

# Rapport-Aware Peer Tutor

We use learning science theories and machine learning methods to build educational technologies that can understand and respond to social dynamics. This project is a virtual peer tutor that can build rapport and support student learning.

## Overview

A significant body of literature describes the positive impact of socio-emotional bonds (such as mutual respect and interpersonal rapport) on learning - and on collaborative work in general. Decades of research on education has demonstrated that learning is fundamentally a social endeavor, where the relationship that students build with their teachers and fellow learners provides a social context that motivates and improves their learning gains.

These social relationships with teachers and peers contribute to students' motivation to learn [1], feelings of belonging [2], and ultimately, their learning outcomes [2, 3]. Most educational technologies, however, focus solely on the cognitive needs of students, often leaving unaddressed the social supports that are essential to learning; particularly essential, in fact, to those students who are marginalized in the classroom because of gender, ethnicity, social class, or disability. In fact, often the students who most rely on such social supports for learning may be the least likely to receive them from peers.

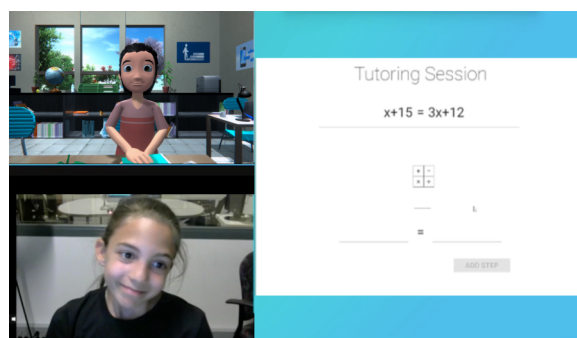
In the 21st century, the need to know how to build these sorts of bonds will only become more important. The fact that employees of companies are increasingly distributed across the world will mean that sophisticated interpersonal skills will be needed to overcome the obstacles represented by cultural differences and collaborations that are distributed in time and space.

And yet, while future-oriented technology-based learning - such as intelligent tutors or other kinds of adaptive learning systems - provide personalized instruction and feedback for a variety of domains - virtually no systems address the teaching of socio-emotional skills (although see our earlier work [4]), nor do previous systems engage learners in an adaptive way in the socio-emotional bond formation that improves learning among human peers.

In the "Rapport-Aware Virtual Peer Tutor" project, unlike other adaptive learning systems, we have developed a virtual partner that can detect the social dynamics (or, "rapport") with a student, and respond in socially-appropriate ways to build rapport over time.

## Social Dynamics: Rapport

To address this gap, we have engaged in a multi-year, interdisciplinary study of the nature of rapport development and its impact on learning processes and outcomes. We have collected over 100 hours of data



**Figure 1.** Virtual Peer Tutor Study

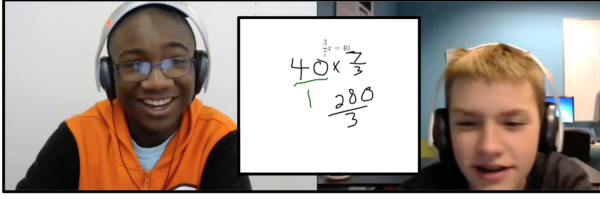
of students tutoring each other in algebra and analyzed the verbal and nonverbal behaviors that contribute to the rapport between them. We found that tutoring pairs with greater rapport engage in more of the socially-supportive behaviors like help-offering, explanation-prompting, comprehension-monitoring, and self-explanations (from tutees) indicative of positive, supportive climates for learning. Students whose rapport with their partner deepens over time also solve more problems and learn more on a post-test [3, 5].

As a result of this work, we have developed the first computational model of rapport [6], which has allowed us to design a virtual peer tutor that can develop rapport with a student to better support them in learning. Imagine a student working with a virtual tutor who takes risks in learning, knowing that they will be supported by their partner, who asks for deeper explanations when they don't understand, knowing that they won't be judged, and who is more motivated to continue learning with their virtual peer despite being frustrated. This is the type of system we are working towards.

## Peer Tutoring Data Collection

To develop a rapport-aware virtual tutor, we start by collecting data on students tutoring each other. We then analyze the verbal and nonverbal behaviors that contribute to rapport, and we obtain ratings for the level of rapport throughout the interaction [7]. We use these data to train machine learning models to detect the current rapport level and reason about the social utterances the virtual tutor should say to build rapport and improve learning.

