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EMPIRICAL RESEARCH

Using Positioning Theory to Study the Role of Emotions in Engineering Problem Solving: Methodological Issues and Recommendations for Future Research

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Background: Engineering is often portrayed as a purely rational discipline, where emotions are considered irrelevant to problem solving. Also, in-depth research on emotions in engineering education is scarce, and most of the existing studies take their theoretical departure in individual and cognitivist perspectives. There is thus a need for emotion research from social interactionist perspectives—such as positioning theory.
Purpose: This methodological paper aims to (1) develop an analytical framework for studying emotions through positioning theory and multimodal analysis, (2) illustrate its use in engineering education research, and (3) discuss methodological issues and offer recommendations for this type of research in engineering education.
Method: To develop the analytical framework, we engaged with philosophical and empirical literature on positioning theory and emotions, as well as empirical data from a pilot study on engineering students' emotional positioning in individual, video-recorded interviews about a wicked sustainability problem. We illustrate the application of the framework and multimodal analysis using three extracts from that data. In line with positioning theory, the analysis focuses on how emotional moral orders are activated and negotiated. Three units of analysis are used: emotion acts, emotional storylines, and emotional positions.
Results: The analysis shows how a dominant storyline of engineering as purely rational can be reconstructed, but also how a competing storyline of emotions as important for engineering can be constructed, sometimes simultaneously. These findings disrupt simplified narratives about engineers as unemotional and show that there are multiple ways of engaging with emotions in engineering problem solving.
Conclusions: We conclude that positioning theory holds much potential for exploring a wide range of social interactional phenomena in engineering education. More research is needed to explore additional types, levels, and orders of emotional positioning to further nuance our understanding of the role of emotions in engineering education.

Keywords: positioning theory; moral orders; emotions; multimodal analysis; sustainability; wicked problems

Introduction

There is today little in-depth research on emotions in engineering education (Lönngren, Adawi, Bellocchi, et al., forthcoming; Lönngren, Adawi, Berge, et al., 2020). In fact, engineering, much like the natural sciences, is often described as a purely rational discipline for which emotions are irrelevant or even detrimental (Sinatra, Broughton, & Lombardi, 2014; Zembylas, 2005). Sheppard, Macatangy, Colby, and Sullivan (2009) offer a vivid explanation of what such a view of engineering entails, adopting a historical perspective:

> Historically, the engineer's assumed perspective was outside the situation or problem—that of a disengaged problem solver who could confidently model the problem in objective, mathematical terms and then project a solution, framed largely in terms of efficiency and technical ingenuity, affecting a system uncontaminated by the frictions of human relationships or conflicting purposes (Cited in Strobel, Hess, Pan, & Wachter Morris, 2013, p. 141).

However, understanding engineering and engineering education as purely rational stands in stark contrast to a large body of (science) educational research showing that emotions "profoundly affect students' and teachers' engagement, performance, and personality development" (Pekrun & Linnenbrink-Garcia, 2014a, p. 659). Research has also shown that emotions are discipline specific and it is, therefore, critical to study emotions in each domain (Goetz, Frenzel, Pekrun, & Hall, 2006), including engineering education.

Most of the existing studies on emotions in engineering education take their theoretical departure in individual and cognitivist perspectives on emotions (Kellam, Constantino, Walther, & Sochacka, 2011; Lönngren, Adawi, Berge, et al., 2020). The focus of that research is on emotions as individual competencies or experiences, such as empathy (Hess, Miller, Higbee, Fore, & Wallace, 2020; Walther, Miller, & Sochacka, 2017), shame (Huff, Okai, Shanachilubwa, Sochacka, & Walther, 2021), and frustration (Estrada & Atwood, 2012). In the broader social science literature, however, there is an emerging body of research that uses discourse analysis to study emotions as social and cultural phenomena expressed in social interaction (Wetherell, 2013). A discursive focus on emotions is important because individual psychological constructs are made relevant and visible only in contextually situated instances of social interaction (Lester, 2011). It is particularly important for studying the role of emotions in teaching and learning involving controversial topics and high levels of social interaction—such as teaching and learning about wicked sustainability problems (Bossér & Lindahl, 2019; Lönngren, Adawi, & Berge, 2020).

In this methodological paper, we illustrate and discuss how positioning theory can be used in engineering education research. As the name alludes, positioning theory attends to "how people use words (and discourse of all types) to locate themselves and others" in social interaction (Moghaddam & Harré, 2010, p. 2). It combines a micro-focus on the details of social interaction with a broader focus on societal discourses and has therefore been described as "offer[ing] a middle-ground to mediate the tensions between proponents of conversation analysis and critical discourse analysis (Kayi-Aydar & Miller, 2018, p. 90). Positioning theory has been recognized as a valuable research approach in education (Kayi-Aydar & Miller, 2018), we are only aware of two previous studies where positioning theory has been used in engineering education research. However, those studies (Berge & Danielsson, 2013; Berge, Danielsson, & Ingerman, 2012) were concerned with engineering identities in collaborative problem solving rather than emotions. Positioning theory has also been used to study emotions in mathematics education (e.g. Daher, 2020; Evans, Morgan, & Tratsaroni, 2006), but we could find no such studies in engineering education. As such, this paper offers novel methodological and theoretical contributions to the engineering education research literature.

Purpose and outline

In this methodological paper, we explore the potential of positioning theory for engineering education research and, more specifically, research on emotions in engineering education. We draw from a pilot study (Lönngren, Adawi, & Berge, 2020) in which we analyzed how engineering students construct and negotiate emotional subject positions in discussions about wicked sustainability problems. We address three aims:

1. introduce an analytical framework for studying emotions through positioning theory and multimodal analysis,
2. illustrate its use in engineering education research, and
3. discuss methodological issues and offer recommendations for this type of research in engineering education.

We hope to inspire other engineering education researchers to consider using positioning theory for research on emotions, as well as other topics, and to sensitize them to some of the methodological issues involved. As such, we also aim to contribute to the ongoing process of broadening the methodological repertoire in engineering education research (c.f. Case & Light, 2011).

The remainder of the paper proceeds as follows. We first situate our work in the broader landscape of research on emotions in education. Next, we describe central concepts in positioning theory and present a framework for analyzing emotions with positioning theory. We then illustrate how this framework can be used in engineering education research, followed by a discussion of a set of methodological issues we encountered in using positioning theory and recommendations for addressing them. We close the paper with remarks on methodological and theoretical contributions as well as directions for future research.

Theory and research on emotions in education

There is a large and rapidly growing literature on the role of emotions in education (Pekrun & Linnenbrink-Garcia, 2014b) showing that emotions are ubiquitous in education and that they "direct interactions, affect learning and performance, and influence personal growth in both students and teachers" (Pekrun, Frenzel, Goetz, & Perry, 2007, p. 13). Moreover, the burgeoning use of complex real-world problems in education adds to blurring "the classic boundaries between emotions and cognition when they prompt students' personal opinions and experiences" (Mirza, 2016, p. 634). This is particularly evident

in teaching and learning about wicked sustainability problems, "due to the seriousness and complexity of these problems" (Ojala, 2015, p. 133; see also Lönngren & van Poeck, 2020).

Despite the growing interest in emotions in education, there is no consensus on how to define the term *emotion* (Izard, 2010; McNaughton, 2013). That is not entirely surprising, considering the range of theoretical approaches underpinning research on emotions (Bericat, 2016; Zembylas, 2007b). However, most educational research, so far, has been dominated by a cognitive-evaluative perspective that sees emotions as individual experiences (Kuby, 2016; Turner & Trucano, 2014; Zembylas, 2007b). From this perspective, emotions are understood as reactions to value judgments of objects and events. This perspective is known as the *cognitive-evaluative view of emotions* (Millán, 2016; Nussbaum, 2004) or the *appraisal theory of emotions* (Scherer, Schorr, & Johnstone, 2001).

To give an example, if we accidentally break a vase, our emotional reaction depends on the value we attach to the vase. This means that emotions are not direct responses to events, but rather "intelligent responses to the perception of value" (Nussbaum, 2001, p. 1). As such, this view of emotions can account for individual differences in emotional reactions to the same event (Scherer et al., 2001) and it also sheds light on the longstanding philosophical question regarding the relationship between emotions and values (Todd, 2014). In short, emotions are construed as individual "cognitive states that allow us to discover values and reasons in the world" (Millán, 2016, p. 119).

Further, most of the existing educational research has focused on achievement emotions—that is, emotions related to taking exams or studying, such as anxiety, pride, and shame (Pekrun, 2005). More recently, guided by a *typology of academic emotions* (Pekrun & Linnenbrink-Garcia, 2012), educational researchers have begun to explore three additional types of academic emotions: (1) topic emotions, which relate to the contents of learning; (2) epistemic emotions, which relate to the cognitive process of learning, such as frustration; and (3) social emotions, which relate to the social process of learning, such as admiration, envy, or empathy. For an in-depth review of this strand of research, the interested reader is referred to Pekrun and Linnenbrink-Garcia (2012).

