Chapter 17
Emotion in Engineering Design Teams

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17.1 Introduction

Knowledge that is relevant to the practice of engineering can be categorized into three domains. First is the knowledge of the natural world that we fashion into engineering artifacts. This includes knowledge domains such as physics, chemistry, biology, and thermodynamics. Second is the knowledge of processes that we may use to transform the natural world into engineered artifacts. These include various engineering design methods, production processes, and mathematical methods. The third is the knowledge of the humans creating and using the engineering artifacts. This involves understanding and improving how engineers perceive, think, and act individually or collectively, such as in teams or organizations, when they are engaged in the daily practice of engineering; and also understanding how the users of these artifacts perceive and interact with them in the course of their life cycle. This domain uses and synthesizes knowledge from other fields such as psychology, group work, cognitive science, sociology, and anthropology that focus on the human as a subject of study. However, it differs in one key respect from these fields in that its focus on the human is rooted in an engineering value system that seeks to understand in order to re-create artifacts and situations for the better. The study of emotion is an important part of the domain of humans creating and using engineering artifacts.

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At the Center for Design Research at Stanford University, we are predominantly engaged in understanding how engineers design new artifacts and how we can help them in designing more effectively. As such, we deal with the domain of humans creating engineering artifacts. In this chapter, we will explore the role of emotions in the activity of designing new engineering artifacts. We begin with a discussion on emotion in the context of engineering design teams, followed by a brief overview of perspectives in emotion research. We then present two research studies which examine the influence of emotion in two situations, namely group ideation and group conflict, which are common to engineering design teams.

17.2 Why Study Emotion in Engineering Design?

The context of our work is creative collaboration amongst engineering designers leading to new product development and eventually product and service innovation in the market place. While engineering has often been defined as the application of mathematics and science to the needs of the society, a definition that nominally has nothing to do with emotions, research on the process of design, in other words – how design happens – reveals quite the opposite.

Engineering designers increasingly work in multidisciplinary *teams* on *complex* and *functional* tasks whose outcome while *uncertain* in terms of the reception in the market place is expected to be *creative* (Figure 17.1).

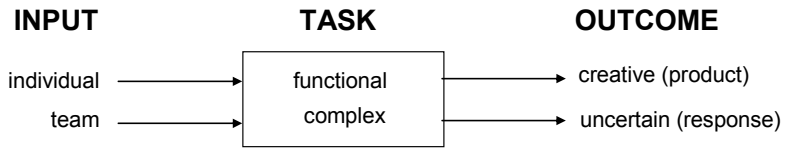

Figure 17.1 Engineers work on complex and functional tasks that require abstract and conceptual ideas to be translated into concrete and physical products, effects, and services for humans. This work is highly contextual and dependent on emotional cues. A systematic understanding of engineering cannot be done without a basic understanding of the emotional dynamics of their work situation

Within this six-element context of their work the only element that is devoid of emotion is the functional task, which essentially relies on mathematical and scientific knowledge. All other elements involve the implicit or explicit use of emotions. This could be, amongst other emotions, the look and feel of the tangible product or service experience (aesthetic), the interpersonal conflict resulting from an unresolved disagreement or perceived humiliation, the excitement over a particular product concept, the fear associated with the danger of product failure, or the shame associated with the utterance of a wild idea. Some of these effects would have had less of an impact if engineering designers did not have to work in

teams, if the fraction of time during which they are engaged in purely functional tasks was large, or if they were not responsible for coming up with imaginative ideas. Indeed, according to Crispin Hales, engineering designers working in industry spend almost 50% of their time and effort attending to tasks that are more social in nature, and more associated with the other five elements where emotions predominate [1]. Needless to say, any attempt to improve the performance of engineering designers through systematic study must pay attention to their emotions.

Given our interest in creativity for which human imagination is the source, we see a direct relation to emotion as expressed by the following simultaneous relations:

- Imagination → Emotion → Action (*e.g.*, verbal expression of an idea).
- Outcome ← Emotion ← Reaction (*e.g.*, non-verbal expression of disinterest by team).

The outcome will include the possibility that the idea is not written in the meeting minutes or public whiteboard used for brainstorming. Also the speaker may feel embarrassed and may no longer wish to contribute to the discussion. In this way, a designer's emotional state allows us to account not only for his or her subjective appraisal of a situation but also for their perception and motivation. When we study engineering in this way, we are able create in a more systematic manner an alignment between people, tasks, and situations that increases the chances for creative breakthroughs.

