Teachers' Disappointment: Theoretical Perspective on the Inclusion of Ambivalent Emotions in Human-Robot Interactions in Education

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ABSTRACT

Following affective turn in cognitive science, recent decades have witnessed an increasing interest toward the role of emotions in education. Ample evidence suggests that learners and teachers experience a variety of emotions, ranging from joy and pride to anger and frustration. However, when it comes to the design of affective behavior in robotic systems for education purposes, the emphasis has been predominantly on communication of positive emotions. While we recognize that positive emotions are fundamental to successful learning, in this paper we wish to make the case for the consideration of ambivalent emotions for the design of social robots for tutoring. To ground this proposal, we focus on the emotion of teachers' disappointment. First, we discuss under which conditions communicated teachers' disappointment, while it may be experienced as emotionally ambivalent by teachers and students, functions as an affiliating pedagogical strategy. We proceed to sketch out the methodological suggestions we consider relevant for future studies of communicated disappointment in human-robot interactions within learning contexts. We conclude with critical reflections about the ethics of responsible designs of such studies.

CCS CONCEPTS

• **Applied computing** → **Education**; • **Human-centered computing** → *Interaction design theory, concepts and paradigms.*

KEYWORDS

complex emotions; teaching; learning; socio-cognitive paradigm; disappointment; robotic tutors; human-robot interaction

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1 INTRODUCTION

Historically learning and teaching were seen as predominantly cognitive activities. However, the shift in our understanding of cognition as inseparable from emotion processes [55] has lead to the formal and ubiquitous recognition that emotions are fundamental in education [42][81]. In line with the affective turn [92], recent decades have witnessed a steady growth in the number of investigations of emotions experienced in educational environments by different participants (e.g., teachers, learners, and parents) [72]. These studies have demonstrated that emotions influence multiple components of learning such as attention, motivation, learning strategies and learning outcomes [66], among others. As Pekrun and Linnenbrink-Garcia rightfully point out, emotions in education are not only experienced – they are *instrumental* for academic achievement and personal growth [67]. Further, from the perspective of socio-constructivist and ecological approaches to emotions [3][21], emotions are not confined to individual minds. Empirical studies and existing subjective accounts of emotion experiences by teachers and learners suggest that teachers' and learners' emotions dynamically shape each other [92][80][34][5]. In our work, we abide by the definition of emotions that integrates intrapersonal and interpersonal (social) dimensions. Following Schutz et al. [72, p.344], we maintain that emotions are "ways of being in the world that emerge from appraisal patterns about perceived successes at attaining goals or maintaining standards or beliefs during activities as part of social-historical contexts".

1.1 Emotions in Technology-based Teaching and Learning

The increasing interest toward the role of emotions has also been paralleled in the field of technology-based learning. Here, the research has focused predominantly on the intrapersonal dimension and solutions designed to detect, monitor and respond in a helpful manner to emotional dynamics of individual learners [53][2][27][28][38]. Many of these studies have been incontestably instrumental for the advancement of the field. However, they have been limited when it comes to the accounting for and the integration of emotioning processes that are intrinsic to teaching and that extend beyond mere support and positive feedback. If we look at the existing solutions in the domain of human-robot interactions (HRI) in learning settings, the prevailing assumption seems to be that the social and affective behaviors that robotic tutors are to express are friendliness and empathy. Empathic, specifically, is one

of the most frequently used adjectives in the discourse on robotic tutors. To cite Jones and colleagues [47, p.285]:

> Robots that are intended to interact with humans must learn how to become empathic rather than merely smart.

While the emphasis on positively valenced emotions and style of feedback as a starting point is sensible [65][77], when it comes to real-life teacher-learner interactions, anyone who has experienced being a learner and/or a teacher will know that classroom emotions are not always positive. Moreover, some of the negative emotions can have a positive effect. In the words of Sue Ellen Henry [44, p.12]:

> Passion and enthusiasm are not the only important emotions: anger, disappointment, and frustration are equally as educationally potent.

Given the complexity and richness of teachers' and learners' real-life emotioning processes, the question that motivates our work is: given what we know about teachers' "emotional geographies" [43] and the dynamical interplay of emotions between teachers and learners [3][21], how should we approach modeling of emotions in robotic tutors? What should we rely on when deciding which emotions, when and to whom these robots are to communicate? In this paper, we will narrow our focus and explore how these questions could be addressed by using the example of emotion of teachers' disappointment and it's effects on learners.

Our choice to focus on disappointment is motivated by the following reasons:

(1) Disappointment has been reported as one of the most frequent negative emotion experienced by teachers [68].
(2) In contrast to anger, display of disappointment in the context of Western educational culture is more appropriate.
(3) Considering the ethics of human-robot interaction research, a robot communicating disappointment is less likely to cause distress in participants in comparison to a robot that communicates anger.