There is an emerging and rapidly growing body of research on emotions in engineering education, but there are still few in-depth studies that thoroughly theorize and empirically analyze emotions or emotion-related constructs (Lönngren, Adawi, Bellocchi, et al., forthcoming; Lönngren, Adawi, Berge, et al., 2020). This relative lack of attention to emotions seems to mirror the unfortunate *depoliticization* of engineering education, which "promotes the bracketing of information that is not strictly technical" (Cech & Sherick, 2015, p. 207). Engineering is often seen as a purely rational discipline, and engineering students are therefore taught to pay attention to technical details and accuracy while bracketing values and emotions (Kellam, Gerow, Wilson, Walther, & Cruz, 2018). However, emotions are ubiquitous and salient in both engineering practice and engineering education. Davis (2017), for instance, in his piece titled "In praise of emotion in engineering", argued that emotions are vital in engineering work aiming to address wicked problems. In fact, engineering students, when confronted with wicked problems, can express high levels of frustration and give up trying to address the problem (Lönngren, Ingerman, & Svanström, 2017). Like most educational emotion research, most of the existing studies in engineering education take their theoretical departure in individual and cognitivist perspectives (Lönngren, Adawi, Bellocchi, et al., forthcoming; Lönngren, Adawi, Berge, et al., 2020). Specific emotions have been studied from such a perspective in engineering education, such as empathy (Hess et al., 2020; Walther et al., 2017), frustration (Estrada & Atwood, 2012), and shame (Huff et al., 2021). Kellam et al. (2018), on the other hand, focus on a variety of emotions in engineering students' *emotional trajectories*.

In the broader educational literature, however, there is an emerging body of research attending to the role of emotions in social interactions (Barker, Nyberg, & Larsson, 2020; Encinas Sánchez, 2014). As Barker et al. (2020, p. 875, emphasis added) made clear:

> [This] approach does not rule out the idea that people experience sensations or feelings while they are interacting. It does, however, provide a different ontological starting point from which we can circumvent the empirical task of attempting to capture what is happening "inside people's heads". In short, it enables us to consider emotion as part of an *interactional* rather than a *mental* reality.

Empirical studies aligned with this theoretical approach attend to *what emotions "do"* in social interactions and do not attempt to isolate emotions from the context in which they occur. Martin (2014, p. 120) explained:

> Emotions serve to situate subjects in relation to their world, orientating them towards its objects with degrees of proximity and urgency, sympathy and concern, aversion or hostility. These emotional orientations are never fixed or complete but are open to contestation and negotiation, mediated often (though not exclusively) by rhetorical argument.

Pepin (2008) outlined six theoretical assumptions that studies on emotions in social interactions share: emotions are (1) situated, (2) sequentially embedded in talk-in-interaction, (3) resources for actions, (4) co-constructed, (5) embodied and

distributed phenomena, and (6) public. There are many different approaches to studying emotions in social interaction. In this paper, we describe and illustrate the use of *positioning theory*.

Theoretical foundations of positioning theory

Positioning theory is one of many approaches to analyzing *discourse*, where discourse is understood as "a particular way of talking about and understanding the world (or an aspect of the world)" (Jørgenssen & Phillips, 2002, p. 1). More specifically, positioning theory is "the study of local *moral orders*" (Harré & van Langenhove, 1999, p. 1), where moral orders "limit, enable, and influence what people can and should do" (Van Langenhove, 2017, p. 11). Moral orders are understood as sets of values related to what is or is not regarded as appropriate behavior for different individuals in a specific interactional context. Three units of analysis are used: speech acts, positions, and storylines. These are often illustrated in the form of a triangle (see **Figure 1**) to underline their interdependence (Warren & Moghaddam, 2018).

In this study, speech acts are understood as socially constructed meanings of actions of speech, as well as non-verbal communication, such as intonation, pausing, body movement, facial expressions, and gestures (Davies & Harré, 1990; Kayi-Aydar & Miller, 2018). We follow Herbel-Eisenmann et al. (2015) and use the term *communication acts* (instead of speech acts) to recognize that social force can be determined by more than just speech. The second construct, *positions*, designates "the momentary clusters of rights and duties to speak and act in a certain way" (van Langenhove, 2011, p. 67). In social interaction, participants assign positions to themselves through *reflexive positioning* and to others through *interactive positioning* (Kayi-Aydar & Miller, 2018). This is a dialectic process, since assigning a position to someone else always also implies assigning a position to oneself—and vice versa. The third construct, *storyline*, is linked to a cultural context beyond the actual conversation and unfolds as participants are engaged in assigning positions to themselves and others through communication acts (Harré & van Langenhove, 1999).

These three analytical concepts allow analysts to study moral orders in social interaction (Harré & van Langenhove, 1999). Moral orders exist at different levels, from local moral orders that are constructed in a conversation to more general moral orders that apply to all interactions within, for example, a country or a culture. Each of these moral orders can be latent or activated in a specific situation. Moral orders are thus both context-specific and multi-dimensional since, in any given situation, people "operate in a complete environment of overlapping and nested sets of moral orders that can result in potential conflicts" (Van Langenhove, 2017, p. 4). In positioning theory, the focus is on how these complex sets of moral orders are reproduced and/or challenged in and through social interaction: "Whenever two or more people meet and engage in a conversation, a local moral order is in play that fine-tunes the more general moral orders" (ibid., pp. 5–6). This also means that people in a conversation can act in ways that are deviant from what would be expected in general moral orders, but that may be appropriate in the local moral order of the conversation.

Moral orders can be activated, but also challenged, through communication acts (Van Langenhove, 2017). By activating moral orders, participants can render new positions available (or unavailable) to themselves and others. These positions, in turn, can render new types of communication acts permissible (or impermissible)—which then again can activate or challenge moral orders. In this paper, we are particularly interested in moral orders related to emotions, which we term *emotional moral orders* (see below).

Developing an analytical framework for studying emotions through positioning theory

As described above, emotions are often theorized as individual, cognitive-evaluative phenomena. Positioning theory provides an alternative theoretical vantage point, allowing us to conceive of emotions as situated and co-constructed resources for actions—that is to say, emotions are interactively performed through communication acts.

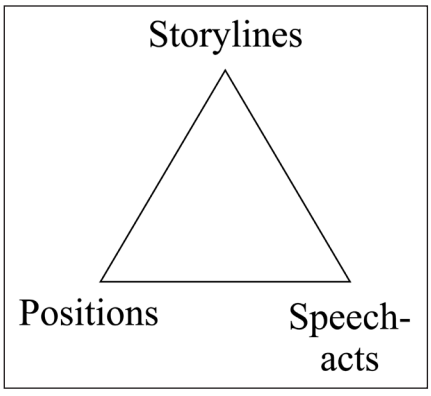


Figure 1: Illustration of the three units of analysis in Harré and Van Langenhove's (1999) description of positioning theory.

Positioning theory has previously been used to explore emotions in interaction (Parrott, 2003; Walton, Coyle, & Lyons, 2003). For example, Parrot (2003, p. 29) described two forms of emotional positioning:

> One way of positioning oneself is to display the emotions that are characteristic of one's position. One way of positioning one's opponents is to state what emotions they ought to be feeling and to characterize as inappropriate the emotions they are feeling.

However, previous work has not clearly conceptualized emotions through positioning theory. For example, Parrot (2003) described emotions alternately as moral orders, communication acts, storylines, a special category of words or expressions, or even—in conflict with positioning theory's theoretical focus on interaction—as individual experiences.

In this section, we develop a more coherent and fine-grained analytical framework for studying emotions through the lens of positioning theory. For this purpose, we introduce the following analytical concepts:

- *Emotion acts* are communication acts, but analyzing emotion acts means an intentional focus on how *emotions* are performed—rather than other forms of social interaction, such as power or gender. Emotion acts are analyzed in terms of *verbal communication*, including semantics (e.g., the meaning of words and phrases) and linguistic features (e.g., verb tense, hedging, or use of first/third person), and *non-verbal communication*, including paralanguage (e.g., verbal stress, pitch, speed of speech, pauses, sighs, or laughter), facial expressions, and gestures (c.f. Glazer, 2016; Hufnagel & Kelly, 2018).
- *Emotion labels* can be part of emotion acts. They are words or phrases that explicitly refer to emotions, such as "happiness" or "frustration" (c.f. Edwards, 1999). *Anti-emotion labels* are words or phrases that indicate a focus on rationality, such as "cold analysis" or "objectively". We note that an analytical focus on anti-emotion labels is particularly useful for studying moral orders related to how emotions may or may not be expressed in engineering education. Further, since emotions are conceptualized here as performed and situated, emotion labels and anti-emotion labels are not understood as words or phrases that have abstract and decontextualized meanings. For example, it is not possible to state that "happiness is a positive feeling that makes you smile". Rather, participants in an interaction co-construct a situated meaning of what an emotion label means and does in a specific situation.
- *Emotional storylines* are socially constructed, situated meanings of emotion acts. In this paper, we focus specifically on emotional storylines related to the role of emotions and rationality in engineering and engineering education.
- *Emotional positions* are positions that are made available (or unavailable) through emotional storylines. Emotional positions are here understood as clusters of rights and duties to perform certain types of emotion acts, but not others.
- *Emotional moral orders* are moral orders that explicate values regarding how emotions should (or should not) be felt or performed. They can be activated and challenged by emotion acts. Several conflicting emotional moral orders can be activated simultaneously, resulting in *value conflicts*. Due to the close connection between values and emotions, value conflicts are likely to stimulate participants to use emotion acts to position themselves and others in relation to conflicting moral orders. Since learning to deal with value conflicts is central in sustainability education, analyzing emotional moral orders is particularly useful in sustainability education research.