17.3 Perspectives in Emotion Research

Imagine three engineers grouped around a table. They are all part of a team and are engaged in a discussion about what they should have accomplished as a final project deliverable (see Table 17.1).

If we are attuned only to speech, this is all we can observe. However, once we start attending to emotional cues, a very different quality of the interaction emerges (see Table 17.2).

Table 17.1 Interaction segment with verbal content only

Speaker	Content
Sarah:	So… what should we have done for the final presentation?
Becky:	So I think this was this conversation that we started while we were walking here, right?
Sarah:	Yeah.
Tom:	Well, do we want to start with what the ideal thing is and then start taking away from there?
Becky:	Ok
Sarah:	We all know what the ideal thing is.
Becky:	We all know what the ideal thing is, it works, it's beautiful, like…

Table 17.2 Interaction segment with verbal content and emotion expression

Speaker	Content	Emotion
Sarah:	So … what should we have done for the final presentation?	[Neutral]
Becky:	So I think this was this conversation that we started while we were walking here, right?	[Neutral]
Sarah:	Yeah.	[Neutral]
Tom:	Well, do we want to start with what the ideal thing is and then start taking away from there?	[there is a dragging quality in his voice and gestures that expresses disinterest in what is being said and disengagement]
Becky:	Ok	[Ok; sounds uninterested and there is an expression of contempt on her face]
Sarah:	We all know what the ideal thing is.	[Neutral]
Becky:	We all know what the ideal thing is, it works, it's beautiful, like …	[laughs nervously and there is a frustrated tone in her voice]
Tom:		[rolls his eyes]

The few seconds of dialog pictured here provide a context for our research. Several past studies have studied internal emotion-related mechanisms, such as the effects of emotional states on individual creativity or decision-making [2, 3, 4]. Little has been done to explore the moment-to-moment role of emotions in creative interactions. For the research described in this chapter we therefore focus on how emotions shape the flow of an interaction and how the quality of that interaction influences the emergence of outcomes. For example, how does Becky's expression of contempt in the example above influence the engagement of her teammates? How will it influence whether Peter and Sarah will listen and build on the ideas she might propose next? As these questions are in the service of developing understanding our research, at the same time, is undertaken in the service of an interest in change. We want to imagine and develop better ways of interacting in an engineering team. For example, can we imagine different reactions by Becky to Tom's proposal that might have led to a more constructive discussion?

Interactions such as the one between Becky, Peter, and Tom are subject to a wide range of emotion-related phenomena. Peter's bad mood over the last week as well as Becky's stress due to an upcoming project deadline both can be assumed to have impacted the interaction above. If we want to study the emotion-related phenomena that are particularly relevant to the moment-to-moment dynamics of an interaction it makes sense to distinguish emotions from a broader range of emotion-related phenomena. One way to achieve this is to define emotion as a specific event in time. Ekman defines emotions to be less than 4 s in duration [5]. This distinguishes it from other phenomena like mood or stress that sustain over longer durations of time. However, this still does not help us answer the basic question "what exactly do we mean by emotion?".

17.3.1 Assigning the Label "Emotion"

Reviewing emotion research over the past 40 years, we realized that there are different perspectives regarding which phenomena the labels emotion and affect can be assigned to. A useful way to anchor ourselves is through the signs and signals that we can detect and experience. These can be broken down into three major categories:

1. internal physiology or biology;
2. subjective experience or feelings;
3. externally displayed behaviors.

The debate then centers on which phenomena to include within the label emotion and how then, what we mean by emotion, comes about.

In terms of assigning labels, we are maintaining two different perspectives in our research.

The first perspective by Tomkins as described by Nathanson [6] assigns the label "affect" to biological signals (Figure 17.2). Feeling is the consciousness of these signals. It is a sensation that can be checked against previous experiences and labeled. It is personal and biographical because every person has a distinct set of previous sensations from which to draw when interpreting and labeling his or her feelings. Emotion is the triggering of memories by feelings and the projection or display of a feeling. For example, Tom's eye roll response may have been a display of a feeling of contempt triggered by memories. Unlike feelings, the display of emotion can be either genuine or feigned [6].

