Framework document for the role of socio-emotional bonding for learning

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Short abstract	The present document summarizes basic psychological concepts related to socio-emotional bonding and empathy, as well as previous research on artificial empathic systems. It describes the needs, affordances and behaviors in successful relationship development between learners and teachers and what is necessary in application to the artificial tutoring system. It closes with a set of recommendations for the development of the EMOTE systems.	
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Table of Contents

1. General Introduction

At the core of the EMOTE project is the development of artificial systems for tutoring children that involve sensitivity to emotional displays of the learner, exhibit expressive behavior, and thus, via the implementation of empathic processes, contribute to the development of a socio-emotional bond between the learner and the robot that serves as the social front-end to the system. The present document summarizes basic psychological concepts related to socio-emotional bonding and empathy, as well as previous research on artificial empathic systems. It will describe the needs, affordances and behaviors in successful relationship development between learners and teachers and what is necessary in application to the artificial tutoring system. It will close with a set of recommendations for the development of the EMOTE systems.

2. Socio-Emotional Bonding

Socio-emotional bonding is a vital element of our well being, representing an essential aspect of healthy individual development and it is fundamental to group formation and social cohesion. In most general terms, social bonding is a socio-emotional process that refers to psychological phenomena in individuals, as well as to properties of dyads or groups. It is believed that the absence of socio-emotional bonds is associated with negative health outcomes and strong negative feelings, such as loneliness (Cacioppo & Patrick, 2008).

In the context of developmental psychology, socio-emotional bonding is usually discussed in the context of maturation that occurs from moments after birth to adulthood – a topic Sroufe (1979) referred to as “Socioemotional development”. For example, a baby does not possess the cognitive prerequisites to model the behavior of others in the same way that a pre-school aged child, or a teenager can. Similarly, there are various changes in emotional behaviors and relationships during the entire lifespan of individuals (Santrock, 2014) that affect how they can and do relate to their social environment.

For the purpose of the EMOTE project, it is important to distinguish between two different aspects of socio-emotional bonding. The first refers to the *capacity for socio-emotional bonding* as a function of age. Here individuals’ experience of interacting with their physical and social environment within biological constraints affects all aspects of personality, emotions, and behavior (see also Santrock, 2014). A six-year old child will bond in a very different way to

a new care-giver than a toddler or infant; a teenager bonds to a peer differently than a 40 year old. The second aspect is the *actual process of bonding*, such as starting a friendship, or getting to know and trust a person, such as a teacher. Both aspects are not independent from one another, because what happens in the short run, in a concrete situation (which may last from minutes to weeks or months) is a function of the capacity for socio-emotional bonding, which is a function of general socio-emotional development.

Due to the importance and complexity of socio-emotional bonding, numerous theories exist on this topic. Describing the developmental perspective and the evolutionary perspective in the present document shall provide a bi-directional approach in understanding some of the most fundamental factors that influence our behavior on a conscious and non-conscious level; most importantly how this understanding can be linked to socio-emotional bonding and learning.

2.1 Theory: Development and Attachment

The human life span is defined by various developmental periods and changes that affect our biological, cognitive and socio-emotional well-being (Santrock, 2014). Developmental theorists often examine these periods, and more specifically, socio-emotional processes and socio-emotional development within Piaget's classical framework of stages of development. Cognitive Development Theory as developed by Jean Piaget (1954, cited in Fischer & Silvern, 1985), described four stages of cognitive development that are processes of organization (learning and collecting data) and adaptation (behavioral changes based on data acquisition). For the EMOTE project the most relevant stage Piaget described is that of 7-11 year old children, defined as the Concrete Operation Stage. This is the key period for children to develop logic based on reliable examples and execute rational and consistent behavior (Labouvie-Vief, Grühn, & Studer, 2010). Since the EMOTE project is focusing on children between the ages of 11-13, elements of the project design will likely assume the children are balanced, reliable and can utilize reason in their interactions.

This period of development seen above, and also explained by Music (2010) is transformative as children build more important relationships with teachers and peers and school becomes more academic in focus. During this time, children develop self-conceptions, moral reasoning and gender-specific behavior (Music 2010). Through the development of self-conceptions, children become more adept at perspective taking and at learning how to express empathy (Music, 2010). In relation to the learning process, children begin to experience different needs

and expectations in emotional and social support, in which the development of self-concept relates to a child's ability to achieve or cope with environmental triggers (Santrock, 2014). Furthermore the changes and developmental growth characterized by adjustments in emotional communication, moral reasoning and behavior, and self-understanding transform the status and meaning of relationships with others (Papalia, Olds, & Feldman, 2008). Understanding these transformations and the process of maturation means addressing the varied needs of this age group as important to the design of interactive processes linked to socio-emotional bonding.

The process of transitioning through various phases of socio-emotional development illustrates the importance of varied aspects of socio-emotional connection and self understanding (Snelgrove & Slater, 2003). Regardless of the specific theoretical perspective, the concept of the self is a strong component in socio-emotional development research. The movement of the self through various phases and levels of self understanding, esteem and awareness play critical roles in our interaction with others (Pfeifer & Peake, 2012).

2.2. Theory: Evolutionary Foundation

Charles Darwin (1872) in *The Expression of Emotions in Man and Animals* emphasized the social and shared nature of human (and animal) expression. Darwin identified that basic emotional components are related to an evolutionary foundation in which environmental events trigger responses in the form of primary emotions (1872). Darwin also demonstrated a framework of reciprocity and argued that humans (and other species) have a need to rely on one another during the life cycle (1872). In present-day evolutionary psychology, the varied stages during the life span are thought to make human beings inter-dependent on each other for survival in which we provide or receive resources that are imperative for our evolutionary fitness (de Waal, 2009). This life cycle dependence is linked to our desire and need to socio-emotionally bond and create meaningful or at least reciprocal relationships leading to automaticity in our empathic responses to others (de Waal, 2009). In human interaction, a distinguishing characteristic in the formation of reciprocal relationships is the capability for self-reflection and emotional reappraisal (Povinelli, Bering & Giambrone, 2000).

Cacioppo and Patrick (2008) highlight that human bonding and the formations of close interpersonal relationships are essential to survival and to our physical and psychological wellbeing. Similarly, de Waal (2009) stated how social bonds and the cultivation of our

"emotional intelligence" to sustain these relationships are a fundamental requirement for human survival and progress. The development of "emotional intelligence" is correlated to the human ability to reflect on their emotional state and change their behaviors towards others to maintain social bonds (de Waal, 2009). What emerges is an understanding of the self, and its' relation to others, as adaptive in terms of physical, cognitive and social skills. This evolutionary construct illustrates how learned behaviors of self-regulation and identity formation help with processing and deciphering of environmental information to better understand and thereby better connect with others (Trzesniewski, Donnellan & Robins, 2008). In turn, these social relationships lead to increased well-being, access to resources, and enhanced survival. This is relevant to discussions regarding the development of artificial tutors, or, in more general terms, companions because it suggests that we are prepared to link to others to cope with environmental challenges: We like and need company!