In this paper, we study (1) how students use emotion acts to position themselves and others in relation to emotional moral orders and (2) how conflicting emotional moral orders stimulate students to use emotion acts. Later, we will see how two emotional moral orders can be activated separately or simultaneously in engineering education: (1) "Engineering should be purely rational", and (2) "Emotions should play a role in engineering". We will also see how three engineering students use emotion acts to position themselves in relation to these two emotional moral orders during discussions about a wicked sustainability problem.

Positioning theory in educational research

Positioning theory is based on social constructionist perspectives on identity and learning, where identity and learning are understood as constructed and negotiated in and through interaction. Therefore, it is highly relevant to educational research (Kayi-Aydar & Miller, 2018; McVee, 2011). In a recent review of educational studies employing positioning theory, Kayi-Aydar and Miller (2018, p. 88) noted:

> positioning theory was used to show how rights, duties, obligations and opportunities are distributed among students and teachers in classroom discourse. In paying attention to the dynamic and contingent nature of positioning, scholars are better able to understand how particular forms of knowledge are (de)legitimated. These studies further make it possible to understand who can gain access to classroom talk, what cultural resources are being used and what kinds of learning opportunities are constructed.

The review included studies concerned with students' positioning in relation to, for example, identity and social status, classroom participation, access to learning opportunities, gender and social class, science and mathematics learning, language socialization, as well as emotions. It also included studies on teachers' positioning focusing on, for example, professional identities, instructional decisions, or creating opportunities or obstacles for student engagement and agency. This body of work suggests that positioning theory may be useful for exploring a wide range of phenomena relevant to engineering education.

Data construction and multimodal analysis for illustrating the use of the analytical framework

In this section, we describe how we have constructed the empirical data in our pilot study and how we have applied the above-described analytical framework—in tandem with multimodal analysis—to three selected data excerpts.

Data Construction

The data in our pilot study (Lönngren, Adawi, & Berge, 2020) was constructed in the context of another study (Lönngren et al., 2017) and consisted of video-recordings of semi-structured interviews with ten third-year engineering students, who were individually interviewed about a wicked sustainability problem—water-shortage in Jordan. The interviewer aimed to stimulate the students to discuss not only the technical but also the social and environmental complexity of the problem. Each interview lasted for about one hour and was transcribed verbatim by the first author, who also conducted the interviews. During each interview, the student and interviewer were seated at a table in a small room designed for student group work (see **Figures 2, 3**, and **4** for illustrations of the interview setup). Written informed consent was obtained from all participants in accordance with national guidelines (Vetenskapsrådet, 2017). In Sweden, formal permission from an ethics board is not required (nor possible to request) for this type of research.

The interviews proceeded as follows. The interviewer first described the structure and aim of the interview, stressing that there are no right or wrong answers and that the study focused on how the students reflected on the problem, rather than their answers about how to solve it. The students then received a short description of the problem of water shortage in Jordan, a schematic map and a satellite image of the Jordan Valley, and a list of six idealized solution alternatives that had been formulated to stimulate students to discuss the problem from different perspectives. Students were then asked to read the problem description and to describe which of the provided solution alternatives they saw as most suitable for dealing with the problem, and why.

The interviewer then posed a series of critical questions to challenge the students' argumentation. These questions aimed to stimulate deeper reflection and appreciation of the complexity of the problem, for example in terms of stakeholders' conflicting values or possible unintended consequences of different solution approaches. The interviewer also encouraged the students to think beyond the suggested solution alternatives and to discuss other ways of dealing with the problem. The students were then asked to discuss the problem from two different professional roles—an engineer and a local politician. For each role, the students were asked to draw a mind map illustrating how they would address the problem from the role character's perspective while thinking aloud. Finally, the students were asked what they thought about the problem and how they experienced the discussion during the interview (see Lönngren et al., 2017, for a detailed description of the interview procedure).

Data analysis

In our analysis, we were primarily interested in how the students used emotion acts to position themselves in relation to emotional storylines about engineering and engineers. Therefore, in contrast to many other studies employing positioning theory, we did not analyze how the participants in the interaction (student and interviewer) positioned themselves in relation to each other. Rather, we analyzed how the students positioned themselves in relation to more general emotional storylines about engineering and engineering education.

The data analysis proceeded through three stages. First, we read through all transcripts multiple times to identify instances of emotion acts, paying particular attention to emotion labels, anti-emotion labels, as well as distinct use of paralanguage, facial expressions, and gestures. We identified 26 excerpts in which students clearly used emotion acts in talking about engineering, engineers, and/or the wicked sustainability problem.

Second, we conducted a first round of analysis of these excerpts. We used storylines as the primary unit of analysis because they provide the necessary narrative context within which positions and communication acts can be understood and described (Davies & Harré, 1990; Harré, Moghaddam, Pilkerton Cairnie, Rothbart, & Sabat, 2009). Therefore, we began with formulating preliminary descriptions of emotional storylines related to engineering and engineering education. Based on these descriptions, we then developed preliminary descriptions of emotional positions and emotion acts. If an excerpt contained more than one emotional storyline, we divided it into subsections and analyzed each subsection individually. In an iterative process, we refined the descriptions by constantly comparing and triangulating across the three units of analysis (Warren & Moghaddam, 2018). The results of this analysis are described elsewhere (Lönngren, Adawi, & Berge, 2020).

Table 1: Formatting conventions for the multimodal transcripts.

Formatting	Meaning
S	Student
I	Interviewer
[…]	Parts of the transcript are omitted
[ ]	Text added for clarity or to describe non-verbal communication
Bolded	Emotion labels and anti-emotion labels
Italics	Verbal stress
Underlined	Aspects of emotion acts other than (anti-)emotion labels and verbal stress: Linguistic features (e.g., hedging, pronouns), paralanguage (e.g., pitch, speed, laughter), facial expressions, and gestures

Third, we selected three excerpts for deeper analysis and to illustrate the use of multimodal positioning analysis in this paper. These excerpts were selected to illustrate how two different emotional moral orders are activated and navigated: the dominant moral order according to which engineering should be purely rational (Excerpts 1 and 3) and a competing moral order according to which emotions should play a role in engineering (Excerpts 2 and 3). The excerpts were taken from three different interviews and three different parts of the interviews: challenging the students' argumentation (Excerpt 1), discussing the problem from the perspective of an engineer (Excerpt 3), and reflecting on the students' experiences of discussing the problem (Excerpt 2).

We expanded the verbal transcripts of these excerpts into multimodal transcripts, which include detailed information about students' gestures and facial expressions, line drawings,[1] and illustrations of sound patterns[2] (c.f. Goodwin et al., 2012). Again, we were primarily interested in how the students positioned themselves in relation to more general storylines. Therefore, while we did include some information about the interviewer's actions in the multimodal transcripts, both the transcripts and our analysis foregrounded the students' actions. Each author then independently analyzed the transcripts and formulated emotional storylines, emotional positions, and emotion acts. Finally, we compared and consolidated the analyses.

The formatting conventions for the empirical excerpts are summarized in **Table 1**. They include transcription conventions as well as analytical conventions (e.g., for indicating verbal stress and emotion labels). Throughout the remainder of the paper, we use the gender-neutral singular pronoun they/them for individual students.

Illustration of results obtained in using the analytical framework

In this section, we illustrate how the developed analytical framework—in tandem with multimodal analysis—can be used for studying the role of emotions in engineering problem solving. To this end, we draw on three excerpts from our pilot study, with some context added from the interviews to facilitate an understanding of the excerpts. The analysis focuses on how emotion acts activate emotional moral orders**,** construct (or challenge) emotional storylines**,** and make certain emotional positions available. The analysis shows how a dominant storyline of engineering as purely rational can be reconstructed (Excerpts 1 and 3), but also how a competing storyline of emotions as important for engineering can be constructed (Excerpts 2 and 3). It also illustrates how students can negotiate tensions between different emotional positions in these two emotional storylines (Excerpt 3).

Excerpt 1: Engineering should be purely rational

The first excerpt (**Table 2**) is taken from the part of the interview where the interviewer posed critical questions to challenge the students' argumentation. Shortly before the extract, the student (S2) had suggested solving the problem of water-shortage in Jordan by building desalination plants. The interviewer then asked how the electricity for the desalination process should be produced, which led the student to suggest a small-scale desalination process based on evaporating water solely through solar heating. The interviewer continued challenging the student's suggestions and argumentation, for example by asking whether small-scale desalination could meet the high freshwater needs in Jordan and pointing out that most electricity production in Jordan today relies on burning fossil fuels. The student responded to several of these challenges by iteratively modifying their suggested solution. Finally, the student concluded that it is not possible to find a solution that

[1] Constructed via https://online.rapidresizer.com/photograph-to-pattern.php.

[2] Constructed via the phonetics software Praat, available at https://www.fon.hum.uva.nl/praat/.

makes everyone happy and that engineers, therefore, should develop technology without asking the general population for their opinions, for example regarding which animal species should be protected or not. The excerpt below begins with the interviewer responding to this suggestion, asking whether it is possible to develop new technology without taking people's opinions and values into account and without taking a personal stance in these types of questions. The interview setup is illustrated in **Figure 2**.

In this excerpt, the student activates a dominant emotional moral order according to which engineering problem solving should be purely rational and emotions and personal values should be disregarded. This emotional moral order is articulated in one emotional storyline: "Emotions are irrelevant and/or detrimental to engineering problem solving" (ES1).