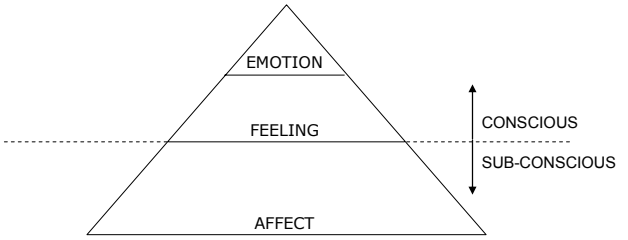

Figure 17.2 Emotion as an emergent phenomena distinguished by its level of awareness and display

The other perspective we maintain is influenced by the work of Scherer and Gross. According to this viewpoint the term "affect" is assigned to a super category referring to all kinds of motivational phenomena [7, 8]. Emotion is a subcategory of affect referring to clearly delineated, intensive patterns of affective processes such as the frustration expressed and probably experienced by Becky in the scenario above. Emotion then is a label assigned to certain combinations of physiology, feeling and behavior [9]. Among other sub-categories of affect we can then make distinctions between stress responses, moods such as depression or

euphoria, and other motivational impulses such as those related to eating, sex, aggression, or pain [7] (see Figure 17.3).

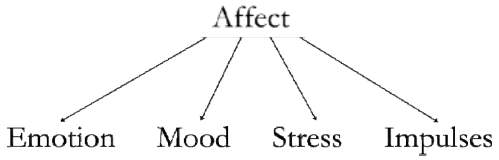

Figure 17.3 Distinction of emotion from other affective phenomena as laid out by Gross [7]

17.3.2 How Does an Emotion Come About?

From a process viewpoint emotion can decomposed into major functional elements and their causal interrelations. The decomposition of an emotion from a process perspective is particularly helpful in thinking about when and how to change emotion dynamics in interactions. To date many different emotion process models exist. LeDoux has written an excellent overview about different models and how they emerged throughout history [10].

Corresponding to the two perspectives in labeling, we can describe two different perspectives on how emotions come about. The perspective on emotion as a result of feelings triggered by memories [6] considers the physiological signal or affect as the beginning of the process that leads to an emotional response. The consciousness of affect leads to feelings which when situated in the context of past memories lead to an emotional response (Figure 17.4). As mentioned earlier, this perspective stresses the biological and biographical elements in the emergence of emotions.

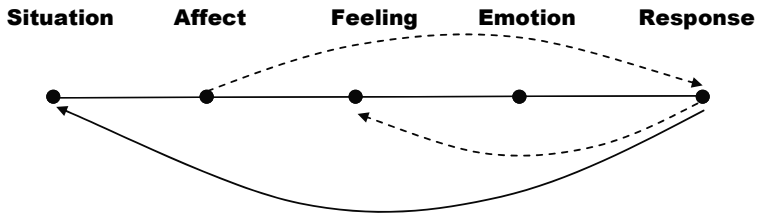

Figure 17.4 An adapted version of Tomkin's stratified model. The dotted lines indicate that the process of emotional responding need not follow a linear sequence

The other perspective corresponds to the modal model of emotion proposed by Gross [7]. The modal model of emotion defines emotion as a person-situation interaction that compels attention, has particular meaning to an individual, and gives rise to a coordinated yet flexible multi-system response to the ongoing per-

son-situation interaction [7]. It decomposes the process out of which an emotion emerges into situation, attention, appraisal, and response and differentiates between different intervention strategies dependent on the point where the intervention is made (Figure 17.5). The modal model thus assigns meaning in the formation of emotion to the individual.

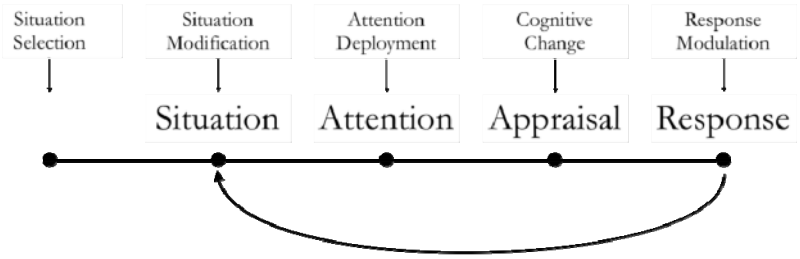

Figure 17.5 The modal model of emotion with specific emotion regulation strategies. Redrawn from [7]