In order to train the machine-learning components of our virtual agent system, we collected ground truth data from pairs of students tutoring each other. We collected



**Figure 2.** Peer Tutoring Data Collection

audio and video data from 22 pairs of middle and early high school students tutoring each other in linear algebra for two weekly hour-long sessions. The students taught each other via video-chat, using a shared whiteboard space, so we could use computer vision to analyze the nonverbal behaviors that contribute to rapport. We obtained ratings of the rapport level between participants for every thirty-second "slice" of the video corpus, using third-party observers in a crowd-sourced approach.

## Machine Learning for Social Awareness

We are in the process of running an experimental trial to evaluate the efficacy of rapport-building social components of a virtual peer tutoring system. We have implemented a set of machine learning models for social awareness and social reasoning as part of the back-end of an adaptive intelligent tutoring system, with an embodied conversational agent as the front-end. We use automatic speech recognition, natural language understanding, and text-to-speech for an end-to-end dialogue system, with a human in the loop providing approval and input on the appropriate tutorial action selection, in a semi-autonomous "Wizard of Oz" approach.

### *Social conversational strategy classification*

We have developed a classifier for the social conversational strategies that students use to build rapport with each other (e.g. self-disclosure, praise, shared experiences) [8]. This module can recognize high-level language strategies closely associated with social goals by training on the linguistic and acoustic features associated with those conversational strategies in our peer tutoring data. By including rich contextual features drawn from verbal, visual and vocal modalities of the speaker and interlocutor in the current and previous turns, we can successfully recognize these dialogue phenomena with an accuracy of over 80% and with a kappa of over 60%.



**Figure 3.** Temporal Attention Model for Rapport Estimation

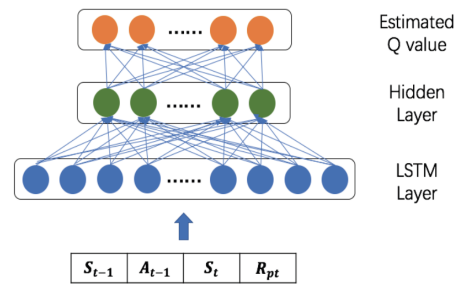
### *Rapport level estimation*

We have developed a classifier of rapport that estimates the current rapport level between the user and the

agent. We use temporal association rule mining to learn the sequences of behaviors that signal high and low rapport [9]. These behaviors include both the visual behaviors such as eye gaze and smiles, and social and tutoring-related verbal behaviors, such as self-disclosure, praise, feedback, hints, instructions. We are also currently experimenting with a different machine learning approach, using "temporally-selective attention models" in a neural network ensemble model to detect the rapport by paying attention to the most informative cues [10].

### *Social reasoning*

We have developed a social "reasoner" module, which chooses the most appropriate social conversational strategy for the agent to use to build rapport with the students [11]. The reasoner is currently designed as a spreading activation network, with weights learned for each set of student behaviors, informed by the current rapport level between student and agent. We are currently experimenting with reinforcement learning methods for tutoring and social reasoning, which can learn from the students' responses to the agent over time [12].



**Figure 4.** Long-Short Term Memory Reinforcement Learning

## Socially-Aware Education Technologies

As virtual agents and AI take on an increasingly important and ubiquitous role in our education and in our lives, we believe that these systems should understand and respond to social dynamics so as to better provide socially supportive climates for learning [5].

We intend to use this system to contribute to a more robust understanding of the ways that social factors between learners, such as their rapport, improve their learning process and outcomes, and to work towards a future where every student can reap the social motivational benefits of learning from and with a tutor with whom they have a close interpersonal bond.

The mission of our research is to study human interaction in social and cultural contexts, and use the results to implement computational systems that, in turn, help us to better understand human interaction, and to improve and support human capabilities in areas that really matter. As technologists, and as citizens of the world, it is our choice whether we build killer robots or robots that collaborate with people, our choice whether we seek to

obviate the need for social interaction, or ensure that social interaction and interpersonal closeness are as important - and accessible - today as they have always been.

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