ES1: Emotions are irrelevant and/or detrimental to engineering problem solving. This emotional storyline is visible in lines 3–8 and 15–19. The student constructs this emotional storyline through several emotion acts. First, they use multiple anti-emotion labels, such as "**basic *theory***" (line 3), "***see* the effects**" (line 4), "***solve the problem***" and "***present*** it to others" (lines 6–8), "***cold analysis***" (lines 15–17), and "***economics***" (line 19). They also place verbal stress on these anti-emotion labels and repeat the word "***cold***". All of these emotion acts are used to describe activities during which emotions should be bracketed, thus activating an emotional moral order in which rationality is highly valued: Science and engineering should be based on general theories and objective observation, and emotions are considered irrelevant or even detrimental. Finally, the student uses facial expressions (frowning) and gestures (rapid movements with a tensed and fully open hand) that construct the activated emotional moral order as not open for discussion. Two emotional positions are made available in this emotional storyline: "Engineers as rational problem solvers" (EP1a) and "Others (non-engineers) as influenced by emotions and therefore not as capable of solving problems as engineers" (EP1b).

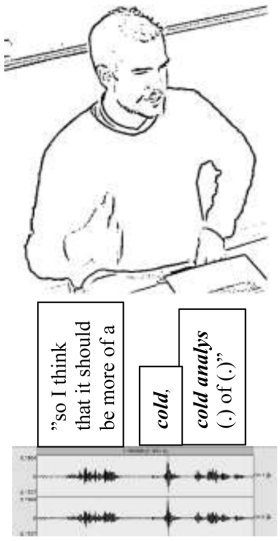
Table 2: Multimodal transcript for Excerpt 1.

Line	Speech	Gestures and facial expressions	Line drawing and sound patterns
1	I: But is it possible to develop technology without ***taking* a stance** on those questions?	I looks at S2 and smiles slightly. S2 looks at I with their left hand at their left hip.	
2	(.)	S2 swallows.	
3	S2: Uhm (.) no. (.) But if it's based on (.) **basic *theory*** (.)	S2 moves their right hand from their shoulder downward so that their lower arm comes to rest slightly above the table. S2 repeats the gesture, but with a smaller movement than before. S2 then keeps the open hand still in front of themselves with the thumb pointing upward.	
4	S2: Then, then you can (.) do (.) uhm then you can ***see* the effects**	S2 nods their head slightly. S2 moves their right hand from their shoulder downward again in an even smaller movement.	

(Contd.)

Line	Speech	Gestures and facial expressions	Line drawing and sound patterns
5	S2: of the technology, (.) maybe before you've *implemented* it.	S2 moves their hand towards the right (the thumb pointing upward) and back towards the left. S2 closes their hand and lowers it so that it comes to rest on the table.	
		[lines omitted]	
6	S2: So ***solve the problem*** (.) and then	S2 moves their right hand from their shoulder downward with thumb and index finger touching, then closes their hand and lets it rest on the table. I takes notes.	
7	S2: you can ***present*** it to others (.)	S2 lifts their right hand from the table and moves it towards the right, still with thumb and index finger touching.	
8	S2: how *how* you would **solve it**.	S2 scratches their forehead.	
9	S2: And uhm, if they **think** you sacrifice **too many** animals (.) in (.) how you ***solve*** (.) **the problem** (.) then they'll probably **vote** *against*	I stops taking notes, puts their hands in their lap, and looks at S2. S2 moves their right hand from their shoulder downward, then toward the right, and back toward the left. I nods slightly.	See lines 3 & 5
10	S2: your **proposal**. (.)	S2 lifts their eyebrows.	
11	S2: But in that case, it has to be *said* that (.) **there may not be any**	S2 moves their right hand from their shoulder downward.	See line 3
12	S2: ***other*** (.)	S2 moves their right hand toward the right	See line 5
13	S2: ***good*** (.)	S2 moves their right hand back toward the left and the toward the right again	

(Contd.)

Line	Speech	Gestures and facial expressions	Line drawing and sound patterns
14	S2: **proposals**. (.)	S2 holds their right hand around the corner of the table-top and drums lightly with their index finger on its edge.	
		[lines omitted]	
15	S2: Uhm, so I think that it should be more of a (.) ***cold***	S2 moves their tensed and fully open right hand from their shoulder downward. S2 frowns.	
16	S2: ***cold***	S2 moves their tensed and fully open right hand up and down quickly several times with the thumb pointing upward. S2 frowns.	
17	S2: ***analysis*** (.) of (.) what **actually *happens***	S2 rests their still tensed and fully open right hand on the table with the thumb pointing upward.	
18	S2: (.) u:hm (.) maybe (.) *based*	S2 moves their right hand toward the right and directly back toward the left.	See line 5
19	S2: on (.) ***economics*** (.)	S2 moves their right hand from their shoulder downward, then places their open hand on the table with the thumb pointing upward.	See line 3
		[lines omitted]	
20	S2: So **it's not up to *me* to *decide* what *I think* (.) about *nature* and (.) how (.) society should be organized**.	I takes notes. S2 points towards their breast and keeps their hand there for a few seconds.	

EP1a: Engineers as rational problem solvers. Evidence of this position is found in lines 6–8 and 15–19. The student uses the same types of emotion acts as described above for ES1 to position engineers as people who should "***solve the problem***" through "***cold analysis*** of what **actually *happens***", based on "***economics***". The engineer should do so without taking others' subjective values and emotions into account and only "***present***" the final solution. The student also positions themselves in relation to ES1 as a rational engineer, stating that "**it's not up to *me* to *decide* what *I think* (.) about *nature* and (.) how (.) society should be organized**" (line 20). Non-verbal communication, such as verbal stress on the first-person pronouns "***me***" and "***I***", as well as pointing towards themselves, strengthens the student's uptake of this emotional position. Through all of these emotion acts, the student positions themselves as an engineer who is a rational problem solver and assigns themselves the right and duty to bracket emotions in problem solving.

EP1b: Others (non-engineers) as influenced by emotions and therefore not as capable of solving problems as engineers. This emotional position is made available in lines 9–14, where the student says "they [others] **think** you sacrifice **too many** animals" and "they'll probably **vote** *against* your proposal". Here, non-engineers are positioned as people who are influenced by personal values (and thus emotions). The student then constructs others' use of values and emotions as illegitimate, stating that "**there may not be any *other good* proposals**." In other words, it is unreasonable to reject the rational

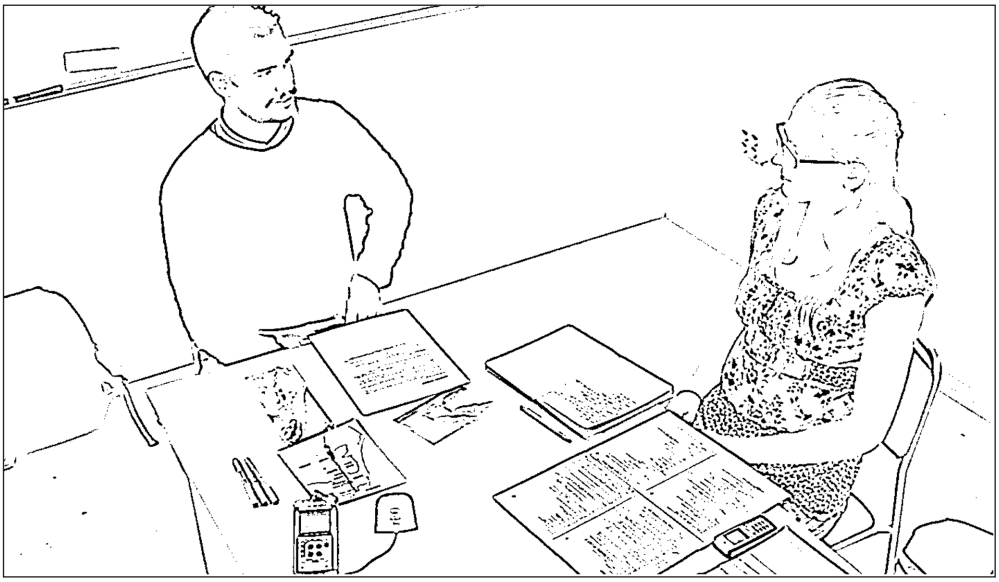


Figure 2: Interview setup for Excerpt 1, with the student (S2) to the left and the interviewer (I) to the right.

solution proposed by the engineer. The student thus positions people who are influenced by emotions as not as capable of solving problems as rational engineers. Non-engineers are positioned as having the right to be influenced by emotions, but also the duty to leave problem solving to engineers (who are more rational).

Throughout the extract, the student uses gestures and facial expressions that position themselves as certain and that construct the activated emotional moral order as unquestioned and unquestionable. When the interviewer challenges this emotional moral order ("I: But is it possible to develop technology without ***taking* a stance** in those questions?"), the student shortly acknowledges this challenge (in lines 2–3, they make a short break, swallow and say "uhm (.) no"), but the student then re-activates the same emotional moral order, stating that decisions should be "based on (.) **basic *theory***".