In decision-making studies and cognitive studies of emotions, disappointment is defined as a negatively valenced emotion triggered by a mismatch between the expected and the actual outcome [35][90], when the outcome is less than predicted [84]. It is appraised as unexpected, having certain (as opposed to uncertain) consequences and as caused by circumstances beyond one's control, or, by another person [91][83][84]. That said, in the context of our work, we choose to conceptualize disappointment as an ambivalent emotion, both from the perspective of associated emotion experience of teachers and from the perspective of the effect that communicated teachers' disappointment may have on pupils. As we will discuss in detail further in the paper, it is not uncommon that, for teachers, experiencing disappointment in their students – while negatively valenced – is coupled with care for and belief in their potential. From the perspective of pupils, recognizing teacher's disappointment may lead to a negative experience of failure and anxiety. However, when appropriate constructive feedback is provided, this experience may be coupled with a sense of hope and recognition of one's own potential to achieve learning goals [32].

Before we proceed to the main discussion, we would like to provide some additional remarks about the scope and aims of this paper.

The objective we are pursuing is of pragmatic nature: we do not seek to resolve nor broaden the conceptual debate on whether disappointment is or ought to be classified as an emotion [56]. That is, in agreement with our references who conceptualize disappointment as an emotion (in contrast to e.g. feelings, attitudes, or moods), we will retain this premise to structure our argument.

Further, the discussion will focus on interactions between teachers and learners exclusively. This presents a certain simplification because, in real-life, interactions with parents, colleagues, policy-makers and other community members also influence teachers' and learners' emotions, motivation and behavior. Considering these lies outside the scope of this paper.

Also, we wish to point out that our aim is not to propose a theoretical framework that would apply to *all* ambivalent/negative emotions in learning settings. Given the complexity of real-life dynamics in classrooms and the variety of human and non-human factors that contribute to learning in case of each individual student [16], we also do not claim that communicated teachers' disappointment will lead to desired outcomes for *all* students at *all* times, even if other minimally required conditions (e.g., relationship of trust, student's self-efficacy etc.) are met. Rather, our main goal is to extend the conversation about how to approach complex and non-positive emotions in human-robot interactions in learning settings from the perspective of socio-cognitive [4] and socio-functional approaches to emotions and motivation, and to discuss some of the methodological aspects we believe should be considered in future studies of disappointment in human-robot interactions.

In what follows, we will first provide a brief overview of the existing approaches to modeling of emotions in social human-robot interactions, with an emphasis on the studies that target applications in educational settings. We will then proceed to sketch out the theoretical foundation that we believe is useful to inform future studies of teachers' disappointment. The paper will conclude with our suggestions how to integrate theory with empirical approaches, and some critical reflections in respect to ethical considerations involved in such studies.

2 SOCIAL ROBOTS AS TUTORS

Robots are increasingly used in education as tutors and peers [64]. For example, in projects such as CoWriter [1], or EU H2020 L2TOR [2], robots are designed according to a specific role, such as a peer, a tutor, or a tool for teachers to use during classes [1] and to facilitate learning through some form of social interaction [6]. These robots have built-in capacities for understanding and displaying cues of social interaction and communication, as informed by the cutting-edge models of human cognition and social competencies [11, 12, 23]. The physical presence of these so-called "social robots" [33], designed to be human-like in appearance and behavior, has been proven to be effective in sustaining attention and motivation of the targeted learners [46]. As tutors, social robots are designed to support learners in keeping up with the planned curriculum

[1] http://chili.epfl.ch/cowriter
[2] www.l2tor.eu

by offering hints or tutorials and sometimes even through direct supervision [6]. While social robots as tutors could in principle be employed to help learners of all ages, school age children have been considered the main target group.

The combination of demonstrating social abilities similar to humans, and the human-like embodiment has been shown to afford the perception of social robots as social agents [75][7], and has been used as one of the common arguments for the use of such robots as tutors, teachers or peers over more traditional screen-based technologies (e.g., computers, tables, smartphones, and virtual agents).

In furtherance of the argument about the importance of affective dimension in human-robot interactions in learning settings, empirical studies of existing applications in the field of technology-based learning suggest that affective component in artificial agents positively enables learning when compared to the implementations where affective and social behavior is left out. For example, Chase and colleagues show [15] that artificial agents that also exhibit social behavior are perceived as more motivating and show a moderate trend for increasing student self-efficacy.

Given the importance and, in some sense, inevitability of emotion component when it comes to social robots in education, we (i.e. researchers, engineers, policy-makers etc.) are left with the decisions regarding the development of affective dimension of human-robot interactions. How are we to approach negative/ambivalent emotions in the context of sHRI? Should we strive to approximate/mimic human interactions, or attempt at exploring the affordances that new technologies bring about? To date, we are far from having conclusive answers to these questions.

