emotions in the same direction, as also indicated by previous research (Becker et al. 2014). Overall, a positive and encouraging emotional atmosphere can positively impact students' emotions and learning through the motivational quality of the learning situation (Pekrun and Perry 2014) and satisfy students' need for relatedness to the teacher (Ryan and Deci 2017). These results provide insights into when it is beneficial for a teacher to express their emotions and when it is not (Quinlan 2016).

When the results regarding the teacher-created atmosphere are seen through the prism of the three-dimensional model of student – teacher relationships in higher education (Tormey 2021), the dimension of warmth is particularly prominent. Students' descriptions of a pleasant atmosphere reflect perceptions of warmth that teachers show in the form of positive emotions, encouragement, or other positive responses. Admiration or even awe can also be present, mostly when students are influenced by the teacher's interest in and enthusiasm about a topic. Feelings of trust or safety can be harmed in situations in which teachers are negative toward students.

Second, teaching procedures appear to be important triggers of students' emotions. For example, monotonous lecturing triggers students' negative emotions, especially boredom. This is in line with Bellocchi et al. (2014), who found that teacher monologues undermine the emotional climate in the classroom. However, Bellocchi et al. also found that despite a negative climate, students can also experience teaching as high-quality if it is meaningful to them. In this study, it is difficult to ascertain whether students' reported boredom related to monotonous lectures was also experienced negatively or whether it is part of a common discourse related to lectures that is shaped more by stereotypes than by individual experiences. However, more versatile and less monotonous lecturing methods can increase students' interest and enthusiasm and improve the motivational quality of studying (see Pekrun and Perry 2014).

Furthermore, our findings show that active learning is associated with multiple emotions and different valences. Active learning tasks can make it possible to see the results of concrete work and experience success (positive emotions due to motivational quality); however, they can be perceived as too demanding if deemed too difficult (negative emotions due to cognitive quality) and can cause a mismatch between competences, the need for autonomy, and the amount of autonomy if help is not available at appropriate times (negative emotions due to problems in autonomy support) (Pekrun and Perry 2014). Interestingly, our results indicate that facing obstacles during active learning tasks is not entirely detrimental to positive emotions. An 'emotional roller coaster' complete with obstacles and negative emotions can make the overall process more rewarding and the positive emotions related to completing a task even stronger – but only if the obstacles and negative emotions are overcome and the outcome is successful. Thus, autonomy, which is related to active learning, can enhance students' positive emotions during learning processes (Black and Deci 2000) but does not seem to be sufficient if timely support is not available. Collaboration with peer students during active learning appears to enhance positive experiences, which can be related to perceived relatedness (Deci and Ryan 2000). However, problems with collaboration are related to negative emotions, as also recognised by Pekrun (2006).

The results related to teaching procedures also highlight important aspects of social – emotional relationships (Tormey 2021). For example, descriptions of monotonous lecturing imply negative emotions but do not indicate whether admiration or awe is still present or whether the students experience safety or even warmth on the part of the teacher. Negative perceptions of inconsistencies in course arrangements and public performances, especially when involuntary, can reduce feelings of trust or safety toward a teacher, harming the student – teacher relationship. Moreover, negative experiences related to active learning tasks are strongly related to a perceived lack of support from a teacher. This can be a sign of a lack of trust and safety experienced by students in these situations, in which they may feel that they are being left alone with the task.

To conclude, our analysis shows that engineering students' descriptions of teaching as a trigger of emotions are closely associated with their relationships with teachers. Interestingly, students' descriptions of teaching procedures, which may easily focus on methods or techniques, also show that many of their emotional experiences reflect – at least to some extent – their social – emotional relationships with teachers (e.g. teachers being available to help during active learning tasks). Thus, promoting warmth, trust, and admiration in the classroom can also positively impact students' perceptions of other aspects, such as teaching methods, and can enhance students' overall learning experiences (Tormey 2021).

The students' descriptions of the student – teacher relationships seem to highlight the role of a teacher as an actor, and students as spectators or objects who are influenced by a performing teacher's actions. This was, naturally, guided by our research question that focused on how students perceive their emotions being evoked by teaching. Some aspects of two-sided relationships were described: teachers' reactions to students' efforts and answers were important sources for emotions and could either encourage or discourage students. The impacts of students to emotional classroom atmospheres, however, could be further investigated.

Student descriptions reflect emotions as by-products of the teaching and learning processes, thus reinforcing the common emphasis on knowledge and rationality in engineering education (Kellam et al. 2018). The results call for the consideration of other socio-cultural aspects, as well (see Bellocchi and Turner 2019). For example, the student emotions described were often high in arousal (e.g. enthusiasm, anger, anxiety), which is more often promoted, valued, and experienced by Westerners (Lim 2016). Therefore, the descriptions and values could be different in other cultures. In addition, engineering is a male-dominant field (Sagebiel and Dahmen 2006), and that may also reflect how emotions are valued, experienced, and discussed by male and female students.

