Emotions in Engineering Education

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1 Introduction

Engineers and engineering students often identify their work as rational, beyond emotion, and engineering is often characterized as purely scientific, involving technical solutions to real–world problems (Cech, 2018; Lönngren, Adawi, et al., 2021; Polmear et al., 2018). However, engineering education and practice are embedded in contexts with complex social relationships, power structures, and conflicting value systems (Cech, 2018). Dealing with engineering problems in these contexts requires knowledge and competencies to collaboratively explore diverse perspectives on a problem and develop socially, ecologically, and economically sustainable technological solutions (Holmén, 2020; Lönngren et al., 2016; Van den Beemt et al., 2020). Engineering education researchers have, for example, demonstrated how emotions matter in engineering ethics and sustainability, social justice work, technological risk management, problem–solving, student development, retention, as well as diversity and inclusion (Hess et al., 2020; Kellam et al., 2018; Lönngren, Adawi, et al., 2021; Roeser, 2012a). These findings are also in line with research in science education (Davidson et al., 2020; Sinatra et al., 2014), sustainability education (Ojala, in print), and many other educational contexts (Pekrun & Linnenbrink–Garcia, 2014a; Zembylas & Schutz, 2016).

Dealing with engineering and sustainability problems requires, for example, critical emotional awareness (Ojala, in print), empathy (Bairaktarova & Plumlee, 2022; Hess & Fila, 2016), emotional intelligence (Lappalainen, 2015), emotional engagement (Gelles et al., 2020), and an ability to navigate conflicting emotion norms (Lönngren, Adawi, et al., 2021). In the engineering education literature, *empathy* has been described as necessary for (a) enabling engineers to design artifacts and processes that meet user's needs, (b) working with communities and clients whose background is different to their own, (c) communicating effectively with colleagues and clients, (d) building teams and resolving conflicts, and (e) responding appropriately to the ethical dilemmas that engineers face (Hess & Fila, 2016). A range of specific emotions (including joy, frustration, pride, shame, and guilt) has also been identified as important in the work and learning of engineers (e.g., Bates & Wilson, 2008; Huff et al., 2021; Warner, 2006).

Emotions are also important for engineering educators and other academic staff. For example, educators are expected to manage their own emotions (Adams & Turns, 2020; Decuir–Gunby et al., 2009; Lawless, 2018), understand and deal with students' emotions (Husman et al., 2015), engage students in critical emotional praxis (Chubbuck & Zembylas, 2008), cultivate a constructive

emotional climate (Bates & Wilson, 2008; Giannakos et al., 2014), and build positive, emotional, and caring relationships in the classroom (Nair & Bulleit, 2020; Quinlan, 2016; Tormey, 2021).

Clearly, to reform engineering education for the 21st century – and equip students with the knowledge, competencies, and confidence to contribute to solving future sustainability challenges – it is vital for engineering education research to engage with emotions in teaching and learning.

1.1 Purpose and Outline

This chapter introduces the complex and multidisciplinary field of research on emotions in engineering education (EEE), which draws on psychological, sociological, and philosophical perspectives and employs a wide range of research methods. Thus, we hope to support researchers new to EEE in navigating and contributing to this nascent field of research.

The chapter starts with a discussion of how emotions are defined in different disciplinary contexts and how emotions, components of emotion, and emotion-related phenomena can be measured. We then provide an overview of theoretical perspectives that are commonly applied in the multidisciplinary emotion research literature. Equipped with a broad understanding of what emotion research can entail, we turn our attention to engineering education and the nascent field of EEE. We summarize four dominant themes in the existing literature, which were identified in a recent scoping review (Lönngren, Bellocchi, et al., 2021): (1) academic emotions, (2) emotions and ethics, (3) emotional intelligence and other socio-emotional competencies, and (4) mental health. Based on existing research and our own experiences of conducting EEE research, we then provide advice for researchers and doctoral students who plan to pursue EEE research. Finally, we outline currently underdeveloped research areas, arguing that more EEE research is needed that employs sociological perspectives, mixed- and multi-methods approaches that do not (solely) rely on self-report measures, studies focused on cultural and gender differences in how emotions are experienced and expressed in engineering education, mental health, as well as engineering educators' and other staff members' emotions and emotion practices.

2 Challenges in Defining Emotion

For centuries, philosophers, physicians, psychologists, and more recently, neuroscientists have studied the relationship between emotion and reason (Lazarus, 1999). From Cartesian philosophical perspectives of the relationship between mind and body to current discussions of whether human emotion is a cognitive or noncognitive phenomenon (England, 2019), the study of human emotion is entangled with disciplinary, ideological, cultural, and political ideas about what it means to be human and how we should live our lives. Moreover, historians of emotion have shown that the study of emotion is influenced by constantly evolving sociocultural and disciplinary trends (Frevert, 2014). Even within the same research discipline, such as psychology, consensus is difficult to reach (Kleinginna & Kleinginna, 1981), and a wide range of definitions and conceptualizations is today used in emotion research (Bellocchi, 2019). Most emotion researchers, however, "generally agree that emotions are episodes with multiple components that are shaped by evolutionary and social contexts and can be expressed in a variety of ways" (Shuman & Scherer, 2014, p. 19).

This general agreement on defining emotion as *episodical* (relatively short-lived) and *componential* (consisting of multiple factors, processes, or components) is mirrored in Kleinginna and Kleinginna's (1981) attempt to provide a consensual yet theoretically flexible definition of emotion, which was based on an analysis and compilation of 92 different definitions available at that time:

> Emotion is a complex set of interactions among subjective and objective factors, mediated by neural/hormonal systems, which can (a) give rise to affective experiences such as feelings of

arousal, pleasure/displeasure; (b) generate cognitive processes such as emotionally relevant perceptual effects, appraisals, labeling processes; (c) activate widespread physiological adjustments to the arousing conditions; and (d) lead to behavior that is often, but not always, expressive, goal-directed, and adaptive.

(p. 355)

Today, Scherer's (2005) component model of emotion is widely cited in emotion research. In this model, Scherer described emotion in terms of five components: (1) motor expression, such as gestures and facial expressions; (2) neurophysiology, including arousal and biomarkers; (3) subjective feeling; (4) motivation; and (5) cognition. Further, *emotion* was defined as "an episode of interrelated, synchronized changes in the states of all or most of the five organismic subsystems in response to the evaluation of an external or internal stimulus event as relevant to major concerns of the organism" (Scherer, 2005, p. 697). Another component model was proposed by Thoits (1990), who described *emotions* as subjective experiences resulting from the interrelation of four components: (1) situational cues, (2) physiological changes, (3) expressive gestures, and (4) words referring to emotions.