2.3. Theory: Attachment

Ainsworth (1989) identifies attachment as a critical component of socio-emotional well-being, as it forms the foundation of interpersonal relationship formation. Without experience or the ability to form a safe and intimate relationship with another, socio-emotional bonding is limited, and loneliness or isolation can result (Ainsworth, 1989). Attachment is understood as "…a deep and enduring affectionate bond that connects one person to another across time and space" (Bergin & Bergin, 2009, p.142). Our ability to socio-emotionally bond is therefore rooted in our experiences with attachment and the types of attachment figures and relationships we have been exposed to. Ainsworth (1989) puts a strong emphasis on the bond between mother and infant, and this maternal-infant bond has arguably been the single most researched type of relationship in the attachment literature. The maternal-infant bond is said to strongly link to infant development and successful advancement into childhood, adolescence and adulthood. Ainsworth further argues that attachment and human bonding is a process that is seen at its most intense during infancy (1989). In consequence, she argues attachment processes form the foundation for successful socio-emotional bonding.

Mary Ainsworth's pioneering research has had a particularly profound impact on the definition of human bonding in Attachment Theory. Relationship formation is, however, also linked to Bowlby's Behavioral Systems Theory (1982, cited in Hofer, 2006). This theory has various, predictable 'working models' of how infants, and later children and adolescents respond behaviorally, cognitively and emotionally to their environment, and how their caregivers

respond in-turn to their needs. Four forms of attachment have been suggested by an extensive body of literature: secure, insecure/avoidant, insecure/resistant, and insecure/disorganized (Bergin & Bergin, 2009). Attachment has most commonly been studied in infants and children responding to their primary caregiver. In this context, it has been shown that the extent to which the primary caregiver manages to attend to the needs of the child is related to the degree to which the child is likely to use the caregiver as a secure base to explore their environment (Ainsworth, 1989). Importantly, however, later research has demonstrated that the effects of early attachment are not limited to secure exploration in the presence of other caregivers. Rather, attachment security has been found to be linked to success in other socio-emotional relationships and interactions as well: As a child is safe to explore its' environment it also becomes more successful and masterful at a variety of activities, including social relationships and navigating the school environment (Bergin & Bergin, 2009).

The 'Internal Working Models' are linked to attachment and socio-emotional successes, is a concept understood as a set of expectations based on remembered events that children will use to assess how they wish to interact with others (Bakermans-Kranenburg, van IJzendoorn, & Juffer, 2003). In terms of socio-emotional bonding the 'Internal Working Model' has three important components: "(1) a model of others as trustworthy, (2) a model of the self as valuable, and (3) a model of the self as effective when interacting with others" (Bergin & Bergin, 2009, p.145). This sets the foundation and predicts the success of socio-emotional interaction and bonding.

Insecure attachment results from a violation to the 'Internal Working Model' and implies that basic levels of trust and confidence are not fully developed (Bakermans-Kranenburg, 2003). This impacts the ability to form an empathic connection, develop empathic concern or form a trust-based relationship with the 'other'. The foundation of socio-emotional bonding is linked to social-emotional competence which is defined by Aviles, Anderson, and Erica (2006) as: "…cooperative and pro-social behavior, initiation and maintenance of peer friendships and adult relationships, management of aggression and conflict, development of a sense of mastery and self worth and emotional regulation and reactivity" (p.33). Individuals, particularly those with secure attachment, will seek to explore and develop new social relationships by sharing experiences, values, beliefs, goals, ideas and interest, with these commonalities serving as part of the foundation for bonding (Carstensen, Fung, & Charles, 2003). To develop intimate bonds with others, similarities should also exist in emotional expression, empathic connection and the development of trust. This often involves the process of emotional

contagion, defined as shared emotional experiences and understanding (Hatfield, Cacioppo, & Rapson, 1994). To develop an empathic and emotional connection requires skill in three distinct domains:

…affective sharing between the self and the other, based on perception-action coupling that lead to shared representations; self-other awareness. Even when there is some temporary identification, there is no confusion between self and other; [and] mental flexibility to adopt the subjective perspective of the other and also regulatory processes. (Decety & Jackson, 2004, p.75)

Successful socio-emotional bonding, in a given situation is arguably a function of the individuals' developmental processes, evolutionary foundation, environmental experiences, attachment processes and their level of emotional intelligence in conjunction with their current environment and present-day experiences. How these factors interact is likely difficult to predict.

2.4 Empathy

A key element of any successful relationship, whether in the process of bonding, as outlined above, or in everyday interaction of an existing relationship, is empathy. The word "Empathy" entered the English language relatively late as Edward Titchener's translation (1909, cited in Davis, 1996, see also later in this section) from the German concept of "Einfühlung" as discussed by Theodor Lipps (1903, as cited in Baron-Cohen & Wheelwright, 2004). Lipps was originally studying aesthetics and was interested in how we project ourselves into what we observe. Psychologically, both Lipps and Titchener believed that empathy occurred by witnessing the emotional state of the other and then internally, unknowingly, imitating that response. This type of process is referred to today as motor mimicry (Davis, 1996). In the last decade, motor mimicry has (re-)gained attention since the discovery of mirror neurons in the macaque by the group of Giacomo Rizzolatti in Parma (di Pellegrino, Fadiga, Fogassi, Gallese, Rizzolatti, 1992). It is believed that a *mirror system* (see also, Keysess & Gazzola, 2010), composed of a network of mirror neurons, plays an important part in mimicry processes. An empathic response is therefore seen as an emotional response in which mimicry or the matching of the emotional response (either positive or negative) is expressed to the 'other' (Gruen & Mendelsohn, 1986; however, see Hess & Fischer, 2013). In other words, this type of empathy has a strong embodied component. In the following, three different empathic concepts shall be briefly described.