Excerpt 2: Emotions should play a role in engineering

The second excerpt (**Table 3**) is taken from the end of a different interview. The interviewer and the student (S4) have discussed the problem and solution approaches from different perspectives for almost an hour. Several times during the interview, the student has expressed that they find it difficult to discuss the problem since it does not seem possible to avoid human suffering and ecological degradation. At the end of the interview, the interviewer picks up on an earlier comment from the student who, in one of the role-playing sequences, had stated that it is "awful" to ask someone to discuss the presented problem in this way. The interview setup is illustrated in **Figure 3**.

In this excerpt, the student activates a competing emotional moral order: "Emotions should play a role in engineering." This emotional moral order is articulated in one emotional storyline: "Emotions are relevant and/or important for engineering problem solving" (ES2).

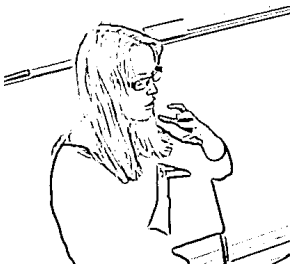
ES2: Emotions are relevant and/or important for engineering problem solving. This emotional storyline is co-constructed between the student and the interviewer. The interviewer first picks up on a remark the student made earlier during the interview where the student said that asking someone to address the presented problem was "***awful***". In two emotion acts, the interviewer re-uses this emotion label (lines 1 and 3). The interviewer thus re-constructs an emotional storyline that had been in play earlier during the interview and in which emotions were constructed as relevant to dealing with the presented problem. Through both verbal (asking) and non-verbal communication (smiling and laughing), the interviewer invites the student to elaborate on their construction of this emotional storyline.

In the remainder of the excerpt, the student constructs an emotional moral order according to which empathy (and thus emotional engagement) is an important virtue. Within this emotional moral order, the student constructs ES2 by using emotion labels such as "**it affects *people***" (lines 4 and 16) who belong to "***our own species***" (line 11). In an emotional moral order where empathy is valued, having to decide "**which *people* should be *affected***" (line 16) is "***morally***" (lines 6–7) "***difficult***" (line 5) and therefore involves a lot of "***emotions***" (line 15). The construction of empathy as important is strengthened through the student's use of verbal stress on many of the emotion labels. It is also strengthened through falling intonation in line 5 and expressive gestures (e.g., tense hand in lines 11 and 15 and large arm movements in line 12). One emotional position is made available in this emotional storyline: "Engineers as empathetic human beings" (EP2).

Table 3: Multimodal transcript for Excerpt 2.

Line	Speech	Gestures and facial expressions	Line drawings and sound patterns
1	I: You said that (.) it is ***awful*** (.) this question.	S4 looks at I, hands in front of their body, left elbow resting on the back of their chair, right elbow resting on the table. I has their hands in their lap and looks at their notebook on the table. S4 slightly tosses their head. I turns to look at S4 and smiles and speaks with a slight tone of laughter.	
2	S4: [laughs] Yes.	S4 smiles and looks at the problem description.	
3	I: What is it that is so ***awful*** about it?	I looks at S4 and smiles. S4 smiles and moves their body forward and then back again.	
4	S4: Uhm (.) the *social aspect*, that (.) **it affects *people***. (.)	S4 looks at the problem description, then slightly tosses their head and looks at I. I nods.	
5	And uh. No, it's a ***difficult situation*** to be in. (.)	S4 looks at the problem description and nods slightly while saying "difficult situation". "To be in" is spoken with a soft voice and falling intonation.	Pitch analysis for "to be in" 
6	I: **Morally**?	I looks at S4 and nods slightly.	
7	S4: ***Morally***, yes, exactly. (.)	S4 looks at the problem description and nods.	
8	S4: Uhm. [exhaling] (.)	S4 tilts head to the left and supports head with the left hand, left elbow resting on the chair's backrest.	
9	S4: I mean, like (.) *ecological sustainability* (.) sure that's [exhaling, inhaling] (.)	S4 lifts head back up into neutral position, looks at I, brings left hand in front of their body and fingers with the sleeve of their shirt. S4 moves their left hand towards and away from their body twice in small movements, then lowers hand and gaze, smiles slightly.	

(Contd.)

Line	Speech	Gestures and facial expressions	Line drawings and sound patterns
10	how should I say *this*? (.)	S4 rests head on their left hand and looks up over the table (but not towards I).	
11	S4: ***Humans***, that's ***our own species*** after all.	S4 lifts head back up into neutral position, looks at I, and brings the left hand to a position close in front of their mouth. The left hand is tense but open and kept still in front of S4's mouth. S4 slightly nods with each word in the phrase "our own species".	
12	S4: But we may not **value** (.) a (.) *bird* differently than a (.) *cat* or an (.) an algae or whatever.	S4 smiles slightly, then moves their open hand to the left while saying "bird", to the right while saying "cat", back to the right (but not as far as the first time) while saying "algae".	
13	S4: Well, maybe we *do* (.) *but* (.)	S4 nods slightly, and slightly moves the hand down and up, looking at I. S4 then moves their left hand back to the right when saying "but", palm facing down, fingers spread, and looks down at the problem description.	
14	S4: But it's not [exhaling] (.)	S4 looks up (but not at I), smiles slightly, then closes hand into a fist.	
15	S4: it doesn't involve *as* much ***emotion***	S4 looks at I, opens hand while moving it away from the body, back toward the body and away again. S4 moves hand back towards the body.	

(Contd.)

Line	Speech	Gestures and facial expressions	Line drawings and sound patterns
16	S4: as when (.) you discuss **which *people* should be *affected*** by it.	S4 looks slightly away from I. I takes notes. S4 moves hand slightly down and up several times, then brings the hand to their chin.	

Figure 3: Interview setup for Excerpt 2, with the student (S4) to the left and the interviewer (I) to the right.

EP2: Engineers as empathetic human beings. Both the interviewer and the student smile and laugh during the initial exchange (lines 1–3), which may serve to position them as co-creators of the emotional storyline rather than conflicting parties. This may be necessary since the student's remark, that the question was "***awful***", could otherwise have been constructed as a critique towards the interviewer. The emotion acts of smiling and laughing are also direct enactments of empathetic interaction through which both the interviewer and the student are positioned as empathetic human beings.

In the remainder of the excerpt, the student positions themselves as empathetic in several ways: First, they state that having to decide "**which *people* should be *affected***" (line 16) puts the problem solver (in this case the student) in a "***morally***" (lines 6–7) "***difficult situation***" (line 5). Second, they use first-person pronouns in lines 11–13 ("our", "we"), positioning themselves as one of those who care for other people. Finally, the student enacts emotional engagement through intonation, gestures, and facial expressions. Falling intonation in line 5, as well as strong gestures in lines 11 and 15, position the student as emotionally affected by other peoples' well-being.

At several times during this excerpt, the student seems to hesitate, for example in line 8 ("Uhm. [exhaling] (.)", resting head in hand), line 10 ("how should I say *this*? (.)"), lines 13–14 ("Well, maybe we do (.) but (.)", "But it's not [exhaling] (.)", slow hand movements), line 15 (bringing hand to chin), and repeatedly looking down at the problem description. This hesitation could have positioned the student as not very certain about the emotional storyline and position they are constructing. In this excerpt, however, it seems to position the student as even more caring: they care enough to take time to reflect on what it means to care for people (and to some degree animals, in lines 12–13). Throughout the excerpt, the student assigns themselves the rights and duties to care for others and, in doing so, express emotions.

Excerpt 3: Conflicting emotional moral orders

The third excerpt (**Table 4**) is taken from the part of the interview where the students were asked to discuss the problem from the perspective of an engineer. Accordingly, the interviewer had asked the student (S7) to assume the role of an engineer tasked to address the problem. The student did not play that role but instead used a third-person perspective to

discuss what an engineer might do in such a situation. They suggested that, as an engineer employed at a company, one should not focus too much on social aspects because it would be unreasonable to expect that an engineer could solve "democratic problems" in Jordan. Rather, an engineer should focus on increasing the amount of available freshwater. The student and interviewer continued discussing what types of potential social and ecological consequences an engineer should consider. The student concluded that an engineer should first assess what solutions would be economically sustainable, since that would be the first priority for the company, and only then assess and report ecological and social consequences of different solution alternatives. However, deciding which consequences to accept—and thus which solution to use—would not be part of an engineer's responsibility. The excerpt begins with the interviewer asking the student whether that means that they, as an engineer employed at a company, would try to be as value-neutral as possible. The interview setup is illustrated in **Figure 4**.

In this excerpt, the student constructs both of the previously described emotional storylines (ES1 & ES2) and thus activates both the dominant and the competing emotional moral order. The student navigates the arising conflict using emotion acts to position themselves as both a rational engineer *and* an empathetic human being.

ES1: Emotions are irrelevant and/or detrimental to engineering problem solving. This emotional storyline was also identified in Excerpt 1. ES1 is here visible in lines 3, 7, 10, and 13. The student uses emotion acts in the form of anti-emotion labels focused on rationality, such as "***discuss***", "***think***", "***objectively***" (line 3), and "**objective**" (line 13). They also use anti-emotion labels in the form of words that are often used in describing structured ways of thinking, such as "**points**" on a list (line 7). The construction of this emotional storyline is strengthened through verbal stress on anti-emotion labels, as well as gestures. For example, in line 7, the student illustrates the "**points**" they are speaking of by repeatedly tapping the back of their pen on the table in a pattern that resembles a list, and, in line 10, they lift and lower their hands in a regular pattern as if intending to, again, illustrate a list of "***important*** problems".