Irrespective of which definition is employed, emotion is often distinguished from related phenomena, such as affect, mood, and feeling. While precise definitions of these terms vary between disciplines and individual studies, most researchers agree on a few basic tenets. For example, *affect* is often used as a broad construct encompassing emotions, feelings, moods, sentiments, as well as non-emotional constructs, such as motivation, interest, and attitudes (Shuman & Scherer, 2014). According to Zembylas (2021), *affect* "encompasses a variety of sensorial processes, experiences, and relations and refers generally to the body's capacities to act, to engage, to resist, and to connect; the term 'emotion' is often used to signal social and cultural constructs and conscious processes" (p. 770). *Feeling* is, at least in component models, typically defined as corresponding to the conscious and subjective experience component of emotion (Shuman & Scherer, 2014). Finally, *mood* is understood as more diffuse and longer-lasting than emotion. Also, while emotions are generally considered to be "about something" (e.g., being angry at something another person has done), moods may not have such an object, and they can, for example, be caused by hormonal changes alone (Fridja, 2008; Shuman & Scherer, 2014). We do not propose that engineering education researchers should agree on consensus definitions for each of these concepts – which would unnecessarily limit the scope of research questions that can be addressed. However, as for any other topics researched in engineering education, it is important to clearly define emotions and any related terms that are used in a study. For a detailed discussion of challenges in defining emotions in education research, we refer readers to Shuman and Scherer's (2014) overview in the International Handbook of Emotions in Education (Pekrun & Linnenbrink-Garcia, 2014a).

In an ongoing systematic review of EEE research, Lönngren et al. (Lönngren, Bellocchi, et al., 2021; Lönngren et al., forthcoming) found that many engineering education researchers do not define what they mean by *emotion* and sometimes even use the term interchangeably with related – but distinct – concepts, such as *affect* and *feeling*. This lack of conceptual clarity in the field is problematic, especially given the interdisciplinary nature of engineering education research, where researchers draw on a wide range of disciplines (e.g., education, sociology, psychology, philosophy, management, etc.). Different disciplines tend to employ different types of emotion theories, which influences what emotion phenomena can be studied and how results can be interpreted and transferred between empirical contexts. Thus, in an interdisciplinary field such as engineering education, researchers can be expected to draw on a range of conceptualizations of emotions and other affective phenomena. These conceptualizations need to be made explicit to allow readers to adequately interpret and judge research findings (Turner, 2009).

3 Theorizing Emotions

Most educational emotion research has so far been informed by psychological, sociological, and critical theories (Chubbuck & Zembylas, 2008). Existing EEE research has almost exclusively relied on psychological theories, while sociological and critical perspectives have not yet been widely used (Lönngren et al., forthcoming). In this section, we describe both types of theories, aiming to support readers in making informed decisions regarding which types of theories to use in which types of EEE studies.

3.1 Psychological Theories – Linking Emotion and Cognition

From psychological perspectives, emotions are conceptualized as complex, intrapersonal phenomena that result in physiological, neurological, and cognitive changes in individuals. These perspectives are commonly used to explore (a) the function of emotion in mediating a person's response to their environment and (b) the ways in which emotion and cognition interact in this process.

In education research, emotions are often understood as mediating how students and educators respond to events related to teaching and learning (Shuman & Scherer, 2014). For example, a student who performs less well than expected on an exam may experience physiological changes (e.g., adrenaline, heart rate, blood flow) which are part of an experience of anxiety or anger and which may lead to reactions to the situation (e.g., argue with the instructor or decide not to invest energy in the course; Zeidner, 2014). Emotion researchers in this tradition highlight the role of *appraisal*, that is, the processes through which individuals evaluate whether a phenomenon or situation is in line with their own values and goals (Moors et al., 2013).

Appraisal is theorized to occur through two processes. First, *primary appraisal* is described as rapid, automatic, and unconscious. It does not generate emotions *per se* but locates the person on a valence dimension (ranging from displeasure to pleasure) and an activation dimension (ranging from low- to high-energy responses) (Murphy & Zajonc, 1993; Russell, 2003; Zajonc, 1980). Thus, primary appraisal regulates readiness (Fridja, 1986, 2007) to respond to a given situation. *Secondary appraisal* involves cognitive evaluation of a situation, resulting in more nuanced placement on the valence and energy dimensions – allowing the person to experience distinct emotions, such as boredom, fear, anger, or awe (Oatley et al., 2006).

3.1.1 Emotion-Related Phenomena Based on Psychological Theories

In education research (including EEE), cognitive appraisal theory underlies, for example, the widely used framework of *academic emotions* (Pekrun & Linnenbrink-Garcia, 2012, 2014b), describing four groups of emotions. First, *achievement emotions* are associated with appraisal of one's own academic performance, for example anxiety, pride, or shame regarding exam results. Second, *epistemic emotions* are linked to appraisal of cognitive processes involved in the development of new knowledge. For example, students who encounter facts or ideas that are not readily integrated into their existing mental models may experience curiosity, anxiety, or frustration as they try to make sense of the new information. Third, *topic emotions* involve appraisal of the topic or subject matter that is studied. Examples include climate anxiety (anxiety and distress about the implication of climate change) and love of mathematics. Finally, *social emotions* are linked to appraisal of social relationships in educational settings. They may include appraisal related to others' achievement (e.g., awe, envy, admiration), psychological safety (e.g., trust, confidence, anxiety), or affection (e.g., love, joy, loneliness).

Indeed, some of these emotions are not simply related to academic settings but can be related to other types of performance, including aspects of performing the roles of an engineer. Engineers

may experience pride and shame related to achievements, envy, and anger related to working in social teams, and curiosity and frustration related to problem-solving (Davis, 2017). Thus, these appraisals are relevant both to the *engineering* and the *education* dimensions of the domain in question.

In Western cultures and philosophy, the predominant traditions of thought have generally conceptualized emotional appraisals as a source of bias and a negative force in human judgment: "more primitive, less intelligent, more bestial, less dependable, and more dangerous than reason" (Solomon, 2008, p. 3). By the 1990s, however, this has begun to change as emotion was increasingly seen as important and potentially valuable both in contributing to reason and judgement (e.g., Damasio, 1994) and to social life (e.g., Hoffman, 2000).

One way of conceptualizing how emotion links to reason and judgment was the idea of *emotional intelligence*, which sought to articulate a model of how emotion and cognition were linked and how these links could be regulated. This idea became particularly influential at this time and widely popularized through the work of Goleman (1995, 2013, 1998), especially in management and leadership disciplines. The original emotional intelligence model, as articulated by Mayer et al. (2000), conceptualized emotional intelligence as involving the ability to (a) perceive and express emotions, (b) understand emotions and emotional change processes, (c) use emotions to facilitate particular types of cognition (e.g., using positive emotions to facilitate creative thinking), and (d) regulate emotions in oneself and others. In this model, *emotional intelligence* is defined as "the subset of social intelligence that involves the ability to monitor one's own and others' feelings and emotions, to discriminate among them and to use this information to guide one's thinking and actions" (Salovey & Mayer, 1990, p. 189). While Mayer and Salovey (1993) conceived emotional intelligence as an innate set of *cognitive* abilities (i.e., not really an emotional phenomenon), other researchers (e.g., Bar-On, Goleman, and Petrides) developed models which saw emotional intelligence as being closer to a personality trait (Corcoran & Tormey, 2012). Petrides et al. (2004) define *trait emotional intelligence* as "a constellation of emotion-related dispositions and self-perceived abilities" (p. 575), which could also be described as *trait emotional self-efficacy* – it concerns peoples' beliefs about their own emotions (Petrides & Mavroveli, 2018).