2.1 Modeling Complex Emotions in Robotic Tutors

According to the systematic literature review of computational research in human-robot interaction over the past decade conducted by Thomaz and colleagues [79], current computational approaches to emotions in HRI have focused on three principle areas:

- Approaches that target intrapersonal affective processes of users, for example, where the objective is to drive elicitation of expressions or to regulate users' attention.
- Approaches to expressions of emotions that can be reliably identified by humans, even when expressed across various modalities. An example of such attempt in the context of disappointment are studies by Embgen and colleagues [30], and Schwenk and colleagues [73], where to signal disappointment, body language and sonic modalities of a robot were engaged. The subjects in these studies were able to recognize disappointment, and even differentiate between disappointment and sadness despite these emotions sharing many similarities.
- Approaches that target automated detection of emotions in human interaction partners. An example pertaining disappointment is a study by Wang and colleagues, [87], where in a scenario of playing a game with a child, in supportive condition, robot acted disappointed when it detected that the child participant was loosing.

While it is useful to study users' recognition of the emotion expression we wish to incorporate in a robotic tutor, such studies alone do not advance us in answering the questions why, how and when within the interaction between learner and robot should an emotion be expressed? In that regard we side with Jung and colleagues' [49][48] proposal to shift focus from the "signaling paradigm" (i.e. assumed coupling between a given emotion and behavioral cues; grounded in the basic model of emotion [29]), to the exploration of the context that leads to the attribution of a specific emotion to a robot. What is even more important, to the meaning of emotions that is attributed to robots by humans in the interaction, and how it affects their affective and motivational dynamics.

In what follows, we will focus on the emotion of teachers' disappointment to further explore how the structure and the pedagogical function of this emotion can suggest ways to approach modeling of ambivalent emotions in robotic tutors in a more ecological manner.

3 TEACHERS' DISAPPOINTMENT

As pointed out earlier, emotions in HRI are both unavoidable and can be instrumental for obtaining desirable learning outcomes. In case of complex and ambivalent emotions such as disappointment, and given the potential vulnerability of young learners, it is important to have a solid theoretical foundation that can inform decisions about and approaches to integration of disappointment in robotic tutors. To lay the foundation of such theoretical framework, in this section we will first discuss possible antecedents of teachers' disappointment in educational settings, the structure of this emotion, and the conditions under which communicated disappointment can have a pedagogical effect.

3.1 Sources of Teachers' Disappointment

Based on the observations of 108 teachers in 93 primary schools in various regions of Slovenia, Prosen et al. [68] list the following reasons for teachers' disappointment expressed in classrooms: students not following teacher's instructions, students failing to perform well academically (e.g., failing a test), and students not paying attention during classwork. Additionally, we can extend this list and include students behaving in unacceptable ways (an example provided by Cross: a student stealing from her classmates [21]) as another source of teachers' disappointment. Given that in all of the instances listed it is the other person (the pupil) who is perceived as an agent behind the event/outcome that causes teachers' disappointment, we can infer that, at least at first glance, teachers' disappointment can be classified as person-related disappointment [84]. However, while in some cases teachers may indeed appraise the event (e.g., pupil's poor performance on a task) that triggered their disappointment as revealing something about the nature or personality of the person assumed responsible for the event (i.e., that a given pupil is lazy or not particularly smart), it will not be the case for all instances of teachers' disappointment. Experienced teachers know that personal characteristics of pupils are not the exclusive reason neither for a poorer performance on a task/test, nor for the instances of social misconduct. For example, poor performance on a task can be associated with personal circumstances of the learner (e.g., problems at home), or student appraising the task as irrelevant, or the task being too difficult. Furthermore, a teacher may attribute a pupil's failure to their own performance as

pedagogues. For example, in [21] one of the teachers-participants of the study reported that she felt disappointed after the incident of a student stealing because she believed she had failed to attend to the student's psychological and physical needs.

To add to the complexity, existing evidence suggest that the same event (e.g., student failing on a test) can be appraised differently by different teachers which may result in teachers experiencing an emotion that differs from disappointment. For example, according to the earlier studies by Graham and Weiner (cited in [34]), students' academic failure was attributed to insufficient effort on behalf of the students and resulted in teacher's anger rather than disappointment. We hypothesize that the discrepancy in emotional responses that are documented in earlier studies (anger in contrast to disappointment or sadness) can also be explained from the perspective of socio-constructivist framework of emotions, wherein emotions are structured not only by personal histories, cognitive appraisal patterns and personality traits, but are shaped by the broader socio-cultural context [3]. Thus, the resulting emotion experience, whether/how teachers will choose to communicate it, will also be affected by what teachers perceive as an appropriate emotion in the context of their responsibilities and goals as educators in a given society [3].