Table 4: Multimodal transcript for Excerpt 3.

Line	Speech	Gestures and facial expressions	Line drawings and sound patterns
1	I: So (.) as an engineer, you would try to be as **value-neutral** as possible?	I stops taking notes in their notebook, puts down their pen, looks at S7, and puts their hands in their lap. S7 has the fingers of their left hand on the table. S7's right wrist rests on the edge of the table, the rest of the hand is lifted a few centimeters above the table and S7 holds a ball pen between the right hand's index finger and long finger. S7 bites their lower lip and wiggles the pen up and down between their fingers.	
2	S7: (.)	S7 turns their gaze upwards and to the right (away from I) for a moment, then back towards I.	

(Contd.)

Line	Speech	Gestures and facial expressions	Line drawings and sound patterns
3	S7: Uhm (.) in *some* ways, *yes* (.) but at the same time (.) I'd try to ***discuss*** (.) problems (.) uhm (.) ***objectively***. (.) But (.) which problems I'd (.) maybe ***think*** of to ***discuss***, (.)	S7 lifts their right hand a few centimeters above the table. S7 moves the hand slightly forward but keeps it above the table. I nods slightly.	
4	S7: I'd *expect* that to be influenced (.) *by* ***my*** **values**.	S7 moves their hand towards the left and then holds it still in front of their body, the ball pen in their hand pointing towards I. I nods slightly.	
5	S7: And that's maybe something you **wouldn't want to avoid *completely***.	S7 moves their body forward slightly and lowers their hand, still keeping it above the table. I nods slightly.	
6	S7: Like if ***I*** (.) ***care*** **a lot** about (.) uhm (.) a certain animal species [inaudible], then I'd maybe (.) have invested some time to (.)	S7 turns the palm of their right hand upwards, lifts the hand slightly, and lowers it again. S7 shakes their head several times in very small movements. I nods slightly. S7 lowers their right hand to the table.	
7	S7: highlight (.) some **points** there.	S7 lifts their right hand again and taps the table with the back of the ballpoint pen five times, moving the hand slightly towards their body for each tap. I nods several times.	 
8	(.)	S7 closes their hand, lowers it, and lets it rest on the table, close to their body. S7 bites their lower lip for a few seconds. I continues nodding.	
9	S7: Uhm (.) And it's not the same as, uhm (.) what you shou- shou- (.)	S7 lifts both hands and turns their palms upwards.	

(Contd.)

Line	Speech	Gestures and facial expressions	Line drawings and sound patterns
10	S7: ideally, I suppose you ***should*** try to, uhm (.) highlight all ***important*** problems. (.)	S7 lowers their hands to the table, both thumbs pointing upwards. S7 raises and lowers their hands three times. Each time S7 lowers their hands, they move their hands slightly away from each other, still with both thumbs pointing upwards. S7 then lets their hands rest in that position for a few seconds.	
11	S7: But I suppose **you can't expect** to be *able* to (.) **think** of ***everything*** (.) but (.) you **should** think about (.) about the ***big*** questions and then, like	S7 first keeps hands in the same position. I nods slightly. S7 then lifts both hands from the table with the palms of their hands pointing downwards with spread fingers. S7 moves their hands slightly forward and backward several times. When the right hand moves forward, the left hand moves backward and vice versa.	 
12	S7: (.) Well, what should I say?	S7 rests their hands in their lap and turns their gaze upwards and to the right (away from I), squinting.	
13	S7: Which areas you **choose** to ***consider***, that *will* be influenced by **who you are as a *person***. (.) But I suppose you can *expect* that that's done **in an objective *way***, and that you try (.) to get (.) some kind of ***holistic understanding*** of it.	S7 turns their gaze back towards I. I nods slightly.	
14	(.)	I starts taking notes. S7 turns their gaze upwards and to the right (away from I)	See line 12

Figure 4: Interview setup for Excerpt 3, with the student (S7) to the left and the interviewer (I) to the right.

EP1a: Engineers as rational problem solvers. This emotional position was also constructed in Excerpt 1. Here, it is constructed in lines 3 and 6–7, where the student uses the personal pronoun "I" together with the anti-emotion labels "***discuss***", "***think***", "***objectively***", and "**points**", indicating uptake of an emotional position as a person who approaches problems rationally.

EP1a is also visible in lines 10–13, where the student speaks of the need to "highlight all ***important*** problems" (line 10) and to "think about (.) about the ***big*** questions" (line 11). The student again uses anti-emotion labels, stating that engineers should approach problems "**in an objective *way***", trying "to get (.) some kind of ***holistic understanding***" (line 13). The verbally stressed words "***important***" and "***big***" could have been interpreted as referring to subjective values—and thus to the importance of emotions. In this context, however, they rather contribute to positioning engineers as people who can *objectively* determine what is important and what is not. The other emotional position found in Excerpt 1 (EP1b) is not made available in this excerpt.

ES2: Emotions are relevant and/or important for engineering problem solving. This emotional storyline was also identified in Excerpt 2. ES2 is here visible in lines 5–7, where the student states that "you **wouldn't want to avoid *completely***" to take personal values (and thus emotions) into account in engineering problem solving. They further state that it is legitimate to "***care* a lot** about" a certain species and to present information selectively based on what one cares about. In other words, emotions related to empathy and care are constructed as something engineers have the right to feel and to let themselves be influenced by. Emotions are constructed as relevant information that can be taken into account in engineering problem solving. However, this emotional storyline is weakened through hedging as the student uses qualifiers such as "***completely***" and "**a lot**". Non-verbal communication also contributes to weakening this emotional storyline as the student places verbal stress on the qualifier "***completely***" and slightly shakes their head several times.

EP2: Engineers as empathetic human beings. This emotional position was also constructed in Excerpt 2. Here, it is constructed in lines 3–4, where the student acknowledges the importance of personal values (and thus emotions), and in lines 6–7, where the student positions themselves as empathetic and thus not quite as purely rational as the stereotypical engineer that is positioned in EP1a. The student states that "if ***I*** (.) ***care* a lot** about (.) uhm (.) a certain animal species [inaudible], then I'd maybe (.) have invested some time" to ensure that issues concerning this species are raised. The emotion label "***care***" is spoken with verbal stress, further strengthening the legitimacy of empathetic feelings in engineering. Both here and in lines 3–4, the student uses first-person pronouns, indicating personal uptake of EP2. This uptake is further strengthened through verbal stress on "***my***" (line 4) and "***I***" (line 6).

In lines 11 and 13, the student constructs EP2 for someone (presumably an engineer) who "**can't expect** to be *able* to (.) **think** of ***everything***". Instead, "**who you are as a *person***" will influence "which areas you **choose** to ***consider***". Again, personal values and emotions related to what one finds important and cares about are constructed as legitimate sources of information for engineering problem solving. Emotion labels in these statements consist of the negated term "***everything***", the word "**choose**", and the expression "**who you are as a *person***". In addition, the student places verbal stress on "***everything***" and "***person***", further strengthening the construction of this emotional position.

Navigating conflicting moral orders. The student repeatedly positions themselves as uncertainty as they navigate the two conflicting emotional moral orders that are activated simultaneously: (1) "Engineering should be purely rational" and (2) "Emotions should play a role in engineering". The student seems to struggle with which of the two emotional storylines (ES1 or ES2) is most important in the situation. This is demonstrated on several occasions when the student uses emotion acts that seem to indicate that they are unsure about what to say: they bite their lower lip (lines 1 and 8), gaze up towards the ceiling rather than the interviewer (lines 2 and 14), squint (line 12), shake their head several times in small movements (line 6), wiggle their pen (line 1), rhetorically ask themselves "(.) Well, what should I say?" (line 12), and use ambiguous statements such as "uhm (.) in *some* ways, *yes* (.) but at the same time (.)" and "maybe" (line 3). In addition, the student uses weakening modifiers/hedges, for example in stating that you wouldn't want to avoid values "***completely***" (line 5) and that you "ideally" should "try" to be objective (line 7); both of these statements would have been much stronger if these modifiers had been omitted. In fact, examining the excerpt as a whole, the student seems to oscillate between positioning themselves in relation to ES1, ES2, and somewhere in between. As two conflicting emotional moral orders are activated simultaneously, the student needs to navigate this conflict and does so by taking up emotional positions as both rational (but not too much) *and* empathetic (but not too much).

As the analysis of these three excerpts shows, applying positioning theory to the study of emotions allowed us to explore individual students' emotion acts while simultaneously relating them to broader societal norms about who engineers should be and how they should—or should not—relate to emotions. It also allowed us to develop a nuanced understanding of different emotional moral orders, storylines, and positions that may be at play simultaneously in engineering classrooms. Finally, thanks to this nuanced understanding, we could identify ways in which emotion-related values can be changed in engineering education (see *Implications for engineering education practice* below).

Methodological issues and recommendations for applying positioning theory and multimodal analysis in engineering education research

Having illustrated how we applied positioning theory and multimodal analysis to explore the role of emotions in engineering problem solving, we now turn to a discussion of four overarching methodological issues we encountered during our analysis: (1) developing a thorough understanding of the empirical context, (2) clarifying and delimiting the analytical focus, (3) comparing findings across several analysts, and (4) conducting and reporting a multimodal analysis. Along the way, we also provide recommendations for applying positioning theory and multimodal analysis in engineering education research.