17.3.3 Distinguishing Between Different Emotions

Even within the category of emotion there are a number of labels that vary by culture and context to distinguish between different emotional patterns. How these distinctions should be drawn is a matter of longstanding debate between proponents of what can be called natural kinds perspectives and proponents of core affect perspectives. The natural kinds perspective asserts that there are a limited number of emotion categories that are inherent in nature, and they are discovered rather than socially constructed. They are given by nature, and rely on distinct neuro-biological mechanisms. Under a natural-kinds perspectives as proposed by Tomkins or Izard, emotions are typically categorized into six [11, 12] to nine [13] "basic emotions" and a number of blends or schemas [12] that refer to the situated occurrence and experience of these basic emotions. Examples of typically listed "basic emotions" are interest, joy/happiness, anger, disgust, and fear. The core affect perspective, on the other hand, asserts that there are no emotion-specific mechanisms but rather a core affect system as a mechanism capable of generating all kinds of emotion-related phenomena [14]. Under a "core affect" perspective, emotions are often categorized dimensionally along characteristics such as valence and arousal [15].

17.3.4 Emotion in the Context of Current Studies

Table 17.3 shows that it is important to be aware that many different conceptualizations of emotion exist. Rather than pointing out a particular conceptualization as

the right one we think that each perspective adds particular value dependent on the specific research questions.

In the context of the research studies described here, we define emotion as a person-situation interaction that compels the attention of and is meaningful to a trained observer within a particular cultural context. We draw distinctions between emotions from a social functionalist perspective [16]. From this perspective it has been useful for us to categorize emotion-patterns based on the effects they have in social interactions. This perspective particularly puts behavioral aspects of emotions such as gestures, body posture, facial muscle movement, voice tone, and speech in the foreground. The definition used here is particularly helpful in studying not only what happens from an emotion perspective when engineers interact but is also helpful in imagining and developing more effective interaction patterns.

Table 17.3 Simplified overview of emotion perspectives

Question	Alternative 1	Alternative 2	Alternative 3
What phenomena do we assign the label affect?	Physiology only. Tomkins as described in Nathanson [6]	An aggregation of different motivational phenomena including emotion, stress, mood, and impulse (Gross [7])	
What phenomena do we assign the label emotion?	Tomkins argues that emotion is the triggering of memories by feelings and the projection or display of a feeling (Nathanson [6])	A combination of physiology, feelings, and displayed behavior. This combination is true for other phenomena besides emotion [7]. Emotion is that which lasts for less than 4 s [5]	
How do emotions come about?	Biologically and biographically determined [6]	The process involves a cognitive mechanism of attention and appraisal. Modal model of emotion [7]	
How do we distinguish between different emotions?	There exist six to nine basic emotions that are biologically hardwired [11, 12, 13] (natural kinds perspective)	Emotions are categorized based on the effect they have in social interactions (socio-functionalist perspective [16])	Emotions are categorized dimensionally along characteristics such as valence and arousal (core affects perspective)

17.3.5 Measuring Emotion

A wide array of instruments are available that are useful in investigating particular emotion-related phenomena in the dimensions of physiology, subjective experi-

ence, and behavior. Subjective experience, for example, can be assessed in discrete intervals using the Positive and Negative Affect Schedule (PANAS) [17], or continuously using the affect rating dial method [18]. With the Facial Affect Coding System (FACS) [19] and the Specific Affect Coding System (SPAFF) [20, 21] powerful assessment tools have been developed to codify facial muscle movement relevant to display behavior (FACS) or complex behavior patterns including, voice tone, gestures, speech, and facial movement (SPAFF). Physiology is often assessed through heart rate, blood pressure, or skin conductivity [22]. In the studies described below we are measuring behavior in interpersonal interactions in teams using a version of SPAFF adapted for design team situations.

17.4 Research Study 1 – The Role of Emotion in Group Ideation in Engineering Design Teams

Any conversation or interaction that involves the discussion of ideas between two or more individuals in a design team can be considered an instance of group ideation. This can range from informal "water-cooler" discussions to more formal design review and ideation meetings. These interpersonal interactions are not devoid of emotions. The emotions expressed and felt during ideation interactions may influence the ideas generated by the design team.