Another approach to linking emotion to reason and judgment is found in research on moral reasoning, where emotion is described as providing an initial ethical appraisal of a situation that can contribute to ethical or moral action. In psychology, this perspective is associated with the social intuitionist perspective of Haidt (2001, 2003), and in philosophy, it is associated with the work of Nussbaum (2001, 2004) and Roeser (2012a). In engineering, for example, Roeser (2012a) argues that emotions improve judgment since

> we need moral emotions in order to be aware of moral aspects of risky technologies. . . . Purely rational reflection would not be able to provide us with the imaginary power that we need to envisage future scenarios and to take part in other people's perspectives and to evaluate their destinies.
>
> *(p. 106)*

3.2 Sociological and Critical Theories – Linking Emotion and Social Contexts

Sociological and critical theories conceptualize emotions not as uniquely biological or psychological but as primarily social phenomena. These theories can be used to study (1) "the social nature of emotions" (Bericat, 2016, p. 495), treating emotions as social constructions, and (2) "the emotional nature of social reality" (*ibid*.), treating emotions as contributing to the construction of social reality. Studying the *social nature of emotions*, sociologists and social psychologists have, for example, used

discourse analytic approaches to explore how emotions emerge in interaction in and across diverse cultural, temporal, spatial, and relational contexts. They have also explored how linguistic descriptions and bodily expressions of emotions are used in interaction to negotiate social realities and relationships (Edwards, 1999; Pepin, 2008; Wetherell, 2013). From this perspective, emotions are understood as complex "intersections of language, desire, power, bodies, social structures, subjectivity, materiality and trauma" (Zembylas, 2016, p. 546). Studying the *emotional nature of social reality*, feminist and critical scholars have explored how social structures – such as cultural ideologies, beliefs, and social norms – constrain and construct interpretations, expressions, and arousal of emotion (Stets & Turner, 2008; J. H. Turner & Stets, 2005). They have explored, for example, how emotions are constructed as separated from reason and rationality (Ritzer, 2011) and how conceptualizations of emotion may reproduce – and resist – power structures and social inequalities (Ahmed, 2014; Boler, 1999; Zembylas, 2007b).

3.2.2 Emotion-Related Phenomena Based on Sociological and Critical Theories

In sociological research on emotions in education, Bourdieu's work has been highly influential. Most importantly, his work on habitus has been leveraged to challenge pervading dualism between concepts such as mind/body, objective/subjective, and emotion/cognition (Bourdieu, 1990; Cottingham, 2016; Zembylas, 2007a). Another influential idea based on the work of Bourdieu is the notion of *emotional capital*, which Cottingham (2016) defined as "one's trans-situational, emotion-based knowledge, emotion management skills, and feeling capacities, which are both socially emergent and critical to the maintenance of power" (p. 454). While emotional capital is similar to emotional intelligence in that it involves identifying emotion as a resource, it locates this resource not within individuals but in macro-social structures, unequally distributed and linked to social power. In education research, this notion "offers a tool for thinking about ways in which emotion practices are regulated within an educational context" (Zembylas, 2007a), for example, in discourses about the importance of fostering emotional intelligence and regulation in individual students.

Research on emotional capital has also been linked to Hochschild's (1979, 1983) work on feeling rules and emotional labor. *Feeling rules* are social norms regarding who is expected to feel which emotions, how to feel them, and in which situations (Hochschild, 1979). *Emotional labor* is the effort professionals perform when they express emotions that are socially expected but not aligned with their inner feelings, or when they try to correct inner feelings to align with social norms and expectations (Hochschild, 1983). Emotional labor has been shown to be pervasive in educational settings since teachers often suppress negative emotions to "convey support, encouragement, and a safe place for their students" and "sustain an outward appearance that produces a particular state of mind in their students" (Fraser & Brandt, 2013, p. 146). Educational researchers have, for example, explored teachers' emotional labor in higher education (Lawless, 2018), science education (Zembylas, 2004), social justice education (Rivera Maulucci, 2013), and many other contexts and disciplines.

Emotions in education have also been explored from feminist and critical perspectives. Many educational researchers in this field have drawn on Boler's (1999) work on emotions and power in education, exploring "how emotions are an invisible presence in education, and how emotions are disciplined to maintain social control" (p. 22), thus upholding gendered and racialized power structures. Ahmed's (2014) work on *emotional politics* and *affective economies* has also been highly influential in research on emotions in education. Ahmed theorized emotions as cultural practices that bind communities together while simultaneously positioning others on the outside; emotions are "produced, circulated and capitalised on to achieve political purposes such as unity or conflict" (Zembylas, 2007a, p. 458). Ahmed's theories have, for example, been used to explore how "emotions are strategically and politically used to frame [educational] policies" (Lindgren & Rönnberg,

2018, p. 57). Other researchers have explored the political effects of specific emotions in education, for example, how disgust can contribute to racial discrimination (Matias & Zembylas, 2014) and how shame can contribute to constructing affective connections in intercultural education (Zembylas, 2008).

In conclusion, education research has demonstrated the usefulness of sociological and critical perspectives in exploring the role of emotions in teaching and learning. Unfortunately, we found very few studies employing these perspectives in the EEE literature (Lönngren et al., forthcoming). Cech and Sherick's (2015) work provides an example of how engineering education researchers can study cultural and structural dimensions of EEE. Through the concept of the *ideology of depoliticization*, they explored engineering students' disengagement (that is, lack of activating emotions) with ethics and social justice issues and the societal consequences such disengagement can have. Another example can be found in Adams and Turns's (2020) case study of educational innovation, which included analyses of, for example, discourses of innovation, distributed structures of course coordination, emotions triggered when innovators break social norms, and innovators' emotional labor. Finally, a study by Lönngren et al. (2021) employed positioning theory to explore engineering students' reflections on how to deal with a sustainability problem. They showed how engineering students negotiated and related to conflicting discourses of engineering as (1) purely rational (that is, unemotional) and (2) requiring empathy (that is, involving emotionality).

4 Methods and Methodologies for Emotion Research

Research on emotions can use a broad range of methods and methodological approaches (Lindblom-Ylänne, 2019; Zembylas & Schutz, 2016), employing different "*measurement paradigms*" (Shuman & Scherer, 2014, p. 17, italics in original). Irrespective of which combination of methods is chosen, however, researchers need to ensure proper alignment between research methods, definitions, and theories of emotions. Different theoretical perspectives point researchers' attention to different aspects of emotions, which can be investigated through different types of methods and methodologies and will result in findings that are applicable to, and relevant for, different types of challenges in engineering education (Shuman & Scherer, 2014). To guide new EEE researchers in purposefully selecting and combining methods, we provide an overview of methods used for studying different aspects of emotions and emotion-related phenomena and examples of how these types of methods have been used in existing EEE research.