Developing a thorough understanding of the empirical context

In the pilot study, the students gave written informed consent for the first author to access all data and for external partners to only view anonymized data excerpts. Therefore, only the first author could view the video data, while the other authors read selected, anonymized transcripts. However, during data analysis, we realized that a thorough understanding of the empirical context—beyond reading selected transcripts—is important for correctly identifying emotional storylines, emotional positions, and emotion acts. Throughout the analysis process, we, therefore, spent a considerable amount of time talking about the research context, both the immediate contexts of individual interviews and the broader context in which the interviews were conducted. For example, the students frequently referred back to what they had said earlier in the interview and to their experiences from a course on sustainability in which they were enrolled during the time of the interviews. We therefore suggest that researchers should strive to obtain informed consent that allows all researchers involved in the analysis to view the video data. We also suggest that all researchers should familiarize themselves with the broader research context. It may also be advisable to complement video data with data from broader ethnographic observation in the research context. This would allow researchers to better understand how participants activate—or challenge—moral orders that may not be made explicit in the video data (which, to allow for a detailed positioning analysis, often is rather limited in scope).

Clarifying and delimiting the analytical focus

We experienced a need to iteratively clarify our analytical focus. First, we needed to identify a distinct analytical focus rather than trying to analyze all forms of communication acts, positions, and storylines simultaneously. For example, MB initially conducted a comprehensive analysis of the selected excerpts, focusing on both emotional and non-emotional storylines and positions. By doing so, MB identified, among others, the following non-emotional positions: (1) "Engineers are subordinated to economists", (2) "Engineers don't make decisions at a societal level", and (3) "Engineers should consider environmental and social concerns in their work". The presence of these positions in the data points towards the value of positioning theory for exploring a wide range of phenomena in engineering education research. However, to address the purpose of our pilot study, we needed to zoom in on emotional aspects.

We also needed to clarify the level of detail in our analysis. Initially, JL analyzed on the level of words or short expressions, while MB focused on whole phrases or sentences. Since our approach to identifying emotion acts focuses on words or short expressions (emotion labels, anti-emotion labels), as well as gestures and facial expressions (Hufnagel & Kelly, 2018), we

eventually agreed to analyze emotional storylines, emotional positions, and emotion acts on the level of words or expressions rather than whole phrases or sentences.

Further, we needed to decide whether we would primarily focus on interactive positioning between student and interviewer or on how the students positioned themselves in relation to emotional moral orders in engineering problem solving. Due to the focus of our study, we were more interested in the latter. Therefore, our multimodal analysis is more focused on emotion acts performed by the students than the interviewer. However, the analysis of Excerpt 2 illustrates how emotional moral orders and emotional storylines can be co-constructed in interaction. In fact, Ritchie and Rigano (2001) argue that a complete positioning analysis of interview data should also explore the interaction between researcher and participant. While such an analysis is beyond the scope of the present paper, it could lead to valuable insights on interactive positioning that, in turn, could be translated into concrete pedagogical strategies. For example, it could provide insights into how engineering educators can strengthen emotional storylines and positions that encourage students to constructively engage with educational material, also called "emotional scaffolding" (Lönngren, Adawi, & Berge, forthcoming; Lönngren, Adawi, & Holmén, forthcoming; Rosiek, 2003).

Possibly because of our narrowly focused analysis, we noticed that emotional storylines and positions sometimes were very similar, almost appearing redundant. We were initially puzzled by this result but concluded that this is probably because our analysis focused on closely related emotional storylines and positions, both of which are focused on engineers/engineering. We expect that we would have found more diverging emotional storylines and positions if we had focused on engineering students' emotional positions in relation to emotional storylines about topics other than engineering, such as gender or politics. Still, in Excerpt 1, the student does position "others" (non-engineers, EP1b). The presence of this position in our analysis indicates that, in a more comprehensive analysis, it should be possible to identify a more diverse set of emotional positions for each emotional storyline. We also expect that researchers will identify more diverse emotional positions if they use naturalistic data rather than interview data and if they, as suggested above, analyze researcher-participant interaction to a larger degree.

The literature on positioning theory suggests several additional ways to specify the analytical focus that was beyond the scope of our pilot study. The following variations of analytical foci are described in the literature:

- Different types of positioning (Kayi-Aydar & Miller, 2018):
  - *Interactive* positioning refers to assigning a position to someone else.
  - *Reflexive* positioning refers to assigning a position to oneself.
- Different levels of positioning (Anderson, 2009):
  - Positioning at the *micro* levels refers to interaction at local/immediate scales.
  - Positioning at *meso* levels refers to interaction at institutional/intermediate scales.
  - Positioning at *macro* levels refers to interaction at structural/distal scales.
- Different orders of positioning:
  - *First order* positioning refers to "the initial act of positioning that introduces a certain storyline" (Bossér & Lindahl, 2019, p. 375).
  - *Second order* positioning refers to situations when the first order positioning "is contested by another person in the conversation" (Warren & Moghaddam, 2018, p. 6).
  - *Third order* positioning refers to situations when first order positioning "is contested by a third person talking about the conversation (i.e., not in the conversation directly)" (*ibid.*).

Kayi-Aydar and Miller (2018, p. 91) suggest that "examining these multiple orders and types of positioning would not only offer richer descriptions of classroom interactions but also help readers better understand the effects of power, resistance or agency in classroom positioning."

In fact, positioning theory is well-suited to analyze issues of power due to its focus on rights and duties associated with positions. All positions, including emotional ones, "involve changes in power, access, or blocking of access, to certain aspects of claimed or preferred identity" (Herbel-Eisenmann et al., 2015, p. 188). Positioning theory has also been widely used to study power issues in education (Kayi-Aydar & Miller, 2018) and a wide range of other contexts, such as public relations (James, 2015) and applied linguistics (Kayi-Aydar, 2018). We therefore expect positioning theory to be a useful lens for analyzing power related to emotional positions and emotional moral orders. Such research could, for example, investigate who is (or is not) allowed to display emotions when, how, and to whom. In this study, however, we decided not to analyze power issues because the power structure in the interviews was not "natural" (Van Langenhove, 2017) due to two primary reasons: First, the interviewer guided and structured the conversation, which means that an analysis of power differences between interviewer and interviewee becomes trivial. Second, the focus of the interviews was on what the interviewees said and valued, not the interviewer. Therefore, at least theoretically, only the interviewees' emotional moral orders were of interest in the conversation, while the interviewer attempted to remain as neutral as possible. (This is of course not strictly

true: although an interviewer's intention may be to be neutral, all interviewers expose values and opinions unconsciously.) In more natural interaction, for example among students in classroom settings, emotional moral orders and power structures are more open to negotiation and social change (Van Langenhove, 2017). When analyzing such interaction, it is therefore highly relevant to include a perspective of power. This is especially the case for studies on emotional positions since emotions and power are closely related (Boler, 1999; Glapka, 2019; Zembylas, 2007a).

Comparing findings across several analysts

After clarifying our analytical focus as described above, each of us individually analyzed the selected excerpts. When we compared our individual findings, we found very little disagreement between analysts: emotional storylines (ES) and emotional positions (EP) identified by several analysts were described in very similar terms, suggesting that our efforts of clarifying our analytical focus were successful. However, certain differences were still present in our initial, individual findings. Iteratively and collaboratively resolving these differences helped us clarify and deepen our analysis in several ways. First, it helped us clarify analytical distinctions between emotional positions and storylines. Our initial findings differed in that respect. For example, TA and MB initially described ES1 as a single emotional storyline, while JL described two distinct emotional storylines. Similarly, JL and MB initially described EP1a and EP2 each as several, distinct emotional positions. As our analysis deepened, we realized that it was difficult to analytically uphold those distinctions, and we decided to collapse them into the more overarching descriptions presented in this paper. Second, comparing our initial analyses helped us clarify *who* was positioned in our data: JL and TA initially described emotional positions for both "engineers" and "self", while MB only identified positions for "engineers". We concluded that "self" should not be described as an emotional position, but rather as the *uptake* of a position—that is, a student positions themselves *as* engineers who are rational problem solvers (EP1a) or empathetic human beings (EP2). Finally, comparing our initial analysis helped us develop a more complete analysis since not all of us identified all the emotional storylines and positions in our individual analyses (**Table 5**). Based on these experiences, we recommend that several analysts should be involved in positioning research and that research teams should allocate sufficient time for iteratively refining their analytical foci and results. We suspect that it may not always be possible to clearly and definitely delimit the analytical focus before having conducted preliminary analyses of one or several data excerpts. We also expect that arriving at stable results will require several rounds of analysis. Thus, collaborative and iterative analysis can help to ensure the validity of this type of research.

Table 5: Emotional storylines (ESs, white background) and emotional positions (EPs, grey background) identified by each analyst (across all three excerpts) compared to the overall results in which we combined the individual analysts' descriptions.