3.2 Disappointment as Indication of Care

Regardless whether we choose to conceptualize instances of teachers' disappointment as person-related or outcome-related, when it comes to the instances of disappointment in educational settings, in contrast to the types of task scenarios traditionally deployed in the studies of disappointment in decision-making, teachers will confirm that their lived experiences of disappointment are associated with commitment to *care* [78], where care is understood as emotional investment in learners' personal and academic success and well-being. In other words, in order to feel disappointed, a teacher would first need to care for the learner's success and to trust such success is attainable. Of course, one can imagine scenarios wherein teacher's disappointment is mediated exclusively by pragmatic self-concern. For example, when pupils' grades factor into funding or subsequent bureaucratic decisions. However, we argue that teachers whose disappointment is mediated solely by self-interest – though not necessarily non-existent – shall not be considered as a model for teacher behavior.

4 PEDAGOGICAL FUNCTION OF TEACHERS' DISAPPOINTMENT

When we talk about pedagogy, teachers' emotions are relevant inasmuch as they help to organize the affective and motivational states of learners. In the words of Sutton [78, p.335]:

> The apparent prevalence of emotions in teaching is only important if there is reason to believe that emotions influence teachers, teaching, and students.

In classrooms, not only positive emotions (e.g., joy, happiness etc.) can and will have a pedagogical effect. Following Jung and Hinds [49], we assert that, when it comes to education, a more useful way to talk about emotions, instead of their positive or negative valence, is in terms of *affiliation*. Namely, whether communicated emotion will lead to learners' cooperation and increased motivation or, to the contrary, disengagement and withdrawal [4]. In line with this reasoning, we will discuss how experiencing disappointment may affect teachers' behavior, and sketch out a set of conditions that we believe to facilitate learners' affiliation in response to communicated teachers' disappointment.

As a starting point, we propose to distinguish between three categories of processes:

a) Behavior and instruction: how experience of disappointment influences teachers' behavior and the choice of instructional strategies.
b) Communication: whether teacher chooses to communicate their disappointment and how they choose to do so (i.e., disappointment as a pedagogical instrument).
c) Effect: learners' emotional, motivational and cognitive response to communicated teacher's disappointment. [5].

4.1 Behavior and Instruction

Per Frijda [36], complex (or secondary emotions), as opposed to basic (primary emotions) do not have a clearly associated action readiness. However, it is assumed that complex emotions can be tied to a constrained range of behavioral responses. In decision-making studies, disappointment as a complex emotion has been shown to be associated with the following response types [84]:

- Distancing oneself from the person that caused disappointment.
- Tendency to get away from the situation.
- Ruminating regarding what might have been done or should not have been done.
- Expecting the agent who caused disappointment to apologize.
- Contemplating a lost opportunity.
- Strive to try harder.
- Wishing for another chance.

Given the lack of empirical evidence from within educational psychology, based on the introspection and available descriptive accounts of teachers' experiences, we speculate that many of these response types will also manifest in situations of teachers' disappointment. We can divide these responses into three classes: 1) Disengagement or apathy, 2) Withdrawal, and 3) Reinforced engagement or trying harder.

Our assumption is that the kind of behavior a teacher opts for will depend on how they appraise the situation. If it is appraised as high on control and self-agency dimensions (i.e. teacher believes it is within their reach to help learners to improve), it is likely that disappointment will lead teachers to engage with learners and suggest ways of improvement. On the other hand, if agency and control score low (i.e. teachers blame the outcome on students'

[3] For more on this see [45]

[4] The approach versus avoid tendencies, as mediated by emotions, in learning settings are also discussed in empirical findings by Meyer and colleagues [63]

[5] It is our assumption that the subjective experience of learners in response to when teachers choose to communicate their disappointment will vary from instances when learners imply teacher's disappointment. Unfortunately, no study to date exists that would compare these two conditions in learning settings. While remaining aware that it might be an oversimplification, for the purpose of this paper we limit the discussion to instances when teachers choose to communicate their disappointment

personality traits, fixed qualities that they are in no position or capacity to change as is the case with straightforward instances of person-related disappointment), disappointment may lead to teacher's disinterest, apathy or, in the worst cases, teacher's quitting the job.

4.2 Communication of Disappointment

Experience of disappointment, irrespective of the associated behavioral response, does not necessitate that teachers will choose to communicate their disappointment to pupils. Given the widely accepted belief among teachers that expressions of positive emotions facilitate teaching, while negative emotions negatively affect effectiveness [34], the question is what motivates teachers' choice to communicate disappointment when they could suppress it as they frequently suppress anger [58]?