4.1 Types of Emotion Measures

So far, most emotion research in education has employed *self-report measures*, that is, research subjects' descriptions of their own emotions. Self-report measures can be collected with quantitative (e.g., surveys), qualitative (e.g., interviews), and multi- or mixed-methods studies, and they are generally relatively easy to collect and analyze. Self-report measures are particularly useful for exploring the subjective feeling, motivation, and cognition components in Scherer's (2005) model, but they can also be adapted for analyzing motor expression and conscious, neurophysiological processes. However, self-report measures are only useful if (1) subjects are cognitively aware of what they feel and what they want to achieve; (2) subjects' interpretations and reporting of their own emotions is not unduly influenced by, for example, a desire to please the researchers; and (3) subjects and researchers share similar linguistic and cultural ways of talking about emotions (Pekrun & Bühner, 2014; Shuman & Scherer, 2014).

To analyze the motor expression component of emotion, *observational methods* are particularly useful, focusing on participants' emotional behavior, including verbal expressions (i.e., speech), as well as non-verbal expressions (e.g., facial, vocal, or bodily displays). These methods can be used in

experimental settings, but they have been more often used in non-experimental settings and field research. In fact, the specific situation in which emotional behavior is displayed can provide information about "potentially emotion-eliciting events and the context in which they occur" (Reisenzein et al., 2014, p. 584). Therefore, situational descriptions are often used to inform analysis and interpretation of emotional behavior (J. C. Turner & Trucano, 2014). An important limitation in using observational methods is that they primarily provide information about *emotional behavior* – rather than the actual emotions participants experience (Reisenzein et al., 2014).

Finally, *physiological methods* can be used to measure the ways in which emotions influence research participants' physical bodies (e.g., heart rate, blood pressure, sweating, or cortisol levels). They are well-suited to attend to the short-term neurophysiologic component in Scherer's (2005) model. They may be particularly useful for exploring nonconscious emotional processes in teaching and learning (Immordino-Yang & Christodoulou, 2014). However, interpreting physiological data is challenging, since "it is not yet fully understood how specific psychophysiological changes relate to particular emotions" (Immordino-Yang & Christodoulou, 2014, p. 616). For example, a high level of physiological arousal, measured as increased heart rate and blood pressure, could signal anxiety but also excitement. In addition, physiological measures can only provide data about phenomena that are easily measurable. Solely relying on these types of measures may also result in low reliability and replicability as important situational factors may be missed. Physiological measures should therefore always be combined with self-report and observational measures to allow researchers to triangulate and make sense of physiological data in relation to specific educational situations (Fulmer & Frijters, 2009; Immordino-Yang & Christodoulou, 2014; Villanueva et al., 2018).

In the EEE literature, most published research has relied on self-report measures. Of these, quantitative approaches have been used most often, followed by qualitative, multi-methods, and mixed-methods approaches. The literature also includes a substantial number of non-empirical, conceptual studies and a few studies employing physiological measures (Lönngren, Bellocchi, et al., 2021).

4.2 Quantitative Methods

The EEE literature (as well as the broader literature on emotions in education) is dominated by studies employing quantitative methods, typically relying on self-report measures. This dominance mirrors a strong focus in the EEE literature on emotional intelligence (Section 5.3), a theme that is often explored through psychometric instruments developed for experimental research in psychology. The most-used instruments are summarized in Table 8.1 (for emotional intelligence) and Table 8.2 (for other emotion-related phenomena). Arguably, the convenient and seemingly objective approach these instruments offer may appeal to engineering education researchers who have a background in science or engineering disciplines. Indeed, these instruments have been shown to be useful for exploring specific emotional phenomena, such as emotional intelligence or exam anxiety. However, used in isolation, these instruments do not provide enough information to develop a complete understanding of complex emotional phenomena and how these phenomena may play out in different cultural and situational contexts (Pekrun & Bühner, 2014).

4.3 Physiological Methods

Physiological methods have not yet been widely used in EEE research. Notable exceptions, however, are found in the work by Villanueva et al. (2015, 2018), who used measures of electrodermal activity, cortisol levels, and serum amyloid A (SAA) proteins to study students' engagement and emotions in different educational settings, including exams. Villanueva et al. (2016, 2019) have also provided experimental protocols for conducting these types of studies. Additional examples of this type of

Table 8.1 Examples of Commonly Used Quantitative Instruments for Researching Emotional Intelligence

Instrument	Purpose/Aim	Source
Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT, Mayer & Caruso, 2002)	Tests emotional intelligence as a set of four abilities through a set of questions which are scored as having correct answers.	Operated by a commercial publisher; use requires payment.
Schutte Emotional Intelligence Scale/ Assessing Emotions Scale (Schutte et al., 1998)	A 33-item self-report questionnaire aiming to test emotional intelligence abilities by asking respondents how good they are at particular tasks.	Published in Schutte et al. (1998) and freely available to use.
Bar-On Emotional Quotient Inventory (EQ-I, Bar-On, 1997)	Tests EI as a mixed set of skills, competencies, and abilities tested by participants ranking their agreement with a set of 133 statements.	Operated by a commercial publisher; use requires payment.
Trait Emotional Intelligence Questionnaire (TEIQue, Petrides et al., 2007)	Tests emotional intelligence as a facet of personality through participants ranking agreement with a set of statements. Available in long format (153 items) and short format (30 items).	Available through the London Psychometrics Laboratory at University College London; donations requested, but not required.

Table 8.2 Examples of Commonly Used Quantitative Instruments for Researching Emotional Phenomena Other Than Emotional Intelligence

Instrument	Purpose/Aim	Source
Achievement Emotions Questionnaire (AEQ, Pekrun et al., 2005)	Assesses college students' emotions related to attending class (80 items), studying (75 items), and being tested (77 items) through a self-report questionnaire in which participants rate their agreement with short sentences.	Published in the technical manual; freely available.
Positive and Negative Affect Schedule (PANAS, Watson et al., 1988)	Assesses mood with two scales measuring positive and negative affect through a 20-item questionnaire in which respondents indicate how often they have felt specific emotions over the past week. A 60-item version is also available.	Published in the technical manual; freely available.

research are found in science education. For example, pulse rate and blood oxygen saturation measures have been used to analyze teachers' expression of emotions in relation to physiological changes (Tobin et al., 2016) and the role of emotions when sensitive and controversial topics are discussed in science education (Calderón, 2016).

There may be several reasons for the relative lack of EEE research employing physiological measures, in addition to the general challenges associated with these measures described earlier. First, physiological measures are difficult to collect in authentic classroom settings (Immordino–Yang & Christodoulou, 2014; Sinatra et al., 2014), not least due to ethical and data protection issues. Second, in interdisciplinary collaborations, scholars trained in engineering may be more likely to take on the role of designing the technological aspects of measurement systems rather than analyzing the role of emotions in education. Finally, much EEE research to date has focused on emotional intelligence, which is typically measured through quantitative instruments.