	Overall	Analyst JL	Analyst TA	Analyst MB
ES1	**Emotions are irrelevant and/or detrimental to engineering problem solving**	Emotions are irrelevant to engineering work. Emotions are detrimental to engineering problem solving.	Engineering is a *rational* business. It is possible and desirable to bracket emotions in engineering work.	Engineers solve problems rationally and without emotions.
EP1a	**Engineers as rational problem solvers**	Engineers as rational problem solvers Self as a rational problem solver	Self (engineer?) as rational, promoting engineering theories that are grounded in economics	Engineers solve problems. Engineers make rational choices that are not based on individuals' opinions or values (ethics).
EP1b	**Others (non-engineers) as influenced by emotions and therefore not as capable of solving problems as engineers**	Others (non-engineers) as people who are influenced by emotions	Others as emotional and therefore not able to solve problems	
ES2	**Emotions are relevant and/or important for engineering problem solving**	Emotions are relevant and/or important for engineering work.	It is not possible nor desirable to bracket emotions in engineering work.	
EP2	**Engineers as empathetic human beings**	Engineers as influenced by personal values Self as influenced by personal values Self as someone who is empathetic		Engineers have personal opinions and can therefore not be fully objective. Engineers should sometimes have personal opinions.

Conducting and reporting a multimodal analysis

There will always be trade-offs between comprehensiveness and depth of analysis, given that each researcher only can devote a limited amount of time for analysis and limited space for reporting results. Our analysis highlights the value of a detailed multimodal analysis for research on emotional moral orders in engineering and engineering education. For example, in Excerpt 1, lines 15–17, several modalities interact and contribute to constructing the emotional moral order that engineering should be purely rational: the student uses anti-emotion labels (e.g., *cold*, *analysis*), repetition of and verbal stress on these words, facial expressions (frowning), as well as gestures. The two authors who did not have access to the original video data experienced that the multimodal transcript conveyed a much stronger construction of this emotional moral order compared to the verbal transcript alone. In fact, TA experienced the multimodal transcript as very powerful, commenting: "you almost get scared reading these excerpts".

At the same time, as the reader will have noticed, reporting on detailed multimodal analysis takes a lot of space, and it may therefore not always be possible to report on all results in a single publication. In our analysis across all 26 excerpts, we identified two additional emotional storylines: (1) "Engineers need to be able to manage others' (non-engineers') emotions" (e.g., overcoming opposition to new technologies) and (2) "Certain emotions are part of what it means to be an engineer" (e.g., to love problem solving). The full results of our analysis are described elsewhere (Lönngren, Adawi, & Berge, 2020). It is interesting to note that these additional emotional storylines are related to the competing emotional moral order according to which emotions should play a role in engineering. We conclude that, in general, more data may need to be analyzed to develop a comprehensive description of emotional storylines and positions related to competing emotional moral orders as the latter may not be activated as often or explicitly as dominant moral orders. We suggest that a reasonable trade-off between comprehensiveness and depth of analysis can be achieved by analyzing data at several levels of detail. First, a broad analysis should be performed across enough data to reach saturation in terms of identified emotional storylines and positions. Second, a more focused analysis should be conducted of a smaller number of excerpts to be able to analyze selected emotional storylines and positions in depth.

In addition to analyzing a sufficient amount of data, it is necessary to report enough data to allow readers to evaluate the conclusions drawn from the analysis. In short data excerpts, it is "often difficult to see positioning because one needs more interactional context to ascertain what people are doing with one another" (Bomer & Laman, 2004, p. 441). As mentioned above, multimodal transcripts require a lot of space, making it difficult to report sufficient amounts of data in journals that only accept relatively short manuscripts. We therefore recommend publishing engineering education research employing positioning theory in journals with relatively generous page limits.

Contributions to research

This paper makes several contributions to positioning theory and engineering education research. The paper contributes to positioning theory by introducing an analytical framework for studying emotions through positioning theory and multimodal analysis. In particular, we have introduced and defined the following analytical concepts: *emotion acts, emotion labels, anti-emotion labels, emotional storylines, emotional positions,* and *emotional moral orders.*

The paper also makes four important contributions to engineering education research. First, we have illustrated how positioning theory can be applied to study the role of emotions in engineering education. We hope that this contribution can inspire other engineering education researchers to consider using positioning theory for studying emotions (and other topics) as *interactive* phenomena—rather than as *mental* phenomena, the latter of which is still the dominant theoretical approach in engineering education research. Second, we have illustrated an approach to multimodal transcription and analysis that should be useful for a wide range of engineering education research, including (but not limited to) analyses of positioning, paying attention to "features such as intonation, pausing, body movement, and gestures—moving beyond consideration only of participants' words" (Kayi-Aydar & Miller, 2018, p. 91). Third, we have started to identify emotional storylines and positions that can shed light on how and why engineering often is constructed as purely rational (Kellam et al., 2018). Finally, our results indicate how engineering students may negotiate a tension between the dominant emotional moral order, according to which engineering should be purely rational, and a conflicting emotional moral order, according to which emotions should be important in engineering. As long as this conflict is present in engineering education, students need to navigate it by positioning themselves as, alternately or simultaneously, rational *and* empathetic.

Implications for engineering education practice

This is primarily a methodological contribution to engineering education research, but we still want to briefly draw out some implications of our analysis for engineering education practice. Although the research is conducted in Sweden, we believe that there are patterns that we can generalize to other contexts (Swedish body language does not differ much from other Western countries). As mentioned above, engineering is often portrayed as a purely rational discipline (Kellam et al., 2018), where emotions are considered irrelevant or even detrimental to problem solving. Our analysis indicates that this also

is true for a Swedish context. We have described this perspective on engineering as the dominant emotional moral order, "Engineering should be purely rational". Some students in our sample, however, activated a competing emotional moral order, "Emotions should play a role in engineering". This finding suggests that the competing emotional moral order may be latently present in engineering education, and it should therefore be possible for engineering educators to activate and strengthen it. In our data, this emotional moral order was specifically linked to *empathy*, suggesting that engineering educators could focus on empathy to open up discussions about the role of emotions in engineering problem solving. Empathy is both a cognitive and an emotive process: "Cognitively, empathy is a process involving understanding the experience of others. Emotively, empathy is understood as the capacity to enter into or join the experiences and feelings of another person" (Strobel et al., 2013, p. 139). As such, empathy plays a crucial role in engineering problem framing (Beckman & Barry, 2012) and engineering ethics (Hess et al., 2020), meaning that these are two particularly relevant instructional contexts for discussing the role of emotions in engineering education.

Future research

Future research should explore emotional moral orders in naturalistic engineering education contexts to better understand how positioning occurs in classrooms rather than only in interview situations. It should also explore other types, levels, and orders of emotional positions that were beyond the scope of this paper, but that we expect to provide valuable insights about the role of emotions in engineering education, not least related to issues of power. Finally, we believe that future research could more closely connect empirical analysis to developing pedagogical tools for engineering education practice. Since positioning theory is focused on what people *do* in social interaction, using positioning theory can generate insights into what people could do *differently*, that is, insights that are actionable in educational practice. For example, the analytical framework presented in this paper can be used to identify situations where students grapple with value conflicts (since such situations are likely to trigger students to perform emotion acts) or where students' emotional positions may hinder learning and development. Such analyses could then be used as a basis for developing *emotional scaffolding* (Lönngren, Adawi, & Berge, forthcoming; Lönngren, Adawi, & Holmén, forthcoming; Rosiek, 2003). Based on the results from our pilot study, emotional scaffolding could, for example, focus on facilitating the activation of latent emotional moral orders or opening up new emotional positions that may enhance learning, for example in developing socio-emotive competencies.

Conclusions

Research on emotions in engineering education is rapidly increasing in recent years, but most studies conducted so far take their theoretical departure in individual and cognitivist perspectives (Kellam et al., 2011; Lönngren, Adawi, Bellocchi, et al., (forthcoming); Lönngren, Adawi, Berge, et al., 2020). In this paper, we have introduced an analytical framework for studying emotions through positioning theory and multimodal analysis. We have introduced the following analytical concepts: *emotion labels, anti-emotion labels, emotion acts, emotional positions, emotional storylines,* and *emotional moral orders*. We have also illustrated the application of our analytical framework in a multimodal analysis of three excerpts from student interviews about a wicked sustainability problem. In these excerpts, one student activated the dominant emotional moral order ("Engineering should be purely rational"), another student activated a competing emotional moral order ("Emotions should play a role in engineering"), and a third student activated both. Our analysis shows how students use emotion acts to negotiate emotional storylines and positions in relation to one or both of these emotional moral orders, which has important implications for engineering education: If a competing emotional moral order is latently present in an engineering education context, educators should be able to use emotional scaffolding to activate it and to intentionally support students in positioning themselves (and each other) as future engineers who are both rational and empathetic—that is, as engineers who can care about both technical details and the well-being of people and the planet. Finally, we have discussed a set of methodological issues we encountered in our analysis and offered recommendations for future research.

We conclude that positioning theory holds much potential for exploring a wide range of social interactionist phenomena in engineering education research. The potential for exploring the role of emotions in engineering education on sustainability or ethics is particularly high because positioning theory focuses analytical attention specifically on values (moral orders). This analytical focus allows researchers to explore emotions that arise when students grapple with value conflicts, which are common in sustainability and ethics education. We also see a large potential for combining research on emotional positioning with the development of pedagogical strategies to enhance student learning, for example by opening up emotional positions that allow students to actively engage with emotions and develop complex socio-emotional competencies.

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Competing Interests

The authors have no competing interests to declare.

Author Contributions

JL conducted and transcribed the interviews and selected empirical excerpts for the analysis in stages 2 and 3. All authors participated in the analyses in stages 2 and 3 and in writing the paper.

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