Socio-functional approach to emotions may suggest an answer. According to this perspective, emotions are not only confined to individual minds but they have a direct social effect [52]. In other words, within the social-functional framework, emotions are said to influence not only the behavior of the agents experiencing emotions but also the behavior of those who perceive these expressions. For example, in negotiations studies, it has been shown that expressions of disappointment may form a basis for a successful negotiation strategy as it signals that one has received less than what they had anticipated. Hence disappointment constitutes a distress call which may elicit prosocial behavior from recipients [85]. Similarly, Wubben and colleagues [90] suggest that expressions of disappointment facilitate cooperation and are conducive to establishing a mutually beneficial relationship [90].

However, merely expressing disappointment does not necessitate that learners will indeed act in a cooperative manner. In the coming section, we will address some of the reasons as to why learners may choose to cooperate in response to communicated teacher's disappointment.

4.3 Effect of communicated disappointment on learners

As mentioned earlier, existing empirical evidence collaborate that teachers' affective responses, both supportive and non-supportive, and learner motivation are interconnected [82]. Per Levering [58], teachers' disappointment may have a "corrective" function as it communicates to learner that: 1) Teacher is present and engaged, 2) Teacher cares, and 3) Invites learner to try harder.

However, Levering also points out that expressing disappointment may lead to undesirable effects, such as decrease in self-esteem and motivation in learner.

How can we differentiate between motivating/affiliating and de-motivating effects of communicated disappointment? In other words, what are some of the affective and cognitive processes from the perspective of learners, and what are the background affective processes that transpire between teacher and learner that lead to the communicated disappointment to have the desired pedagogical effect? To answer this question, let us consider the dimension of care discussed earlier. Per Wong and Dornbusch [89], middle school students were more motivated, and more likely to be helpful and cooperative when they believed that teachers cared about them. These findings collaborate Maehr's [60] proposal that achievement motivation is a process, rather than a trait, and is largely psychosocial by nature. That is, provided the overall positive and trusting relationship between teacher and learner [39], disappointment signals to learner that teacher cares and has certain expectations and trust in their success. This also suggests that, should a teacher choose to communicate their disappointment, it is recommendable to do so in a supportive and constructive manner [82] [32]. Following psycho-social perspective on motivation, pupil's strive to try harder or to avoid teacher's disappointment stems not from their wish to "protect" the teacher from the quantifiable outcomes on a task. Rather, the motivation is associated with the interpersonal outcomes, i.e. learner's with to make the teacher proud or to ensure that the teacher likes them.

While recognizing the importance of psycho-social (relational) component to motivation, it is our view that the latter has to work together with more individual-centered and cognitive components of motivation (e.g., learner's goals, self-efficacy, task relevancy etc.) for the desired pedagogical effect of disappointment to arise. For example, even if learner believes the teacher's good intent and wishes to maintain teacher's positive disposition, they may still choose not to engage with the task if they find it irrelevant, or if they believe they are not able to tackle it. This point has also been highlighted by Levering [58, p.73]:

> A pedagogically sensitive educator knows how to balance the motivating force of expectations with the risk of unpleasant feelings and lack of success. On the one hand, it is the task of a teacher to set (with students) appropriate expectations and to try live up to them. On the other hand, it is a teacher's responsibility to understand the possible harmful effects of disappointments and frustrated expectations and to show students how to benefit even from life's difficulties.

4.4 Interim summary

To summarize the discussion thus far, we will re-iterate through the core assumptions behind our theoretical approach to emotions in education: 1) Teachers' and learners' emotions bi-directionally influence each other, 2) Teachers' emotions can and will meaningfully affect students, and 3) Teachers' emotions, including negatively valenced and ambivalent emotions, such as disappointment, can have a positive pedagogical effect.

In this light, we conceptualize teachers' disappointment as a complex ambivalent emotion [37] that bridges intra-personal and inter-personal dimensions, and, though not a social emotion in a strict sense [41], it does involve a social component and can elicit learners pro-social and behavioral effects (i.e., learners affiliation with the task). For the latter to be achieved, we believe the following conditions must be met:

- *Relationship of care and trust between teacher and learner:* learner has to interpret teacher's disappointment as an expression of belief in their potential and abilities.
- *Regulation of expectations:* the expectations of teachers' regarding the task at hand have to be clearly set in advance.

- *Communication style:* emphasizing high scores and social comparison or using sarcasm will most likely result in negative motivation. This means that whether disappointment will have a positive pedagogical effect will also depend on the affective style of communicating this emotion.
- *Appropriate teacher's attribution:* if a student's lower than expected performance is attributed to laziness or bad character, rather than real need, the teacher is unlikely to provide appropriate instructional and emotional support [78].
- *Appropriate learner's appraisals:* the task has to be of relevance, and at the level of difficulty that learner believes they can address.
- *Providing feedback:* it is important that expression of disappointment by teachers is coupled with appropriate feedback and/or constructive criticism [32].