4.4 Qualitative Methods

Even though quantitative methods have been most frequently used in EEE research so far, the EEE literature also includes studies employing a range of qualitative methods, including self-report measures (e.g., interviews), artifact analysis (e.g., student writing or course descriptions), and observation (Lönngren, Bellocchi, et al., 2021). Interviews have, for example, been used to explore emotions in terms of engineering students' lived experience, identity development, or positioning (e.g., Huff et al., 2021; Kellam et al., 2018; Lönngren et al., 2020). Artifact analysis of course documents and written reflections have been used to inform a study on engineering students' experiences of perplexity in a design innovation course (e.g., Ge & Leifer, 2020). Finally, observations have been used to study how engineering students and educators express emotions in social interaction, for example, during a lecture or student group work (e.g., Lönngren, Adawi, et al., 2021; Tanu et al., 2017; Wells, 2005).

The field of EEE research may benefit from using qualitative methods more often and more intentionally. Qualitative methods may be particularly useful for expanding EEE research on emotions in social interaction, for example, exploring how emotions and emotion norms are co-constructed in specific educational contexts. Qualitative observational methods can be used to study co-construction of emotions in real time, as it unfolds during observed interactional episodes (Hufnagel & Kelly, 2018; for example, Lönngren, Adawi, et al., 2021), as well as over time through ethnographic observations (e.g., Chubbuck & Zembylas, 2008; Zembylas, 2004). Artifact analysis can provide insights about how co-construction occurs asynchronously over time. For example, researchers could analyze how emotions play out as students produce texts (e.g., Zembylas et al., 2008) or physical products in design projects. Finally, interviews can elicit real-time emotional co-production (e.g., between researcher and participant) and relate back to previously experienced emotions, thus allowing researchers to explore longitudinal social construction of emotions across different contexts (i.e., typically also including/engaging people who are not actively involved in the research; for example, Chubbuck & Zembylas, 2008).

4.5 Multi- and Mixed Methods

EEE researchers can choose from a wide range of methods to explore emotions, components of emotions, and emotion-related phenomena. However, studying emotions by employing a single type of data may lead to incomplete understandings of emotional phenomena. In fact, educational researchers have stressed the need for multi- and mixed-methods approaches in emotion research to be able to do justice to the inherent complexity of emotions, the multitude of ways in which emotions can be defined and theorized, and the diverse roles emotions play in teaching and learning (Lindblom-Ylänne, 2019; Schutz et al., 2016). In addition, mixed- and multi-method research studies can allow researchers to combine benefits and mitigate drawbacks associated with individual methods (Fulmer & Frijters, 2009). It is also important, however, to be aware of the challenges associated with synthesizing data collected through different approaches: mixed- and multi-methods studies need to be carefully designed regarding each individual method, combination of data and findings across methods, and alignment of theoretical perspectives associated with each method (Choudhary & Jesiek, 2016). The nascent body of EEE research includes a few studies employing mixed-methods (e.g., Hess et al., 2020; Tafur Arciniegas, 2015) and multi-methods (e.g., Leicht et al., 2009; Villanueva et al., 2018) approaches. As the field matures, we expect that many more studies will benefit from intentional and purposeful combination of different research methods.

5 Prominent Themes in the EEE Literature

Having discussed theoretical and methodological perspectives that frame the scope of possibilities in conducting emotion research, we now turn our attention to extant research on EEE. Specifically,

we describe four prominent themes in the EEE literature, based on a recent scoping review of the literature (Lönngren, Bellocchi, et al., 2021).

5.1 Academic Emotions

While the framework of academic emotions is seldom applied explicitly, the EEE literature includes studies on all four types of academic emotions (achievement, epistemic, topic, and social emotions).

Achievement emotions. In the wider educational literature on emotions, there is a strong focus on achievement emotions. This literature is dominated by research on achievement in terms of educational outcomes, most often test anxiety. But achievement emotions have also been related to educational processes, such as students' perceived ability to focus during a lecture or to engage with a practical task (Pekrun & Perry, 2014). Surprisingly, the focus on achievement emotions appears to be less pronounced in the EEE literature, but there are a few studies on the influence of emotions and emotion-related competencies on achievement (Anand et al., 2016; Rizwan et al., 2019; Skipper & Brandenburg, 2013; Villavicencio, 2011), students' emotional experiences of examination (Villanueva et al., 2019), students' coping strategies for dealing with achievement emotions (Bélanger et al., 2007; Deveci, 2016), and ways in which educators can help students reduce test anxiety (Bellinger et al., 2015).

Epistemic emotions. Epistemic emotions can be triggered when learners' views of knowledge and learning are challenged. In engineering education, students' views are likely to be challenged when they are confronted with uncertainty and ambiguity, or when they are required to take responsibility for their own learning (Ge & Leifer, 2020; Lönngren et al., 2019). These situations are more likely to occur when educators use pedagogical approaches that emphasize active learning, teamwork, interdisciplinary interaction, and open-ended problem-solving (Owens et al., 2020). It is therefore not surprising that much of the existing EEE research related to epistemic emotions has focused on design tasks (Adams & Turns, 2020; Ge & Leifer, 2020; Villanueva et al., 2018), teamwork (Leicht et al., 2009; Sunderland et al., 2014), and problem- or project-based learning (Chance & Williams, 2020; Deveci & Nunn, 2016).

Social emotions. Pedagogical approaches that challenge students epistemologically may also pose social challenges. For example, engineering students have been shown to experience social anxiety related to their role and status in teamwork and anxiety related to speaking in front of peers and teachers (Mohd Radzuan & Kaur, 2011; Vitasari et al., 2011). Emotions have also been shown to be important in student–teacher relationships (Tormey, 2021). Another strand of EEE research has focused on emotions related to diversity, equity, and inclusion issues, such as students' sense of belonging (Rohde et al., 2018), experiences and expressions of emotion in underrepresented groups (Decuir-Gunby et al., 2009), and a range of emotions related to students' social identities (Martin et al., 2019). However, these studies have only begun to scratch the surface of the complex array of ways in which social emotions emerge in, and impact on, in engineering education. There is a clear need for more research in this area, for example, on emotions in student–teacher relationships (Tormey, 2021), the emotional experiences of social inequalities (Rodriguez, 2017), and emotions in social justice education (Chubbuck & Zembylas, 2008; Zembylas, 2012).

Topic emotions. Topic emotions have so far mostly been researched in relation to broad disciplinary topics, focusing on students' emotions related to mathematics (Jaltare & Moghe, 2020; Jamil et al., 2011), programming (Giannakos et al., 2014), and writing (Quinto & MacAyan, 2020). More research is needed to understand emotions related to specific topics in engineering education, such as emotions triggered in teaching and learning about sustainability, social justice, inequality, or norm criticism (Kalonaityté, 2014; Lönngren et al., 2019; Ojala, 2013; Zembylas & Chubbuck, 2009). Research should also explore a range of topic emotions, beyond the current dominance of research

on anxiety. Research focused on ethics is relatively strong in EEE, which will be discussed in the next section.