In order to study the effect of emotions during interpersonal interaction on the ideas developed, we video-taped nine design teams discussing ideas for a product concept in an engineering design project course at Stanford University. These tapes were analyzed to study the quality of interpersonal interactions and how they affect the quality ideas that are being discussed. We used a modified version of SPAFF developed by Gottman [21] to manually code the emotions expressed during the ideation interactions in the team. From a preliminary analysis of the video tapes, we can infer the following:

1. Emotional quality of interaction varies across time within a team.
   The emotional quality of an interaction is determined by the emotions expressed by individuals participating in the interaction during the course of the interaction. We identified seven different emotion codes based on the modified version of SPAFF coding scheme. These emotion codes were pushy, frustration, tension, neutral, validation, play/humor, and excitement. The emotion codes are described briefly in Table 17.4.
   Arranging these emotions on a negative to positive scale over time, we could plot the emotional variation within a design team. As an example, Figure 17.6 show an emotional variation graph for Team A over a duration of 40 min.
   We can see from Figure 17.6 that Team A had moments of positive and negative emotions. The next question is whether the emotions are related to the quality of ideas discussed in these moments.

Table 17.4 Emotion code descriptions used in the study

Emotion code	Description	Examples
Pushy	This emotion code describes behavior that pushes a particular agenda onto others. It is generally recognized through use of non-conditional terms in language like "obviously", "absolutely", *etc.* It is also recognized though the tone of voice that is forceful and even at times aggressive. Body posture associated with the code is erect and rigid	"For sure, we are lacking post-its"
Frustration	Frustration is a code that denotes constrained anger. The anger will appear constrained or out of the obvious awareness of the speaker. Voice cues include the lowering of the voice and speaking in an even, staccato rhythm, as if to communicate to the partner that the speaker is at the end of her rope	"I always wanted to buy the chair, but you guys were against it" (spoken in a staccato rhythm)
Tension	Tension communicates anxiety, worry, and nervousness. Indicators include nervous gestures, fidgeting, stuttering speech, and incomplete or unfinished statements	"Well, I uh... it's just that whenever... I mean, umm, when I wa... want to uh... want to go out I feel that I... it's like I always have to ask" (speech disturbance)
Neutral	Neutral code represents the dividing line between positive and negative codes. Indicators include relaxed quality with even pitch and volume of voice	"Shall we begin?" (asked in an even volume)
Validation	Validation communicates sincere understanding and acceptance. Indicators include head nods, verbal sounds of acceptance like yes, yeah, ok, paraphrasing, and finishing each other's sentences	"Yes! It is projector screen floss"
Play/humor	Play and humor have been grouped together in this code. Indicators include shared laughter, and playful actions accompanied by smile or laughter	Playful interaction over a whiteboard marker
Excitement	Expression of passionate interest in person, idea or activity. Indicators include expression of joy, delight, high volume, pitch exclamations, and shouts	"When your boss is angry the room shakes!" (spoken in a high-pitched tone with laughter)

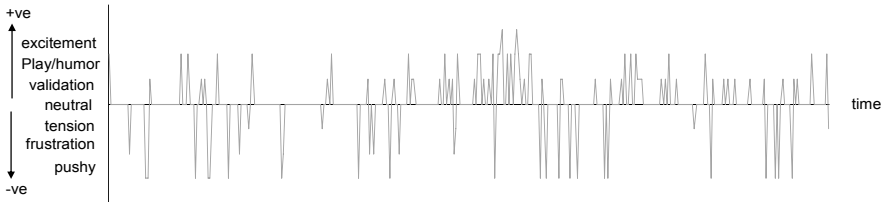

Figure 17.6 Emotional variations over 40-minute duration in Team A. Excitement, play/humor, and validation codes indicate positive emotions; tension, frustration, and pushy codes indicate negative emotions

2. Positive emotions more than negative emotions are associated with interactions where ideational responses are emergent and spontaneous.
   The video segments of the nine ideation session were decomposed into interaction segments based on topical continuity of individual responses. If an individual initiates a new topic through a verbal or non-verbal action, then that indicates the start of a distinct interaction segment. If others respond to it and their responses are linked to each other topically, then their interaction could be categorized as one interaction segment. When we analyzed the interaction segments in a team ideation session, we realized that:
   1. not all of them were related to product ideas;
   2. they had different qualities depending on how a response was linked to previous actions. For example, in question answer interactions, the responses were directly constrained or even demanded by the previous action, the question. In some idea proposal interactions, the responses to an action were more emergent and spontaneous. By emergent response, we mean that the response was not fully determined by the previous actions. Emergence is an event in complex systems that cannot be predicted in advance, but can be found to be emerging from an interaction of several dynamic elements [23, 24]. By spontaneous responses, we mean the responses that were observed to be qualitatively without premeditation.