The concept of *cognitive empathy* has a long history, starting with the works of Heider and Simmel (1944). In this classic study, participants were shown animated geometric shapes, which they treated as deliberate agents with specific objectives. This early study thus already demonstrated the existence of automatic and intrinsic mental attribution processes. Cognitive empathy continued to be conceptualized as a maturing skill or ability by early developmental psychologists such as Jean Piaget (see Baron-Cohen and Wheelwright, 2004) that increases in accuracy during childhood. The work of later developmental researchers, e.g., Wimmer and Perner (1983, p. 104), further demonstrated how children "…around the ages of 4 to 6 years [have] the ability to represent the relationship between two or more person's epistemic states…". Today, this concept is referred to as 'empathic accuracy' or 'theory of mind', which argue that the cognitive abilities to view, interpret and make conclusions are sufficient to understand how another person views and perceives the world (Davis, 1996). Therefore if learned and properly acquired, it is possible to infer the mental/internal state of the other based on one's individual perspective and the other person's perceived experiences (Baron-Cohen & Wheelwright, 2004). This concept of cognitive empathy does not require embodiment, such as mimicking a particular movement – here everything happens in the mind when faced with particular situations or behavior of others.

While the extremes of cognitive empathy and automatic mimicry show a clear theoretical contrast, they are not necessarily regarded as mutually exclusive. Thus, Hawk and colleagues recently investigated perspective-taking and nonverbal mimicry as two simultaneous paths to empathy in the case of empathic embarrassment (Hawk, Fischer, & van Kleef, 2011). Specifically, they (Hawk, et al., 2011) studied the responses of participants who were instructed to objectively watch a confederate vs. to engage in perspective-taking. The confederate was instructed to enact embarrassed vs. unembarrassed behaviors while dancing, and recorded on video. Path analyses showed both perspective-taking and mimicry to be involved in the indirect effects of embarrassment displays. As Hess and Fischer (2013) further argue, mimicry and perspective taking may therefore both help people to understand the emotions of other people, and to feel empathy with them. Further, current theories of emotional mimicry (Hess & Fischer) emphasize the role of contextual information. I.e., emotional mimicry is not about direct motor mimicry as such, but it is based on a contextualized interpretation of the signals as emotional intentions.

The model of *affective empathy* has been conceptualized more contemporarily and has a large impact on the understanding of empathic processes today. It was initially defined by Ezra Stotland (1969), to explain empathy as an 'observer' reacting emotionally to the 'other' based on the perception of emotion being experienced (Davis, 1996). The work of Dan Batson and colleagues (Batson et al., 1991) in his empathy-altruism hypothesis was even more limited to affect alone, concluding that experiencing empathy was rooted only in the experience of concern and compassion while bearing witness to another's suffering (Kruger, 2003). Martin Hoffman's theory (1984, 1987), in Hoffman (2008) defined empathy as "…an emotional state triggered by another's emotional state or situation, in which one feels what the other feels or would normally be expected to feel in his situation" (p. 440). Presently, the concept of affective empathy has re-appeared in related terms such as emotion "catching" (Hatfield, Cacioppo, & Rapson, 1994); intuiting or projecting of oneself onto the other and the "imagine other" perspective (Batson, 2009), "role-taking" or the "imagine-self" perspective and "empathic-distress" (Hoffman, 2008). Emotional contagion and how we experience the emotion of others (empathic concern) or over-experience the emotion of others (empathic distress); including what variables are most important in response conditions are highly relevant when identifying forms of empathy. There is a clear relationship between the concepts of cognitive and affective empathy, but they are not identical.

The theory of imitation and empathy relates to the concepts of facial empathy, facial feedback hypothesis and motor mimicry; i.e., the concept that "…people automatically and non-consciously mimic the behaviors and mannerisms of their interaction partners…" (van Baaren, Decety, Dijksterhuis, van der Leij, & van Leeuwen, 2009, p.32). This concept relates back to the concept of "Einfühlung" as discussed by Lipps (1903) and referred to at the beginning of this section, as well as the work of Charles Darwin (1872), John Lanzetta (1970) and Paul Ekman (1969, 2003) all discussed in Levenson (1996). The idea of facial modulation in which the face would become a feedback system that would influence the formation of emotion, and subsequent level of communication is also presented (Levenson, 1996). Further experiments have shown that generating a specific facial expression creates autonomic nervous system changes which results in experiencing the analogous emotion (Ekman, Levenson, & Friesen, 1983). Imitation of the 'other' operates as a 'bridge' to the formation of empathy which involves mapping of specific behaviors of the 'other' onto our own representations of the specific behavior (van Baaren et al, 2009). This further identifies the formation of empathy as directly linked to the social nature of emotion; as discussed by Kappas (2013) emotions can be accompanied by expressive behavior and emotions serve as an attachment element between

individuals. Therefore imitation of the 'other' (who is expressing an emotion), by the 'observer' (who is showing a related expressive behavior), will result in higher levels of perceived similarity between the 'other' and the 'observer'. In this context, imitation has been referred to as the 'social glue' that unites individuals and social groups together (van Baaren et al., 2009). Mimicry, like motor mimicry, is not necessarily confined to the face – but can involve also gestures, mannerisms, or changes in body posture. For example, the concept of mimicry, of actions and postures, commonly referred to in terms of the chameleon-effect (Chartrand & Bargh, 1999), has illustrated that individuals who display greater amounts of dispositional empathy are able to generate and maintain greater social connections and that these connections are formed with higher degrees of liking and ease of communication (Decety & Lamm, 2006). In addition mimicry studies identify that participants with high empathy scores produce higher levels of facial mimicry in comparison to low score participants (Sonnby-Borgstr öm, J önsson, & Svensson, 2003). While this is an active area of research in social psychology, not all types of imitation and mimicry have been systematically studied. Suffice it to say that liking leads to behavioral imitation and imitation, in turn, leads to liking.

The above research on the differing aspects of empathy has led many researchers in the fields of cognitive, developmental, social, evolutionary, clinical psychology and social neuroscience to attempt to agree on three different aspects of empathy (Decety & Lamm, 2007). As outlined by Janssen (2012), they include: "…recognizing someone's emotional state (i.e., cognitive empathy), the convergence of feelings between people (i.e., emotional convergence), and responding to another person's (inferred) feelings or the emotional convergence those feelings initiate (i.e., empathic responding)" (p.143).

As described above, the expression of empathy and empathic understanding is foundational to our interpersonal relationships with others and our ability to communicate with them. There is a pervasive motivational drive to form relationships; this motivation was highlighted in Maslow's (1954) hierarchy of needs where he identified 'love and belongingness' in the center of his hierarchy. This *need to belong* is what drives humans to form relationships (Baumeister and Leary 1995). It refers to the relational processes outlined at the beginning of this report and the intrinsic drive and motivation for social bonding is the explanation for why countless studies illustrate that social bonds form easily and quickly, even "…in the absence of any special set of eliciting circumstances or ulterior motives" (Baumeister & Leary, 1995, p.502). Because we know that people bond easily out of a "need" we have, this reasons to assume that a natural bonding is likely to occur also between a child and a robotic tutor, or more

general, an artificial agent (virtual and/or embodied), as long as the agent is able to respond to these needs.