5.2 Emotions and Ethics

Historically, emotions have been regarded as problematic in moral decision-making since they were thought to introduce "biases that threaten objectivity and rationality" (Roeser, 2012a, p. 107). Three distinct but related challenges to this view have been offered in the EEE literature, focusing on (1) care ethics, (2) emotional empathy, and (3) other moral emotions.

Care ethics. This perspective has its roots in the work of Gilligan (1982), who argued that an understanding of moral judgment as rationalistic and individualistic reflects masculine biases. She showed that boys typically make moral judgments by applying values and rules, while girls typically focus on social relationships and consider moral problems in terms of how their social network should respond. Gilligan's (1982) work helped launch a feminist *ethics of care* (Fisher & Tronto, 1990; Noddings, 1988, 2012), exploring moral judgments in terms of peoples' vulnerability and the situated relationships in which people interact. EEE research on care ethics is not yet well developed (Van der Poel & Royakkers, 2011), but a few studies have explored it in relation to, for example, engineering design (Pantazidou & Nair, 1999) and social justice in engineering practice (Riley et al., 2009). While emotion was not the central focus of this work, care ethics was originally developed as a counterpoint to overly cognitive accounts in mainstream moral psychology and philosophy (Gilligan, 1982), and it is therefore clearly relevant for EEE research.

Emotional empathy. Defined as "an emotional state triggered by another's emotional state or situation, in which one feels what the other feels or would normally be expected to feel in his [*sic.*] situation" (Hoffman, 2008, p. 440), *emotional empathy* is crucial for understanding other peoples' vulnerability. In engineering education research, Walther, Miller et al. (2017), and Walther et al. (2020) developed a model of empathy as a learnable skill. Hess and Fila (2016) and Hess et al. (2020), on the other hand, defined *empathy* not as a skill but as cognitive or affective positioning of oneself with respect to others. They also explicitly linked empathy to engineering students' ethical development. Finally, Lönngren et al. (2021, 2020) identified empathy as an emotion norm in engineering education, allowing students to position themselves as empathetic and, thus, emotional human beings. Moreover, the role of empathy on engineering design and design thinking has been explored by Bairaktarova et al. (2016) and Bairaktarova and Plumlee (2022). One of the pedagogical techniques used to strengthen engineering students' understanding of users' needs, the empathy map technique, focuses on categorizing users' emotions and feelings as a guiding premise of empathic design (Bairaktarova et al., 2016).

Other moral emotions. In recent years, the focus in EEE research has been broadened from empathy to a wider range of moral emotions. For example, Huff et al. (2018, 2021) explored the moral emotion *shame* through interpretative phenomenological analysis, and Gelles et al. (2020) identified *anger* as an important emotion in fueling advocacy against unjust academic structures. In the wider literature, moral emotions have been explored in relation to individuals' ethical judgment and behavior in several ways. First, moral emotions have been theorized as sources of *moral insight*, which, in turn, can be processed cognitively and contribute to intentional risk assessment in engineering: "Emotions such as fear, sympathy, and compassion help to grasp morally salient features of risky technologies, such as fairness, justice, equity, and autonomy that get overlooked in conventional, technocratic approaches to risk" (Roeser, 2012b, p. 820). Sunderland (2014; Sunderland et al., 2013, 2014) used this approach to explore emotions in engineering ethics education. Second, moral emotions have been conceptualized as sources of *moral intuitions*, which may be less amenable to cognitive processing but still influence ethical judgment and behavior (Greene & Haidt, 2002; Haidt, 2003). There is

today general agreement on the importance of emotions in engineering ethics education, but more research is needed to better understand how different types of emotional information, experiences, and processes influence ethics learning in engineering education.

5.3 Emotional Intelligence and Other Socio-emotional Competencies

The *emotional intelligence* concept was first developed by Salovey et al. (2008), who highlighted the synergistic relationship between emotion and reason:

> Humans are not, in any practical sense, predominantly rational beings, nor are they predominantly emotional beings. They are both. Thus people's abilities to adapt and cope in life depend on the integrated functioning of their emotional and rational capacities.
>
> *(p. 535)*

Salovey et al. (2008) described emotional intelligence in terms of four components: (1) ability to perceive, appraise, and express one's own emotions, as well as perceive and appraise others' emotions; (2) ability to use emotions to facilitate cognitive activities, such as problem-solving; (3) ability to understand and analyze emotions, including the ability to label emotions with appropriate words and recognize relationships between emotions; and (4) ability to manage emotions, in oneself and others.

Reviewing the EEE literature, Lönngren et al. (Lönngren, Bellocchi, et al., 2021; Lönngren et al., forthcoming) identified emotional intelligence as one of the most frequently researched topics. EEE studies in this area have focused on (1) emotional intelligence and other socio-emotional competencies of engineering students (e.g., Bhave et al., 2020; Botello Ojeda & Fragoso Luzuriaga, 2015; Carballeira et al., 2019; Luisa Casado et al., 2016; Tekerek & Tekerek, 2017) and (2) emotional intelligence in association with other variables, such as self-regulation (Saibani et al., 2015), coping strategies (Bélanger et al., 2007), teamwork (Deveci, 2015; Lee et al., 2018), academic performance (Anand et al., 2016; Rizwan et al., 2019; Skipper & Brandenburg, 2013), leadership (Lappalainen, 2015), entrepreneurship (Anesukanjanakul et al., 2019), and employability (Xu, 2013).

While emotional intelligence receives a lot of attention in EEE, the concept has sometimes been used uncritically, and some authors have referred to popular work (e.g., Goleman, 1995) rather than scientific publications (Lönngren et al., forthcoming). Uncritical use of the concept is problematic for several reasons. First, it risks perpetuating a dualistic understanding of emotion as different and separated from reason, since "to argue that emotion needs to be included in education . . . through emotional intelligence skills . . . is to assume that emotion is not already part of reason" (Zembylas, 2016, pp. 542–543). This risk is particularly problematic in engineering education, where educators struggle to teach topics such as ethics, sustainability, and human-centered design. Discussions about these topics are difficult to reconcile with the prevailing rationality discourse in engineering (Lönngren, Adawi, et al., 2021; Roeser, 2012a), and it would therefore be unfortunate if emotional intelligence research contributed to strengthening these discourses. Second, calls for emotional intelligence are often based on problematic assumptions that students and educators should engage in individual, emotional self-control and self-improvement – they are expected to conform with dominant emotion norms, irrespective of whether those norms are beneficial for teaching, learning, and responsible engineering practice. Increasing homogeneity in emotion practices can also lead to reduced diversity, inclusion, and creativity in engineering classrooms (Boler, 1999; Webb, 2010; Zembylas, 2007a, pp. 456–458). Finally, emotional intelligence has often been theorized as an antidote to undesirable, "untamed," and even dangerous emotion. Such emotions have often been associated with women and underrepresented groups, who risk being stereotyped as overly emotional and – consequently – less able to assume positions of political or financial power. Thus, uncritical use of emotional intelligence risks perpetuating existing power hierarchies and inequalities (Boler, 1999).