   The ideation interactions with emergent and spontaneous responses were associated with positive emotions like validation, play/humor, and at times even excitement. Table 17.5 contains a brief section illustrating the emotional cues in an emergent, spontaneous interaction segment.

Positive emotions, thus, seem to be closely linked to the spontaneous emergence of ideas in an engineering design team. While further studies are necessary to understand and model the role emotions play in creative interactions, we can propose a few hypotheses on how emotions factor into group creativity. Emotions could play a two-fold role in group ideation:

1. Positive emotions could act as indicators of personal resonance with an idea. We have observed in our video data that the occurrence of positive emotions, especially excitement, is associated with remarks on personal significance of the idea being discussed. In other instances, positive emotions are associated with the shared imagination of a scenario being discussed. In the latter case, positive emotions tend to be shared while in the first case, they may be limited to an individual.
2. Positive emotional expression about an idea may facilitate the development of the idea. Prior research on group creativity that focuses on the process of creative collaboration [25] shows that group creativity depends on accepting what is presented and extending it further into imagination. The key is to not let the present action constrain the future possibilities, and yet the future emergent possibilities should build on what is accepted in the present. In this delicate balance, emotions could play the role of creating resonance with a presented idea while motivating further engagement with the idea.

Table 17.5 Emotional cues in a spontaneous ideation segment

Speaker	Content	Emotional expression	Gesture	Tone of voice	Facial expression
A	What about like, people need lighting that inspires them, but how do you know when they need to be inspired? What if we had watch, right, that senses your vital signs and it's like… ok, Brendan's falling asleep and is hungry, something like that…	Neutral	Waving hands	Neutral	Smiling
B	It senses your heart rate…	Neutral	None	Neutral	Not visible on camera
A	And it like…	Neutral	None	Neutral	Smiling
B	Shocks you!	Play/humor	Waves his hands	Playful	Not visible on camera
A	Shocks you	Play/humor	Mimics B's gesture	Playful	Smiling
C	(laughing)	Humor	Not visible on camera	Genuine laughter	Not visible on camera
D	Oh, yeah, you know like...	Validation	Standing up and moving towards A and B	Interested	Not visible on camera
A	It all of a sudden like, plays some pumped up music like	Play/humor	Rocking on his feet	Neutral	Smiling
B	(makes a guitar jamming sound)	Play/humor	Bobbing his head	Playful	Not visible on camera
A	Jam, truck jam, or something	Neutral	Moving to face D	Neutral	Smiling

17.5 Research Study 2 – Team Conflict in Engineering Design Teams

Conflict in an engineering team can have adverse consequences for the product being developed like inhibition of ideas, skewed decision-making priorities, delayed product completion and even failure in the marketplace. Team conflict is an important topic of research that has been studied in the past [26, 27]. Jehn [27] proposed that intragroup conflict could be categorized into task conflict and relationship conflict. Task conflict is defined as "*disagreements among group members about the content of the tasks being performed, including differences in viewpoints, ideas, and opinions*" [27]. Relationship conflict is defined as "*interpersonal incompatibilities among group members, which typically includes tension, animosity, and annoyance among members within a group*" [27]. It is cur-

rently held that task conflict is beneficial and relationship conflict is detrimental to team performance [27]. However most of the studies pertain to the content of conflict and not to the process of how it unfolds over time. When we study what is happening moment-to-moment in a team conflict situation, we need to pay attention to the role of emotions expressed by the team members.

We can examine a sample of team conflict that we recorded on video as part of a study on disagreement in engineering design teams in order to illustrate how emotions form an important dimension of conflict that can be separated from the content of a disagreement.

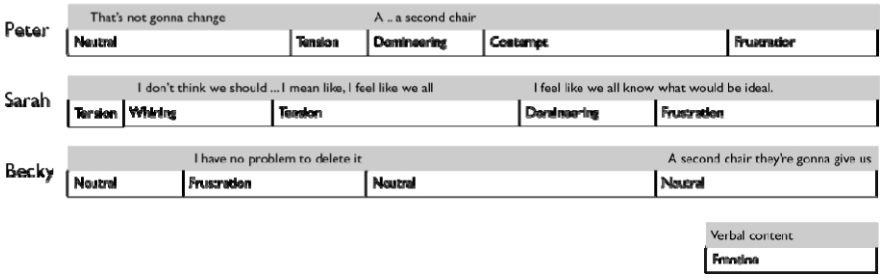

Figure 17.7 A disagreement conversation with verbal content and emotion expression