In summary:

- Social bonding has evolutionary origins
- The need to bond appears to be a strong motivation common in all humans
- In children, aspects of social bonds can differ depending on age and maturational processes
- Social interactions, and here particularly empathic processes, affect the quality of any social bond
- Differences have been reliably demonstrated regarding quality or type of social bond in the context of attachment
- Taken together, this suggests that children are ready to bond to others, particularly caregivers. This is highly relevant for tutors in the present context (see next section).

Given that it has been reliably shown that humans tend to treat machines, and particularly computers and robots, as "people" (*the media equation*, Reeves & Nass, 1996; see also section 4). An analysis of human-human bonds can be informative. However, we do not know what the effect of differences in cognitive skills, reactivity, and expressiveness of the robot will have on:

- 1) The establishment of a bond
- 2) The maintenance and development of the bond over time
- 3) Inter-individual differences between children in how they relate to the robot.

Hence, a better understanding of these issues will be a focus of the ongoing activities in the next couple of years in the EMOTE project.

3. Socio-Emotional Bonding and Teaching

Several reviews of educational psychology literature have demonstrated that socio-emotional well-being is critical to school success (Bergin & Bergin, 2009). The function of the classroom setting is to provide the learner with a secure environment in which they are free to safely explore their environment: physically, mentally and emotionally. This is clearly linked to the process of secure attachment formed between teachers, peers and learners in the classroom environment. Bergin and Bergin (2009) argue that the teacher is seen as available, thereby allowing the formation of a socio-emotional relationship, by being physically present, able to

communicate openly, responsive to a learner's request for help and aware of the needs of the learner. The security and level of attachment to the teacher and classroom is predictive of academic success and is expressed through various behaviors depending on the age, previous experience with attachment, past developmental issues and varied environmental exposure of the learner. Ainsworth (1989) suggested that teachers (caregivers) are also able to create secure levels of attachment with insecure learners if the focus is on providing a safe and reciprocal relationship instead of responding with hostility or rejection. Taken together, these arguments highlight the importance of emotions expressed by the teacher, as well as sensitivity to the expressive behavior of the learners in the context of classroom or dyadic interaction.

3.1 Emotional Aspects: Learner and Teacher

Meeting the socio-emotional needs of learners requires consideration of a combination of emotional, cognitive and environmental factors, which impact learning outcomes in the classroom, including the formation of secure attachment. Certain perceived characteristics of teachers and the learning situation may facilitate learner engagement. Perceived caring of the teacher, a well-structured classroom environment, as well as high, clearly articulated, and fair expectations have been suggested in particular (Klem & Connell, 2004). These characteristics create high levels of engagement which results in high classroom attendance and leads to higher test scores and overall grades (Klem & Connell, 2004). In classroom environments where teachers foster trust and show learners genuine care and concern, motivation increases, grades increase, and negative or risky behaviors have been shown to decrease (Bergin & Bergin, 2009).

Bergin and Bergin (2009) have suggested the following six techniques that teachers can utilize to foster socio-emotional well-being and emotional attachment in the classroom:

1. Increasing sensitivity and showing warmth and positivity when interacting with learners,
2. Detecting various cues from the learner,
3. Being well prepared for class and creating high expectations for learners,
4. Being responsive to a learner's agenda complemented by using inductive rather than coercive discipline,
5. Helping students exhibit pro-social behaviors to their peers, and
6. The implementation of interventions for difficult circumstances faced in the classroom.

Bergin and Bergin (2009) have suggested that these six methods are seen as core elements of effective teaching which has led to increases in learning, motivation and engagement and teachers utilizing these skills reported increased personal enthusiasm in the classroom. Studies on the process of emotional transmission/contagion between learner and teacher also demonstrate that teacher enjoyment is positively correlated, with learner engagement regardless of the subject matter, which leads to increases in participation (Frenzel, Goetz, Lüdtke, Pekrun, & Sutton, 2009). Teacher enjoyment and its' impact on learner engagement continues to be replicated in classroom environments (Bergin & Bergin, 2009).

While Bergin and Bergin (2009) make particularly detailed suggestions about how teacher behaviours and school organization may improve academic achievement through secure teacher-student relationships (TSRs), other research has looked at associations between TSRs, engagement, and academic achievement at a more general level. In a recent meta-analysis, Roorda and colleagues (Roorda, Koomen, Spilt, & Oort, 2011) integrated the effects of 99 studies that looked at TSRs, engagement, and achievement. They reported overall medium to large associations between TSRs and engagement, and small to medium associations with achievement. Furthermore, they emphasized that, unexpectedly, stronger effects were observed for higher grades. This suggests that a good bond with teachers does not automatically lose importance as children get older. Naturally, however, highly aggregated research at the level of meta-analyses cannot be as specific about the precise nature of the psychological concepts and mechanisms as any individual study. For this reason, the more inclusive term of TSR is used in some of the most relevant research rather than attachment per se, even if attachment can be assumed to be one of the core components of this relationship.

A more detailed look at the potential factors and processes involved in the formation of TSRs has, for example, been offered by Klem and Connell (2004). In their view, learners respond to the quality of TSRs with varied levels of "commitment", i.e., regular attendance at school, and how they react to, or cope with, negative school events. For example, TSRs impact whether students will be more likely to examine and change their own behaviour, or if they rather downplay the importance of an event or deny responsibility (Klem & Connell, 2004). More specifically, Klem and Connell (2004) discuss the student's "reaction to challenge", which is defined as how a learner copes with specific learning tasks, based on their level of perceived security and socio-emotional well-being. This is where they argue that relationships with teachers really matter. If, as Klem and Connell (2004) suggest, education is comprehensively

reformed with relationships and support in mind, learners may respond more optimistically to such challenges, by pushing through the challenge using problem solving techniques. Otherwise, learners appear to be more likely to avoid or delay activities due to a fear of failure, and show negative emotions such as anger, sadness or anxiety (Klem & Connell, 2004). Avoiding or delaying interaction in the classroom leads to a cycle of disengagement. This presents a great challenge in the classroom environment.