In addition to emotional intelligence, EEE researchers have explored a range of other socio-emotional skills, including motivation and emotional regulation (e.g., Cheng, 2017), transversal competencies (e.g., Luisa Casado et al., 2016), professional skills and generic skills (e.g., Pertegal-Felices et al., 2010), and self-efficacy (e.g., Lappalainen, 2015). There is also an emerging body of research on grit in engineering education (Direito et al., 2021; Duckworth et al., 2007). Unfortunately, like emotional intelligence, these concepts have often been used uncritically and inconsistently (Direito et al., 2021; Zembylas, 2016). It would therefore be useful if future EEE research on emotional intelligence could adopt critical and sociological perspectives to develop a more nuanced understanding of the social and educational consequences that may result from teaching emotional intelligence in engineering education.

5.4 Mental Health

The World Health Organization (2022) defines *mental health* as "a state of mental well-being that enables people to cope with the stresses of life, realize their abilities, learn well and work well, and contribute to their community" (para. 1). In line with this definition, we understand mental health as a multidimensional construct that involves (1) competency in completing tasks, (2) interpersonal connection with others, and (3) intrapersonal peace with oneself. A large body of psychological research highlights how emotions and emotion-related phenomena (e.g., emotion regulation, anxiety, depression) are relevant to understanding mental health (Berking & Wupperman, 2012; Cisler et al., 2010; Joormann & Stanton, 2016). It is therefore not surprising that mental health is a relatively common research focus in the EEE literature (Lönngren, Bellocchi, et al., 2021), where mental health is often explored in relation to students' academic performance and performance-related emotions, particularly anxiety. Some studies focus on overall academic performance (e.g., Jamil et al., 2011; Villavicencio, 2011); others explore performance in specific tasks, such as, programming (Jaltare & Moghe, 2020), working in high-voltage laboratories (Güneş & Özsoy-Güneş, 2016), exams (Bellinger et al., 2015; Ramming & Mosier, 2018), delivering presentations (Mohd Radzuan & Kaur, 2011), or technical writing (Quinto & MacAyan, 2020).

Most of the published EEE studies on mental health aimed to understand how students could better regulate their emotions to meet the demands of existing tasks in the existing curriculum. The curriculum itself, on the other hand, has often been perceived as, fixed and existing tasks have seldom been scrutinized. Much of this research has also focused on what is healthy and desirable for the engineering profession (i.e., competent engineers) and less on what is healthy for individuals within engineering education and practice. Hypotheses or research questions in this line of research have typically conceptualize emotion as a phenomenon that, if not well regulated, would inhibit learning as marked by academic performance or engagement. In other words, most of the existing EEE research mental health has employed deficit framings of mental health, for example, associating certain emotional states with mental health disorders. Positive and neutral emotional states associated with mental health, such as enjoyment or relaxation, have received less attention.

There is also an emerging body of EEE research on mental health in relation to *care* (Section 5.2) rather than students' performance and productivity (e.g., Berdanier et al., 2020; Danowitz & Beddoes, 2020; Stefl, 2020). This strand of research is often focused on social emotions (Section 5.1), as well as issues of *identity* and *belonging*. For example, Wilson and Wilson (2020) analyzed how students from underrepresented groups experienced emotions that exacerbated their sense of isolation in engineering education. Further, Huff et al. (2021) and Sharbine et al. (2021) explored how a specific emotion, *shame*, can threaten students' sense of belonging and well-being. Employing a more conceptual approach, Tormey (2021) proposed a model for student–teacher affective relationships in higher education in which emotions were related to affection, attachment, and psychological safety. Finally, Jensen and Cross (2021) highlighted the complex relationships between engineering identity,

cultures of stress, and mental health, amplifying the need to investigate mental health in engineering education for its own sake, rather than in the interest of increased performance in academia and engineering practice.

6 Practical Advice for EEE Research

Based on our review of the existing EEE literature (Lönngren, Bellocchi, et al., 2021; Lönngren et al., forthcoming) and our own EEE research (e.g., Direito et al., 2021; Huff et al., 2021; Lönngren, Adawi, et al., 2021; Tormey, 2021), we offer four points of advice for researchers and doctoral students who plan to pursue EEE research.

1   *Get familiar with the existing EEE literature, as well as emotion literature from the wider field of educational research.* Only if we are aware of previous work can we contribute to the collective endeavor of developing new knowledge – which then can be used to achieve real change in engineering education practice. It is also helpful to read emotion literature from other disciplines, such as psychology, philosophy, or sociology. Such reading helps develop a broader understanding of the wide range of emotion-related phenomena that can be researched and the large array of theoretical and methodological approaches that are available.

2   *Define what you mean by "emotion."* As discussed in Sections 2 and 3, different disciplines define emotion in different ways. Therefore, just like any other theoretical concepts used across disciplines, emotions and emotion-related phenomena need to be properly conceptualized, enabling others to understand the assumptions on which the research is based. Moreover, it is important to make *informed* and *intentional* choices of how to conceptualize emotions. Due to the contested nature of "emotion" in different disciplines, definitions and theories of emotion are not neutral and may position the research within long-standing academic debates. For example, defining emotions as purely neurobiological phenomena – ignoring the ways in which emotions are shaped by language, culture, and power relations – also means *defining out* of emotions many of the features that are most interesting to social scientists and many educational researchers. Unfortunately, clear conceptualizations of emotion are today often missing not only in the EEE literature (Lönngren et al., forthcoming) but also in other emotion research (Pepin, 2008). One reason may be that emotions are ubiquitous in all human practices, which may lead us to assume that everyone thinks of emotions in the same way.

3   *Ensure appropriate alignment between theoretical perspectives, data collection methods, analytic approaches, and research questions.* Such alignment is a prerequisite for high-quality research in engineering education (Huff et al., 2020; Sochacka et al., 2018; Walther, Sochacka, et al., 2017). Alignment is also important in emotion research, since different theoretical perspectives "suggest different structures and measurement of emotions" (Shuman & Scherer, 2014, p. 25). While we found relatively high degrees of alignment in the EEE literature (Lönngren et al., forthcoming), we suspect that much of this alignment is due to the availability and frequent use of published measurement instruments (Tables 1 and 2) for which standard procedures for data collection and analysis have been established. In addition, around one-third of published EEE studies (Lönngren et al., forthcoming) did not conceptualize emotions or emotion-related phenomena in any way. For that part of the literature, it was not possible to assess alignment between theories, methods, and research purposes, which means that misalignment may be much more common than the levels found in our literature review. As the field matures, we hope for more intentional conceptualization and a greater variety of theoretical perspectives and research approaches. These developments, we believe, will greatly increase the need for EEE researchers to pay careful attention to theoretical and methodological alignment.