In the example in Figure 17.7 the quality of the interaction is characterized by negative emotions such as frustration, domineering, and contempt. In a social context these emotions often have the function of alienating people from each other. The very same content however could be delivered with a different set of emotions. Peter could deliver his statement "a second chair" without the lecturing and somewhat condescending tone in his voice and instead say the same words expressing interest. Following the flow of emotions during conflict situations turns the spotlight away from what a team is disagreeing about (whether it be relationship-related issues or task-related issues) and towards *how* a team is engaging in a particular disagreement.

Furthermore, building on the model of marital conflict proposed by Gottman [28], we can propose a model of conflict for engineering design teams that incorporates the role of emotion as a mediator of good or bad team conflict.

Gottman [28] proposed a relationship between the flow of emotional expressions that are exchanged during an interaction, the way this flow of emotions is perceived, and the physiological responses. The emotion flow can consist of positive emotions like interest, validation, and humor, or negative emotions like contempt, belligerence, and domineering. Based on the ratio of positive to negative emotions expressed in a flow over time, the perception of the partner changes from a state of well-being to a state of distress. If more positive emotions are expressed, the state remains in well-being. If the ratio of positive to negative emotions falls below 1, then the state shifts to a state of distress. Once a shift has occurred in perception, further expression of negative emotions by the other partner is attributed to the person rather than to the situation thus precipitating a down-

ward spiral in the relationship. While being in a state of well-being negative emotions are generally attributed to the situation and not the person. If there are negative emotions one might think, "Maybe he or she is just having a bad day.". However, while being in a state of distress, those same negative emotions are attributed to the person. One might then think, "He or she is just that kind of a person who does this.".

We propose that in a team conflict situation as well, the amount of positive to negative emotions expressed during a disagreement discussion influences how team members perceive each other. We call a disagreement discussion over a task related to the design project a task conflict. If in a task conflict, greater amount of positive emotions are expressed, then it is a positive task conflict which enables the team to remain in a state of well-being. If in a task conflict, greater amount of negative emotions are expressed, then it is a negative task conflict. With repeated occurrences, negative task conflict can lead to state of distress, in which team members make personal attributions that are stable over time. This state of conflict where team members attribute negative emotions to each other's personalities is similar to the relationship conflict defined in literature [27] as being detrimental to the team. Thus, emotional expression could be the mediator of good team conflict (task conflict with participants in a state of well-being) or bad team conflict (relationship conflict with participants in a state of distress).

Understanding the role of emotion in team conflict enables us to recognize when to intervene in team disagreement situations. Currently, we are engaged in developing this model of team conflict further and designing facilitation tools that can be used by engineering design teams to resolve negative team conflict.

17.6 The Cultural Context of Emotion

The emotional categories we mention in these research studies are labels that we assign to behavior. The coding of observable behavior into meaningful categories is with reference to the culture in which the situation of study occurs. The two studies described here occurred in a European-American cultural context and were analyzed in the same cultural context. Hence we should note that the categories are salient from a European-American cultural perspective. If we were to conduct studies in a different cultural context say East-Asian or African, the behaviors and their interpretation by both the participants in the study and the researchers could be different.

17.7 Looking Forward

Now that we can detect and categorize behavior into different emotions, what can we do with it? One alternative is to train engineers to recognize and understand the

different emotional categories and how emotions play into their activity of designing. This may enable them to be more aware of emotions as they occur in practice and respond to them appropriately. Another alternative is to give real-time feedback to engineering design teams about the condition of their team interaction based on emotional expression as a variable of measurement. This could be achieved through technological tools that could detect emotions and display feedback, or through human observation and coaching. The paradigm of coaching in engineering design is useful for providing an informal knowledge channel to the design team [29]. Emotion as an indicator for team performance could be beneficial to a coach in guiding a team effectively.

17.8 Conclusion

Schön [30] describes the world of the practitioner as dealing with messy realities that the technical rationality of academic researchers too often abstracts away from their studies. Emotion often resides in the part that is abstracted away. However, we have seen in this chapter that we do have tools and methods to study emotion and to gain a deeper understanding of engineering practice. We therefore foresee a future in which the study of emotion is an integral part of engineering knowledge and practice much like thermodynamics, mathematics, and manufacturing.

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