3.2. Disengaged Students: Challenges

Already the behaviorist tradition in psychology (e.g., Skinner 1977, 1984) studied numerous issues in the classroom that appear to prevent learners and teachers from being engaged with each other. Skinner identified four primary issues: A lack of clarity about what is being taught, a deficiency in foundational teaching and learner understanding, the expectation that all students' progress at the same pace, and a lack of well-constructed educational programs resulting in less opportunities for reinforcement (1984). Behaviorists have suggested addressing these as primary issues that should be focused on the level of the class before targeting specific students. Skinner (1984) argued that concentrating on the 'whole' would result in less disengaged learners. Two things appear remarkable here. The first is the, for Skinnerian behaviorism (see Feldman, 2012), unusual focus on groups, rather than the reinforcement of individuals. The second is to become aware of the lasting impact the behaviorist tradition appears to have had on student-teacher interaction even up to the present day, where we aim to design empathic robots. However, Skinnerian reinforcement is not what we should primarily have in mind when designing behavioral strategies of socially aware empathic robots. In certain cases, this difference may appear to be subtle – yet reinforcement learning is not based on building empathic bonds between people. Rather, reinforcement is a rather separate process, and in some ways even at odds with, the attachment-oriented approaches to empathic learning discussed earlier. These are about sensing affective states and responding as a function of these states, with the goal of creating emotionally adaptive behaviors.

While we emphasize that Skinnerian behaviorism is in some ways too limited in its focus on reinforcement learning, the behaviorist tradition was nevertheless relatively concrete in the advice given to teachers. In situations with disengaged learners, for example, Skinner and Belmont (1993) argued that it is imperative that the teacher spends time forming an interpersonal relationship with the student; increasing guidance, showing enthusiasm for the

learner, offering more praise or reinforcement and focusing attention on their behaviors to increase motivation. More recently, other aspects of disengagement have captured the interest of pedagogic research past the Skinner era. Thus, disengaged learners tend to exhibit a conscious opposition to the learning process (McFadden & Munns, 2002). To combat resistance, teachers can utilize preference and choice making with the disengaged learner while also increasing positive reinforcement. An example of preference includes allowing students to choose what subjects they would like to study first in a session. An example of choice would be allowing students to make a decision as to what activity they prefer, the level of interaction, or the reinforcement for completion of the activity (Skinner & Belmont, 2003). These strategies, focusing on content rather than affect, have been shown to increase learner interest and learner motivation (Morgan, 2006). This research will be of particular interest to the design of the learning scenarios in the EMOTE project, as discussed in Deliverable 2.1.

What other factors may influence learner engagement? In a recent meta-analysis on the positive impacts of learner centered education, Cornelius-White (2007) further highlighted the above mentioned elements in facilitating learner engagement in the classroom. The meta-analysis suggests a number of positive effects of learner-centered education: Learners had higher results in critical and creative thinking, higher basic IQ scores, high motivation and participation, reduced negative classroom behaviors and higher pro-social behaviors towards themselves and others (Cornelius-White, 2007). Importantly, all of these positive effects were associated with higher levels of socio-emotional bonding and well-being, suggesting that the presence of positive emotional bonds may have been of particular importance.

More focused on specifically empathic aspects of interactions than the Skinnerian tradition, has been work inspired by Carl Rogers (e.g., 1957), as well as by early ethologists such as Lorenz and Tinbergen (e.g., Lorenz, 1937; Tinbergen, 1963). Carl Rogers's (1957) person-centered therapeutic theory suggested that learning is rooted in socio-emotional wellbeing and bonding in which an individual is encouraged to reach their full potential; this is achieved through empathy, cooperative learning and interdependence in the session, or educationally, in the classroom. Likewise, ethologists studied affiliative bonds as a central process of mammalian adaptation (Feldman, 2012). Thus, while comparative ethology has been defined as "the biological study of behavior" (Tinbergen, 1963, p. 411) that included the systematic study of human and animal behavior at a detailed level, it clearly recognized the importance of early human bonds for the development of love as well as exploratory behavior (see e.g., Lorenz, 1981, p. 274). Starting from this background, more recent research in biological

psychology has studied the micro-level of social behaviors such as gaze, touch, or social distance in addition to biological factors such as the role of oxytocin for social affiliation (Feldman, 2012; Scheele et al., 2012). These types of micro-behaviors may be of particular interest to the EMOTE project because they relate to current research in the social and biological sciences from a theoretical perspective that explicitly included mental and emotional processes

3.3 Engagement: Nonverbal Behavior and Emotion Sequence

Sidner and colleagues (Sidner, Lee, Kidd, Lesh, & Rich, 2005) suggest that, in addition to the aforementioned aspects of teachers that are linked to learning success and good teacher-learner relationships, there are also basic, nonverbal behaviors that increase socio-emotional connection and human-human engagement. These behaviors are the basis of the *principle of conversation tracking,* which examines how human-human interaction takes place in collaborative conversation (Sidner et al., 2005). Key components of nonverbal, human-human interaction include facial tracking of the conversation partner in balance with looking away; taking note of the environment and relevant stimuli and also being able to multi-task (Sidner et al., 2005). Other basic nonverbal components of human-human engagement include: The direction of gaze to attend to the conversation partner, head movements including nods, head shakes, sweeps and positioning angle, and body language towards the collaborator. These components are important in creating meaningful engagement and aid in socio-emotional bonding. One word of caution is appropriate here – some of these behaviors have been shown, at least in non-school contexts, to differ across cultural contexts (see, e.g., Bull, 2002).

Finally, Frymier and Houser (2000) describe successful learning as an emotional process, in which learning typically takes place during an emotional sequence. The interpersonal relationship between a learner and teacher is seen as a reflective emotional sequence in which the teacher responds to multiple needs of the student, and the student reflects back that their needs were met (Frymier & Houser, 2000). Research in affective computing has emphasized the role of emotions in learning, memory and pro-social behavior. Whereas happiness, or positive emotion, has been shown to facilitate these processes, anger or negative emotions have been found to result in decreases in learning, motivation and memory (Moridis & Economides, 2008). The Kort-Reilly-Picard dynamic model of emotions proposes that learning is a process that takes place in transitioning between four stages; "…according to this model, during learning, the student repeatedly passes from curiosity to disappointment, frustration

and acceptance" as outlined in Moridis and Economides (2008). The model identifies that as learners progress through these stages they are experiencing 'constructive learning' which increases motivation and participation in the classroom environment (Moridis & Economides, 2008). The learning is constructive as they gain personal agency over the learning process by pushing through emotional states. The acceptance stage is when a learner, based on moving through uncomfortable emotions, discovers or creates a solution (Moridis & Economidies, 2008 and D'Mello, Jackson, Craig, et al., 2008). It can therefore be concluded that the emotional state of the learner impacts the classroom environment, socio-emotional relationship development, and academic success. In addition, by utilizing the right techniques, it is hypothesized that the emotional state can be altered so that disengaged learners can become reengaged in the learning environment and activity. While these models are interesting and carry the promise to be applicable in the field of social robotics, it currently remains an empirical question as to the extent they will be validated. From a psychological perspective, success is likely to lead to a promotion focus (Higgins, 1997), whereas difficult challenges and failure lead to prevention focus which in turn should affect the motivational stance of the learner. Thus it is critical, to repair frustration and lead the learner in a positive context to discovery and learning. Emotion and learning success could be seen in a reinforcing loop where positive emotions support learning success and learning success is a positive experience.