4   *Commit to emotion as an intentional, primary research focus.* In previous EEE studies, emotions have often been studied as incidental phenomena, that is, emotions emerged as salient phenomena in research that originally intended to explore something else. For example, many of the existing studies have focused on improving learning of professional competencies, where emotions are identified as barriers or facilitators for such learning. Intentional research design is crucial for achieving alignment between theories, methods, and research questions. It also enables researchers to explore emotion-related phenomena in more depth, which in turn creates opportunities for leveraging EEE research for educational change. Finally, intentional design is important for safeguarding ethical conduct. Participants may share sensitive personal data, such as information about their mental health, and we need to ensure that these data are handled appropriately.

7 Widening the Scope of EEE Research

In Section 5, we have described four dominant themes in the EEE literature. Here, we outline six thematic, theoretical, and methodological opportunities for widening the scope of EEE research.

First, EEE research needs to attend to a diversity of emotional phenomena, beyond emotional intelligence. The strong dominance of research on emotional intelligence today risks perpetuating a narrow understanding of the role of emotions in engineering and engineering education. Some examples of under-researched emotional phenomena in research from sociological and critical perspectives are *feeling rules* and *emotional labor* (Hochschild, 1979, 1983) and emotional capital (Cottingham, 2016; Zembylas, 2007a). In research from psychological perspectives, *social emotions* (Pekrun & Linnenbrink-Garcia, 2012; Tormey, 2021) deserve more attention. The concept of social emotions may also provide an opportunity to bridge individual (psychological) and sociological perspectives in EEE research.

Second, EEE research should explore the role of emotions in different educational settings and with diverse participants. Today, mirroring the wider field of engineering education research, most of the existing EEE research has focused on higher education. While a few studies have started to explore other educational levels, including secondary education (McEneaney & Nieswandt, 2017; Sánchez-Martín et al., 2017), primary education (Campbell & Jane, 2012; McMahon, 2012), pre-school (Ismail et al., 2017), pre-kindergarten (Lippard et al., 2017), informal education (Ofori-Boadu et al., 2019), as well as transitions between educational levels (Budny et al., 2010; Du-Plessis & Steyn, 2006), studies in these contexts are still scarce. Most EEE research has also concentrated on students, with only a few studies focusing on engineering and technology educators' emotions (Jha & Singh, 2012; McMahon, 2012; Rodriguez, 2017) or emotions in professional engineering contexts (Guntzburger et al., 2018; Lappalainen, 2015). More research is clearly needed on educators' and other staff members' emotions as well as emotion practices in diverse educational settings.

Third, cross-disciplinary research is needed to understand differences and similarities in the role of emotions in teaching and learning across engineering disciplines. In EEE, emotions have been studied in a variety of engineering disciplines, such as architectural (Saibani et al., 2012) and construction engineering (Owusu-Manu et al., 2019), biomedical (Hess et al., 2020) and chemical engineering (Botello Ojeda & Fragoso Luzuriaga, 2015), computer engineering (Bélanger et al., 2007; Pertegal-Felices et al., 2010), industrial engineering (Lee et al., 2018), manufacturing engineering (Brubaker et al., 2019), and marine engineering (Chung et al., 2019). These studies have shown that emotions are important in many engineering disciplines. However, the existing studies were not conducted in such a way to allow direct comparison across contexts, and we are therefore not yet able to draw conclusions regarding similarities and differences in how emotions influence teaching and learning across engineering disciplines. This is unfortunate since research has shown that the specific ways in which emotions influence teaching and learning can be discipline-specific

(Goetz et al., 2006). Hess et al.'s (2020) study on empathy in biomedical engineering provides a clear example of discipline-specific emotions – the study focused on students' emotions as they are confronted with having to test and euthanize research animals as part of their laboratory coursework (and future profession). A better understanding of disciplinary variation of the role of EEE would also contribute to developing a better understanding of how EEE research can be transferred and translated between educational contexts.

Fourth, EEE research needs to pay more attention to cultural contexts in which the research is conducted. Emotions may be experienced and expressed differently across cultural contexts, which creates challenges for interpreting cross-cultural differences and may result in misrepresentation of emotions in non-Western contexts (DeCuir-Gunby & Williams-Johnson, 2014). EEE research should therefore be conducted within and across diverse cultural contexts and employ theories and methodologies that are culturally relevant for the respective contexts (*ibid.*). While the existing EEE literature has been produced by authors in many different countries, research conducted by authors affiliated with institutions in North America, Europe, and Asia is still strongly over-represented (Lönngren, Bellocchi, et al., 2021). This distribution of authors reflects similar, and equally problematic, trends in engineering education research at large (Williams et al., 2014).

Fifth, we see a need for more EEE research drawing on sociological perspectives (Lönngren, Adawi, et al., 2021). Such research would, for example, allow the field to explore the role of emotions in creating, maintaining, or challenging power hierarchies in engineering education:

> Paying attention to the politics of emotions in [education] means analyzing and challenging the cultural and historical emotion norms with respect to what emotions are, how they are expressed, who gets to express them and under what circumstances. . . . [T]here is always something "political" in which teachers and students are caught up as they relate emotionally to one another across classroom spaces, because power relations are unavoidable; there are always emotion norms caught up in subject-matter epistemologies and pedagogies, emotion discourses and emotional expressions in the classroom.
>
> *(Zembylas, 2016, p. 545)*

Sixth, there is a need for more research employing methods that do not (solely) rely on self-report measures. For example, EEE researchers could explore research methods employing measurement of physiological markers (Villanueva et al., 2018) and observation of emotions in social interaction (Lönngren, Adawi, et al., 2021). Due to the complexity of emotions, there is also a need for more multi- and mixed-methods EEE research (Schutz et al., 2016).

8 Concluding Thoughts

Despite the well-documented importance of emotions for engineering education and practice, most engineering education today still prioritizes cognitive aspects of learning. Hoping to contribute to a better understanding of emotional aspects and their importance for engineering education, we have introduced widely used disciplinary and theoretical perspectives in emotion research, as well as a range of methods and methodologies that can be used to explore emotions, components of emotions, and emotion-related phenomena. We have also outlined the emerging field of EEE research, describing four dominant themes in the literature: (1) academic emotions, (2) emotions and ethics, (3) emotional intelligence and other socio-emotional competencies, and (4) mental health (Lönngren, Bellocchi, et al., 2021; Lönngren et al., forthcoming). Finally, we have provided practical advice for EEE research and outlined areas for future research. There clearly is a large and rapidly growing interest in EEE, and we see many opportunities for further research and practical

applications as we strive to reform engineering education for the 21st century. We invite other researchers and doctoral students to join the emerging conversation and to connect with other EEE researchers in the Emotions in Engineering Education Network (EEEN, n.d.).

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