To validate these conditions, further studies of communication and the effects of teachers' disappointment are necessary.

5 DISAPPOINTMENT IN HUMAN-ROBOT INTERACTIONS

To anticipate the discussion in this chapter, we wish to point out that, while it is inevitable that disappointment arises in teacher-student interactions, in the context of human-robot interactions it is important to remain aware of possible negative experiences of young learners in response to this emotion when it is communicated by an artificial agent. This means, we remain open to the possibility that future empirical studies may reveal that a social robot expressing disappointment is not desirable (i.e. it is perceived negatively by the learners and it does not lead to desired motivational and cognitive response).

5.1 Methodological Suggestions

The theory of teachers' disappointment as a pedagogical strategy that we presented above suggests a host of potentially important variables to be considered for future studies of communicated disappointment and its effects in human-robot interactions in learning environments. Among the process/outcome oriented variables are: learner's emotional response to communicated disappointment, learner's motivation and self-efficacy, learner's behavioral response (i.e. affiliation versus withdrawal), learner's performance on a task. A (partial) list of parasocial and relational variables that may mediate the process/outcome variables: trust in robot, emotions experienced towards the robot (e.g., attachment, care), attitude towards the robot (e.g., indifference, wish to please etc.). Last but not least, the list of individual variables includes: learner's age, personality type, task relevance, among others. We believe this list is to be refined and completed as more evidence from field studies become available.

All these variables could be used to propose numerous research hypotheses. However, given the current lack of empirical and descriptive studies emphasizing the role of disappointment as a pedagogical strategy in human-human interactions, we will refrain from formulating any such hypotheses at the present time. Instead, in what follows, we will lay out the broader methodological considerations that will provide more context to some of the variables listed above, and that we believe important and relevant for future studies of disappointment in human-robot interaction from the perspective of the socio-cognitive and socio-functional approaches to emotions that inform our work.

Recently, the HRI community has showed recognition of the value of empirical methods that extend beyond the positivist tradition and narrowly defined empirical paradigms from experimental psychology [24]. Our approach to investigating emotions with regard to the development of social robots as tutors aligns with these new perspectives: that is, we argue that for more ecologically sound and process-oriented studies of disappointment in learning settings, qualitative and mixed methods, such as participatory design [9][57][10], long-term studies [54][25][51], and studies "in the wild" [71][69][50] are appropriate. We believe that these methodologies, that have already been demonstrated useful in the cited HRI studies, will help to come closer to capturing the dynamic and inter-dependent aspects of teaching and learning and to ensure a strong recurrent interaction between theory and empirical work.

In respect to future empirical studies of disappointment in HRI, our suggestions are as follows:

Identification of appropriate cues and modalities to communicate disappointment: first and foremost, we propose to focus on what we can systematically take as appropriate cues of communicated and perceived disappointment in HRI. In agreement with the discussion in the preceding sections, for a robot this means that the multi-modal cues for communication of disappointment should not only signal the emotion in question, but also emphasize its association with the belief in learner's success. For example, the bodily cues can be coupled with linguistic expressions such as "I trust you can do better". For a more human-centered approach, we suggest to anticipate trials with robots by empirical investigations (i.e., video recordings, observation grids, accompanied by interviews) of modalities and linguistic cues that teachers engage when they communicate disappointment.

Identification of appropriate interaction sequences where disappointment is to be communicated: similarly, as discussed in the earlier sections, there is no standard protocol or rule-book to guide decisions when communication of disappointment is appropriate. In the context of teacher-learner interactions, this decision will depend on a number of factors, e.g., the history of interactions, learner's personality, teacher's teaching "style", task-related aspects, teacher's belief about what range of emotional expressions is appropriate, and whether it is well-suited for a given learner etc. This complexity means that, if left for researchers to decide upon, this decision will be taken in isolation from the lived situations of teacher-learner interactions. While we fully understand that it is impossible to contextualize this decision for every classroom, we nevertheless believe that, at least at the stage of hypothesis building, teachers and learners should be invited to participate in the conversation where they can reflect on their experiences and share their views. Based on these conversations, coupled with empirical observations of teacher-learner interactions, several strategies can be identified and tested.