4. Socio-Emotional Bonding and Embodied Artificial Tutors

There exist, in principle, many forms of social interaction with nonhuman entities that have only relatively recently attracted the attention of empirical research (see Cerulo, 2009). However, not all of these are of equal importance in the context of the EMOTE project. Understanding human-artificial agent interaction or human-computer interaction (HCI) in relation to socio-emotional bonding requires examining how humans, in particular children, respond to these types of interaction partners. Reeves and Nass (1996) introduced the concept of The Media Equation, suggesting that we often engage with technology in a social way, similar to real life interactions. Specifically, interacting with certain types of media or artificial agents carries the expectation that the interaction will adhere to, and follow specific social rules of interaction that are experienced in human-human interaction in the natural world (Reeves & Nass, 1996). There are related concepts that are relevant in the context of Human-Machine Interaction. For example, the concept of Ethopoeia describes a process that "involves a direct response to an entity as human while knowing that the entity does not warrant human

treatment or attribution" (Nass & Moon, 2000, p.94). Rosenthal von der Pütten, Krämer, Hoffman, Sobieraj and Eimler (2013) have further suggested that the greater the similarity of interaction applied from human-human, to artificial agent, the greater likelihood meaningful interactions will take place. Establishing a 'connection' or 'relationship' with a computer, technology source or artificial agent possibly is assumed to begin as an automatic process, however the development of a socio-emotional bond requires more specific interactive processes that imitates human-human interaction and the resulting changes in relationship, involving mental models that predict certain behavior.

4.1. Robotics and Education: Current Views

Various pedagogical theories exist within the framework of educational robotics substantiating the use of various programming techniques and the selection of electronic or mechanical robot kits, or humanoid robots (Mubin, Stevens, Shalid, Mahmud, & Dong, 2013). As discussed previously, Jean Piaget's Theory of Cognitive Development (1954), as cited in Labouvie-Vief and colleagues (2010), was a foundational theory in which learning was viewed as being shaped by a learner's knowledge and what they experience. The work of Vygotsky in Social Development Theory as discussed in Talja, Tuominen and Savolainen (2005), conceptualized that learning was a process of collaboration in which education and socialization were combined processes; this introduced the concept of peer or tutor-based learning, frequently used in robotics education. In addition, the Theory of Social Constructivism, building on the ideas of Vygotsky, introduced the model of scaffolding, "*i.e.,* breaking up complex tasks into smaller tasks, a common occurrence in robotics education" (Mubin et al., 2013, p.5).

The theory of constructionism, now the most utilized theory for studying the integration of robots into educational environments, as applied by Papert, (1980, as cited in Mubin et al., 2013) shifted the above educational concepts. The theory of constructionism expanded the views of Piaget and Vygotsky by adding that true learning occurs when a student is able to assemble their knowledge and present it, thereby ruminating on their problem-solving skills based on the motivation to assemble said knowledge (Mubin et al., 2013). Students therefore will utilize their knowledge about the real world in combination with what they infer about the virtual nature of robotic interaction; this theory fits with the goals of robotics education, which is "…hands-on, encourage[s] students to think and be creative and [is] based on problem solving" (Mubin et al., 2013, p.4). This theory of learning promotes active learning and collaboration and is commonly described as discovery learning; these two components are

critical in learner success in the classroom and also the development of socio-emotional bonding between learner and artificial agent.

4.2. Embodied Artificial Agents: Roles in Companion Learning

The use of artificial agents in learning takes place in varied educational environments. These include intra-curricular settings, which are in the school and part of syllabi or specific educational goals, or extra-curricular settings, taking place after school hours either under teacher-supervision, parental supervision or workshop formats (Mubin et al., 2013). The role of the artificial agent can take on various forms/roles within the learning process depending on the needs of the instructor, student, or learning activity. Mubin and colleagues (2013) identified the following roles:

- The role of a passive teaching aid or tool. This is particularly useful if students are building or programming robots themselves.
- The role of peer companion/ co-learner in which the robot can actively participate, cooperate and interact with the learner.
- The role of mentor in which the robot instructs or tutors the student.

The recent review relating to the applicability to robotics in education by Mubin and colleagues (2013) further suggests that more technological advancement is required for robots to take on the role of 'tutor' as greater programmable robotic perceptive abilities need to be established. Depending on the type of task that a student is asked to perform, varied types of artificial agents have been recommended. In basic learning and simple structured activities, students have been shown to prefer a peer-style or companion robot and in more complex learning, like language activities, they preferred a tutor-style (Mubin et al., 2013). The capabilities of the embodied artificial agent in relation to social behavior and interaction processes will be discussed further, including the ability to form a socio-emotional bond.

4.3. Embodied Artificial Agents: Emotional Engagement

As discussed, learning is a process that may be greatly influenced by the emotional state of the individual (Picard et al., 2004). Implementing artificial agents into intra-curricular environments with a desire to impact learning, or to form socio-emotional bonds with students, requires that the agent is able to recognize emotion accurately and also interacts with programmed 'human-like' responses (Morides & Economides, 2008). The fields of human-computer interaction (HCI) and human-robot interaction (HRI) have acknowledged the need to

recognize affective states in the user. The key to creating socio-emotional bonds between humans and artificial agents is rooted in the agent conveying an understanding of emotional intelligence and the ability to develop a system that can personally analyze a user's emotional state and respond accordingly (Pantic & Rothkrantz, 2003). This strong correlation between affective states and learning has led to technological advancement in the development of 'affective tutoring systems' (Moridis & Economides, 2012) and 'affect-aware tutors' (Woolf et al., 2009). Classical theories on emotion have been utilized to develop software for emotion recognition, particularly Ekman's neuro-cultural theory (e.g., Ekman & Cordaro, 2011). Using the anatomically based Facial Action Coding System (FACS; Ekman & Friesen, 1978), software such as the FaceReader (Noldus Information Technology) in Moridis and Economides (2012) attempts to identify the "basic emotions" of joy, sadness, anger, disgust, fear and surprise (see also Calvo & D'Mello, 2010). Such algorithms promise to provide artificial agents with the capacity to identify and respond to the affective states of learners.