Overall, the results suggest that emotions are highly present in engineering education, and that they are triggered through diverse and complex processes (Kellam et al. 2018). Therefore, their role cannot be ignored. The shift in the educational paradigm in engineering education towards active learning (Lima, Andersson, and Saalman 2017; Streveler and Menekse 2017) presents one justification for this. Emotions related to active learning seem to be especially complex and depend on the outcome of the study process. Similarly, previous research views emotions as important in, for example, creativity (Chemi, Grams Davy, and Lund 2017), solving complex problems (Lönngren et al. 2020a), and collaboration (Davis and Bellocchi 2018; Järvenoja and Järvelä 2009), which are important aspects in both active learning and the engineering profession.

Practical implications

This study suggests that teachers should acknowledge certain teaching-related aspects that can enhance engineering students' emotional experiences. The crucial step is to recognise the extent to which paying attention to the social relationships in the classroom can impact students' emotions. First, teachers' interest, enthusiasm, positive emotions, and encouragement affect students' perceived positive emotions. Besides aspects related to teachers' expressions, undermining warmth, safety, and trust in teaching procedures (e.g. course arrangements, lecturing, and active learning tasks) may negatively affect students' perceptions of those procedures. It is therefore important to create consistent course arrangements, consider the negative emotions related to public performances, and make lectures more versatile and interesting for students. Active learning tasks are an effective way to increase students' positive emotions, as they can offer students autonomy and experiences of success, among others. However, it is important not to leave the students alone with the tasks. Our findings suggest that it is crucial to ensure that students feel that help is available. Moreover, as collaboration is a vital part of an engineer's work, recognising the multivalence emotional aspects of collaboration is also important in engineering education.

Future research

Our findings indicate that students' emotions are closely related to their teachers' emotions. Therefore, more research is needed on teachers' emotion regulation to deepen our understanding of affective relationships that are created during learning processes. In addition, the findings call for more research on the student – teacher relationships in engineering classrooms. It would be especially important to focus on how both teachers and students contribute to these relationships and emotional classroom atmospheres, as well as to consider socio-cultural aspects, such as gender and culture, more carefully. Future research should also more thoroughly explore the effects of teaching methods on student emotions and the effects of these teaching-related emotions on student learning from quantitative, qualitative, and mixed-methods perspectives. Moreover, the study of active learning environments is of great importance because they seem to evoke mixed emotions in students. In addition to students' and teachers' perceived emotions, physiological

measurements during emotional experiences can provide important insights into the emotional processes in the classroom, especially during active learning.

Conclusions

The main conclusion of this study is that although students do not associate all their teaching-related emotions with student – teacher relationships, these relationships are strongly reflected in their descriptions. Therefore, the results suggest that besides appropriate decisions related to teaching methods and practicalities, teachers in engineering education should pay attention to fostering relationships based on warmth, trust, and admiration in the classroom (Tormey 2021).

Teachers play a key role in creating a classroom atmosphere, which seems to be recognised by students. When students describe the perceived teacher input as positive (expressions of interest, enthusiasm, positive emotions, and encouragement and positive responses), they experience positive emotions themselves. Similarly, perceiving teachers' actions as negative (expressions of boredom, negative emotions, and negative behaviour) is associated with perceptions of negative emotions.

Perceptions of inconsistencies in course arrangements, a monotonous lecturing style, and public performances in class are examples of teaching procedures associated with students' negative emotional experiences. Active learning tasks, on the other hand, can evoke both positive and negative emotions. They can support positive emotions through active work and offer the possibility to see concrete results and experience success and collaborative work with peers. Negative emotions are related to problems in collaboration but mostly to obstacles that students might face during tasks, especially when they feel that there is no help available.

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Ethics declarations

This study was conducted according to the guidelines of the European Research Council (2018). Permission for the research project was obtained from the higher education institution in question. The participants were provided with all the relevant information about the goals of the study, anonymity of participants, data collection, data storing and analysis. The participants had the right to withdraw from the study at any point. The participants signed a voluntary consent to participate in the study. The guidelines for an ethical review in human sciences in Finland are defined by the Finnish National

Board of Research Integrity. According to their principles, the researchers of non-medical research involving human participants must request an ethical review statement from a human sciences ethics committee if the study contains any of the following:

(1) participation in the research deviates from the principle of informed consent,
(2) the research involves intervening in the physical integrity of research participants,
(3) the focus of the research is on minors under the age of 15, without separate consent from a parent or carer or without informing a parent or carer in a way that would enable them to prevent the child's participation in the research,
(4) research that exposes participants to exceptionally strong stimuli,
(5) research that involves a risk of causing mental harm that exceeds the limits of normal daily life to the research participants or their family members or others closest to them or
(6) conducting the research could involve a threat to the safety of participants or researchers or their family members or others closest to them.

This research does not meet these requirements and, thus, no ethical review statement was required.

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