Testing the effect of communicated disappointment in HRI by experimentation: From learners' perspective, the focus should

be not only on whether communicated disappointment is recognized, but rather on how the recognition of this emotion, as communicated by a robot, ties into consequent task-related behavior and motivation; also in comparison to condition when disappointment is not communicated (i.e., when the feedback style is neutral). Additionally, as discussed earlier, a learner's response to a robot expressing disappointment may also depend on how they appraise the task. This is something to be considered and controlled for. For these purposes, classical experimental set-ups in the wild can be considered. An additional aspect to be considered is participants' sensitivity to the expectations of experimenter. Known under the name of Rosenthal effect, according to Dillenbourg and colleagues [26], in education, this phenomenon is not a bias but an efficient pedagogical mechanism in its own terms. That is, given the sensitivity of students to teachers' expectations, it is advisable for a teacher to make their expectations explicit. If a robot takes on the role of a teacher (to an extent), we propose the following aspects for empirical investigation: a) How sensitive, if at all, are the learners to the expectations when set by a robot? b) To what extent are the expectations that learners set for themselves affected by the presence of a robotic tutor?

Aspects of disappointment that are contingent: based on what was discussed in respect to disappointment and relationship of care and trust in the earlier chapters of this paper, it is our assumption that one-off short interactions with a robot are appropriate if we want to limit ourselves to the investigations of the signaling function (whether disappointment is recognized), but are not the best choice if we want to learn more about the subjective experience, and whether robot expressing disappointment is of genuine pedagogical significance for a given learner. The methodological difficulty with extended interactions is to define what constitutes "long-term". The discussion on how to address this challenge is outside the scope of the given paper. Here it will suffice to point out that, whatever the chosen length will be, it should allow for a history of interaction with a robot in order to: 1) allow for the learners to establish reasonable expectations as to what a robot can and cannot do, 2) to establish a relationship of trust.

On the most basic level, trust in HRI can be conceptualized as either the aspect of mere reliance on a robot, or as a dimension of interpersonal relationship [59]. In the context of social robots for education, trust as mere reliance means a robot will function properly in accordance with its defined task and purpose. That is, the robot will not break; it will reliably register, store and recall some features of interactions with different learners; it will not compromise with regard to the issues of privacy (for example, a learner may share with a robot some sensitive information). For the trust to be considered at the level of interpersonal interactions, it is prerequisite that both parties have capacities for higher mental states and moral reasoning, capacities that are currently reserved only for other human beings. That said, to meaningfully consider trust in HRI, it is useful to distinguish between trust as an attitude and trust as a property [62]. Given that social robots cannot be said to be trustworthy beside the property ascription of trustworthiness by humans, we suggest to limit the conceptualization of trust on the level of social relationship as a characterization of an attitude held by humans toward robots. That is, in the context of empirical investigations, our proposal is to direct attention to human-centered perspective. Namely, based on prior beliefs, personality and other, users may or may not judge a robot as trustworthy. This is of advantage when we consider that robots for educational purposes commonly target children as learners. Because children form attitudes that are rooted in beliefs that are not yet on the same level as those of adults (they do not follow the same logic), they are able to consider trust in social robots not simply as something to be justified but also as opening up a space for exploration. Young learners might simply use their imagination, employ pretence, engage in play, and build narratives to relate to social robots as tutors, and thereby engage actively in the construction of these robots as such [8]. This enables trust in these interactions to be understood differently from what we could normally expect from adults. For the empirical studies of emotions in interactions with robotic tutors, this suggests that children may bring forth dimensions of trust that are not constrained by rational considerations. It is our belief that these in turn will be of relevance for the studies of disappointment in HRI. However, what these dimensions might be and how they affect the perception of disappointment communicated by a robotic tutor is yet to be explored empirically.

6 CRITICAL REFLECTIONS

Given that most social robots for education target young learners, HRI studies operate with what is considered a vulnerable societal group (other examples of such groups are elderly, sick people and people with special needs). Given that children are not always able to express clearly to what extent they feel uncomfortable in a situation, they require special consideration and protection when participating in research studies. This, of course, does not necessitate that young learners, as a group, should be excluded from the design process of social robots for tutoring. Rather, we want to stress that when testing and implementing social robots for interaction with vulnerable subjects, the experimental study designs should be careful to respect the individuality and the subjective experience of the participants.

6.1 Ethical Considerations

Conventionally, good research ethics presupposes that placing a participant in a situation that can cause physical or psychological harm is not permissible, even if predicted results of the study are potentially valuable for the research community. However, investigations of ambivalent emotions, such as disappointment, require that we do exactly that. As discussed earlier, teachers' disappointment can function as affiliation emotion provided certain conditions are met. Lest it may have no desirable effect or, in the worse-off scenarios, lead to learners' experiencing emotional distress, such as shame or anxiety.