Yet, there are reasons to believe that a basic emotions approach might not be very useful in real world situations (Kappas, 2010). It would be preferable to provide a more detailed assessment of facial activity without imposing a small number of categories. In other words, a direct measurement of Action Units (AU) would provide the greatest flexibility. However, not all AU's are equally reliable, when measured with automated systems (see Chu, Torre, & Cohn, 2013 and Valstar, Jiang, Mehu, Pantic, & Scherer, 2011).

Furthermore, since the affective states of learners were not always understood and assessed using the six basic emotions listed above, Woolf and colleagues (Wolf et al., 2009) developed a scale, defined in 'cognitive-affective' terms, in which the four most identified emotions of joy, anger, surprise and fear were placed on varied axes. Utilizing defined 'cognitive-affective' terms allowed researchers to account for emotional experiences of boredom, anxiety, frustration and confidence, outlined previously in pedagogical processes. Understanding these emotional experiences links to what teachers identify as the 'vicious cycle', when students are trapped in a negative emotion related to the learning process, impacting engagement. Recent research has already attempted to address student engagement emotionally and pedagogically. The development of an intelligent tutoring system, the AutoTutor, helps students learn by conversing in 'natural language' with the student and offering responses that are sensitive to the affective state of the learner (Graesser, Chipman, Kind, McDaniel & D'Mello, 2007). This technology responds to affective processes experienced during complex learning scenarios and attempts to assist learners as they cycle through: confusion, frustration,

boredom and flow (Graesser et al., 2007). Expanding learner feedback, Morides and Economides (2012) suggest that the affective state of the learner can be altered through an agent expressing empathic feedback. This process then results in learners becoming more engaged and interested in the learning task and also demonstrating higher levels of self-efficacy in performing other classroom activities (Morides & Economides, 2012).

Humans often interact with technology in similar ways to how they interact with humans in a social relationship (see e.g., Cerulo, 2009). Research has continued to test these interaction processes in learning scenarios, suggesting that when empathy or support is provided (from a human or artificial source) learning is improved (Woolf et al., 2009). Students, who engage with a frustrating task via a computer, have been shown to spend significantly more time on the interaction if they are offered an empathic response from the computer program, often in the form of helpful hints or positive feedback (Klein, Moon, & Picard, 2002). These emotional responses also increase the complexity of the artificial agent, and in turn improve the level of engagement in the child (Michaud et al., 2007). Specifically for child-computer interaction (CCI), key differences have been observed for how children interact socially with technology and/or artificial agents (Read & Bekker, 2011). Children are able to constantly adapt to the presenting interface. Concerns regarding fun and playability are more important than issues of usability, in contrast to that of adults, who adapt less quickly and expect functionality (Read & Bekker, 2011).

One of the key benefits to the use of artificial agents as tutors or as peer-companions is the creation of a low-pressure educational environment where learners are able to work at a pace that they perceive as comfortable (Hyun, Kim, Jang, & Park, 2008). In these environments, when artificial agents model empathic responses, the engagement of the learner in both the task and interaction increases. Learners also feel less embarrassed to ask repeated questions to the agent, in comparison to a traditional teaching environment involving a human teacher, where the perceived risk of being judged is less threatening (Woolf et al., 2009). The ability to ask more questions increases the learners' confidence in the learning process and comfort in the classroom environment. Learners feel less anxiety/stress and reduced nervousness in asking and receiving help from an artificial agent as it is associated with less judgment and stigma (fear of disappointment) than when interacting with a teacher (Tüzün, Yilmaz-Soylu, Karakus, Inal, & Kizilkaya, 2009).

Highlighting importance of empathic processes in the creation of a socio-emotional bond, researchers have proceeded to study some of the affective qualities necessary to define an 'emotional-learning agent' (Morides & Economides, 2008, see also Picard et al., 2004):

1. Recognize the running emotional condition of the student
2. Recognize when to intervene in order to influence the student's emotional state based on a new educational pedagogy integrating emotional models in learning and
3. Produce the most optimal emotional state for learning (Morides & Economides, 2008 p.329).

These central concepts important to agent programming, are components of empathic responding and affect recognition which are shown to reduce learner frustration and increase learner engagement. The above factors of an 'emotional-learning agent', as developed and tested by Morides and Economides (2008), also produced stronger effects when a female character was presented versus a male. Researchers hypothesize that this is a result of empathy being identified as a more intrinsic feminine quality (Moridis & Economides, 2008 and Bickmore & Picard, 2005). More research is needed to determine how exactly tutor characteristics and learner characteristics interact in a particular learning scenario. This will continue to be a topic of research interest during the design of learning scenarios and interactive components in the EMOTE project.

4.4 Embodied Artificial Agents: Nonverbal Behavior

In addition to a focus on empathic responding and affect awareness, a key component of learning, interaction, and socio-emotional bonding in HRI is the capacity to have social dialogue, social interaction, recognition and display of nonverbal behavior/cues and expression of social competencies (Picard et al., 2004, and Bickmore & Cassell, 2005). In HCI and HRI, it has been proposed that the higher the number of social cues displayed by the technology becomes, the greater will be the social reaction and response. This is an interesting suggestion that might be addressed empirically in the EMOTE project. It is important to note that arguments like "more is better" have an intuitive appeal, but have been shown not to be correct in related research on mediated communication (Walther, 2011 and Baylor & Kim, 2009). More social behaviors are positively correlated with increased socio-emotional bonding and perceiving the behaviors of the artificial agent as having more meaning (Appel, von der Pütten, Krämer, & Gratch, 2012). There are fundamental categories of social communication

that will have an impact on the programming of the embodied artificial tutor. In terms of developing an empathic connection previous work with embodied artificial agents has focused on three factors: proximity (creation of communal relationship), and facial and body expressions (emotional expressions easily identified by the observer) through these nonverbal channels (Paiva et al., 2004). The initiation and termination of communication is most vital as it includes inviting and farewell contact, reaction to the other, nonverbal cues such as head tilts and eyebrow raises and body posturing (Bickmore & Cassell, 2005). In the learning context particularly, turn-taking in conversation is important for understanding and progressing through an activity. By utilizing turn-taking programming, artificial agents are able to await and confirm responses, based on verbal and non-verbal cues, while also identifying when a learner is no longer engaged (Sidner et al., 2005). Turn-taking behavior that is then personalized to the child-user (as seen in the iCat experiment in which the artificial agents' response is based on the affective state of the participant) results in children perceiving the 'robot' as more engaging and supportive (Leite et al., 2012). Engagement is frequently rooted in the process of collaboration. Programming virtual agents or robots with diverse conversational sub-systems, in conjunction with gathering various sensory information (via skin conductance, heart rate, or facial activity) has been effective, yet more research is needed (Sidner et al., 2005 and Castellano, Leite & Paiva, 2011).