To anticipate such situations of potential harm, one solution is to inform participants about the aims of the study. Unfortunately, this may also mean that the results of the study will be influenced by this decision [70]. In some studies of trust in HRI, which are similar in terms of ethical considerations, a game-theoretical experimental set-up has been used to simulate a situation in which participants

believe that their behavior involves a degree of risk [20][61][86]. Whether this approach is applicable to the study of disappointment is open for a debate.

Last but not least, it is important to mention the ongoing debates about the overall desirability of social robots in everyday life of vulnerable groups. While the origins of this debate are in the domain of application of robots in healthcare for elderly [76][19], the current aim to implement social robots for children in educational settings raises similar concerns [88]. One of the main arguments against such robots is that children may not be able to fully comprehend that robots, despite their human-like appearance and behavior, are not social agents like humans. Thus, the primary concern is that interactions with such robot will be deceptive: children may feel fooled or duped when they treat a robot as if it was capable of having emotions, desires and moral reasoning. The focus of the paper does not permit us to address this argument in extended form. However, given that our perspective on emotions and teaching and learning processes is rooted in socio-constructivist and phenomenological traditions, we agree with Coeckelbergh [17] in his argument that worries about deception in HRI is only a problem for those whose ontological and epistemological positions presuppose a clear divide between objective reality and mere appearance. We believe that, instead of focusing on the metaphysical distinction between reality and illusion, it is more constructive to consider how social robots *appear* to those interacting with them in a given situation. This means that, in our view, children are able to perceive and to relate to social robots in different ways and in different times and contexts, and have a non-conflicting experience where robots can function simultaneously as tool- and agent-like, which has already been discussed by Hannibal [40].

6.2 Vulnerability

To conclude, we would like to share our broader reflections on the topic of vulnerability that extends beyond ethical considerations pertaining vulnerable groups, common in the field of sHRI. Specifically, we would like to talk about vulnerability as a part of the human condition [14][31][18]. As such, it concerns everyone no matter the age, gender or status. Here, we define vulnerability as *the capacity to be hurt.*

In the context of education, we consider that vulnerability can be experienced equally by teachers and learners alike when they engage socially; and can be associated either with fear and shame or empowerment and creativity [13]. From the perspective of the learner, vulnerability is a fundamental aspect of learning because, in order to achieve progress, a recognition of one's own limitations is a necessary condition. Therefore, for the learners, disappointment is associated with ambivalence and risk, where negotiations about the boundaries and self-worth are carried out, but also with a possibility for self-reflection and growth.

From the perspective of the teachers, experiencing disappointment is also associated with vulnerability: disappointment would not mean much if teachers were not able to place hopes in others, and, what is also important, in their own role in success of others. As discussed earlier, the care that teachers experience for their students makes them both receptive to the possibility that some students will not live up to the expectations that are set not only by the teacher, but by the institutionalized system of education. Thus, while at first glance, teachers' disappointment may seem as something that arises from procedures of systematic and standardized teaching and measured learning outcomes, deeper considerations suggest vulnerability that is associated with social and emotional bond and aspirations for others.

7 CONCLUSION

In this paper we focused on the exploration of the structure and pedagogical effect of teachers' disappointment from the perspective of socio-constructivist and socio-functional approaches to emotions and as grounded in the existing accounts of teachers' experiences. We discussed possible antecedents of teachers' disappointment, addressed teachers' motivation to communicate disappointment to learners and sketched out a number of conditions that we believe important for the communicated disappointment to have a positive, affiliating pedagogical effect.

From a theoretical standpoint, we hope to have shown that, for the conceptual foundation of teachers' disappointment that allows to account for the dynamic nature of teacher-learner interaction, an approach that integrates appraisal theories of emotions with socio-constructivist and socio-functional stances is useful. This is because, taken in isolation, appraisal theories assume a close connection between emotion as experienced and emotion as displayed [22]. However, as we discussed, teachers' disappointment also bears a social, communicative function; and it can be the case that teachers will choose not to display their disappointment where they believe it may have detrimental effect on learners, or where they find such expression inappropriate. To the latter point, disappointment is only of pedagogical value to us if we look at the unfolding of this emotion, what it leads to, and the meaning ascribed to it by learners.

Regarding future modeling of negative and ambivalent emotions in robotic tutors, while we abide by the non-replacement principle (i.e., "social robots may only do what humans should but cannot do" as defined by Seibt [74]), given the evidence indicating simplicity and eager with which humans engage in affective, HRI being a situation of possible deception, we believe that *informed and ethically considered* exploration of how expressions of such emotions will interact with humans' affective states and motivation are warranted. To this point, we conclude that, at this stage, for the proper hypotheses and interaction scenarios or action sequences formulations, more exploratory studies that are carried out outside laboratories, that would also engage stakeholders such as teachers and parents, and engage a mix of methodological approaches to data collection and analysis, are necessary.

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