Understanding the relationship between meaningful social dialogue and the development of trust is a key component in the formation of a socio-emotional bond between learner and agent. Forming this socio-emotional bond is a reflection of the creation of an interpersonal relationship between the agent and the learner. As highlighted by Bickmore and Cassell (2005), an interpersonal relationship in human-human interaction is multi-dimensional and includes the following components: "…small talk, avoiding face threats, reciprocal appreciation, building common ground, coordination, solidarity, familiarity and affect…" (p.31). The function of these behaviors in verbal conversation is to develop trust and an emotional bond. Nonverbal behaviors play an equally important role in the development of socio-emotional bonding; the most crucial immediacy behaviors include: "…close conversational distance, direct body and facial orientation, forward lean, increased and direct gaze, smiling, pleasant facial expressions and facial animation in general, nodding, frequent gesturing and postural openness" (Bickmore & Cassell, 2005, p.32).

Social dialogue with artificial agents is clearly multi-faceted. In the context of the EMOTE project, this has the consequence that many verbal and nonverbal traits of human-human

interaction must be understood, modified and then programmed so socio-emotional bonding and relationships formation can occur. A recent longitudinal study on child-interaction with a Nao robot suggests that children are most responsive when the artificial agent is able to adapt its behavior to the interaction (Belpaeme et al., 2012). The ALIZ-E EU Integrated Project is continuing to research varied levels of responsiveness in interaction between a child and the Nao to develop technology to assist in developing and sustaining social bonds with artificial agents and children. These developments, paired with advances in robotics education will be useful when planning interactive experiments between child and artificial agent for the EMOTE project.

The automaticity of mimicking behavior is particularly significant in the development of artificial agent nonverbal behavior. Mimicry (unconscious) is understood as the tendency to adopt behaviors, mannerisms or various bodily postures of interaction partners without awareness or the intention to do so (Chartrand & Bargh, 1999)). The automatic mimicry of nonverbal behaviors between interactions partners include: "…speech patterns, facial expressions, emotions, moods, postures, gestures, mannerisms, and idiosyncratic movements" (Lakin, Jefferis, Cheng & Chartrand, 2003). Mimicry also includes synchrony between interaction partners and behavior matching; particularly in a classroom environment, students mimic the behaviors of their instructors and the students they interact with (Lakin et al., 2003). The research of Chartrand and Bargh (1999) also indicate that unconscious mimicry leads to greater interpersonal closeness and 'liking' of the interaction partner. The desire to affiliate and develop social bonds with others is directly correlated to the process of mimicry; creating this type of interactive process in the learning environment will be necessary. These automatic layers interact with more controlled processes in mutual regulation of emotion (Kappas, 2013) and are likely particularly powerful in creating a sense of being connected.

There has been accumulating evidence that socio-emotional bonding between learners and artificial agents is, based on the literature, similar to the socio-emotional bonding that occurs between learners and teachers. The accurate acknowledgement, interpretation and response to a learners' affect establishes an emotional connection. Even if the response is simple, the acknowledgement of the learners' needs forms the foundation (Woolf et al., 2009). In addition, programming artificial agents to interact according to human-human social interaction standards, allows for normative interaction processes. The verbal and nonverbal cues and responses allow for continued engagement and for the learning process to take shape; these interactions continue to develop trust and reliance which encourages learners to

engage constructively with the artificial embodied tutor to the benefit of the learning progress (Moridis & Economides, 2012).

5. Implications for EMOTE Design

The EMOTE project aims to improve our understanding of embodied artificial tutors on the learning environment. One of the challenges is to relate the vast body of research in education, learning, emotion, developmental, and social psychology to the interaction of children and tutoring robots. At a practical level, this integration requires collaboration between psychologists and members of the other disciplines represented in the consortium - as well as with teachers that are consulted at every step of development and evaluation. Our survey on the functions and mechanisms of socio-emotional bonding provides an important starting point for further systematic research on the best practical implementation of concrete robot-child bonding behaviors in the EMOTE project. Clearly, factors such as emotional mimicry, expressions of empathic concern and distress, conversational turn-taking, and engagement vs. disengagement, are very relevant here. Much of this more fine-grained layer of research, for example with the Wizard of Oz paradigm, or on social vs. task engagement has already begun, and is described in detail in other deliverables (e.g., D.2.1, D.5.1). It is furthermore evident that the concrete implementation of the robotic tutor in EMOTE will have to overcome empathy-related challenges that are tied to the design of the available hardware. Here, D3.2 will provide another piece for the puzzle in the form of a validated corpus of nonverbal acoustical emblems that can help to mitigate the expressive limitations of the Nao robot. At other levels, the consortium has already taken important steps in the development of custom tools for the study and development of more empathic tutors (see, e.g., D5.1). These types of tools and technical advances promise to significantly improve the real-time responsiveness and synchronicity of the system – and these are factors that appear to be likely to have a profound impact on the tutor's capacity for emotional mimicry and initiation of attachment processes. While many of the concrete variables will require additional empirical research, the survey on the role of socio-emotional bonding presented in this deliverable should be helpful to understand the main issues discussed in the psychological literature about empathy, attachment, and the evolutionary and historical foundations of the psychological concepts in particular. This is important because, as we have seen, socio-emotional bonding is significantly more complex and multi-faceted than a simplistic reinforcement view might suggest.

An issue in the use of robots in educational contexts is that it is most commonly seen as an extra-curricular activity. It is not given merit as a potentially enriching tool for in-classroom teaching and is not commonly part of formal education or defined in curricula (Mubin et al., 2013). The EMOTE project will work with teachers' directly to develop learning activities that are tied into an appropriate curriculum and also aligns with the role of the artificial agent in the classroom. An important contribution of the EMOTE project is to design emotionally sensitive interactive behaviors of embodied and virtual tutors that aid in learning as part of the curriculum. Finally, one of our aims further includes demonstrating to educators that "…the intention is not to replace them with robots but rather provide them with a teaching tool/aid that can complement the learning experience and motivate the students" (Mubin et al., 2013, p.5).

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