Designing Effective Behaviors in a Social Robot that Supports Collaborative Learning in Middle School Mathematics

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Key Challenge

How can a teachable robot learn to use dialogue, gesture, and gaze to support the dyadic collaborations of middle school mathematics students? Addressing this problem requires work in human-computer interaction, natural language processing, machine learning, and cognitive psychology.

Data Collection and Analysis

28 undergraduate students worked in pairs to teach a Nao robot how to solve ratio problems.

Used exploratory analyses, qualitative coding, & automated metrics to understand which factors produce more learning & rapport.

Emma:	So step one was to figure out how much of my battery is used in one hour. How do I figure out how much of my battery is used up in three hours?
Student:	because we know the ratio we can now apply this to the three hours that the battery is used
Emma:	Ratios. Can you tell me how that works?
Student:	because we know three fortieths of the batteries power is used in one hour we can apply that to three hours
Emma:	So I am thinking it makes sense to multiply. What do you think about multiplying?
Student:	yes you should multiply three fortieths by three

Green: Expressions that has not been established as shared expressions yet. Yellow: newly initiated shared expressions

Dialogue between Emma and a student, with shared expressions annotated.

Two undergraduate students teach Emma about mathematics content over Zoom.

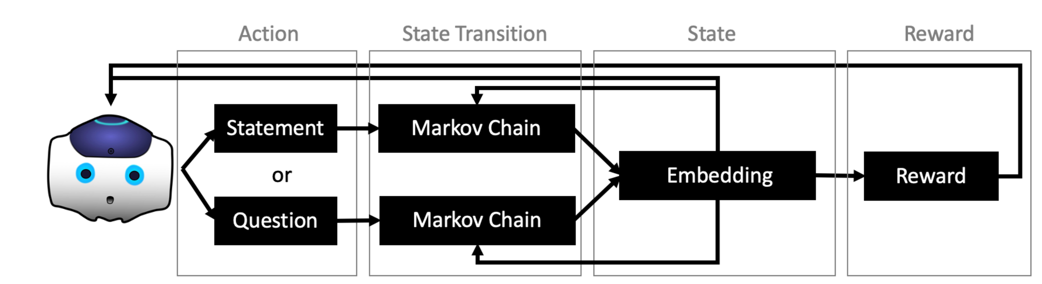
Learners with similar knowledge to their partners felt more rapport with Emma *(r=.58).*

Learners who initiated shared expressions with Emma felt more rapport with Emma *(Spearman's rho = .529)*.

Reinforcement Learning Simulations and Experiments

Built an environment to simulate student teaching Emma. Permutes collected data to create larger dataset of responses, & models how Emma's actions affect cooperation between the students.

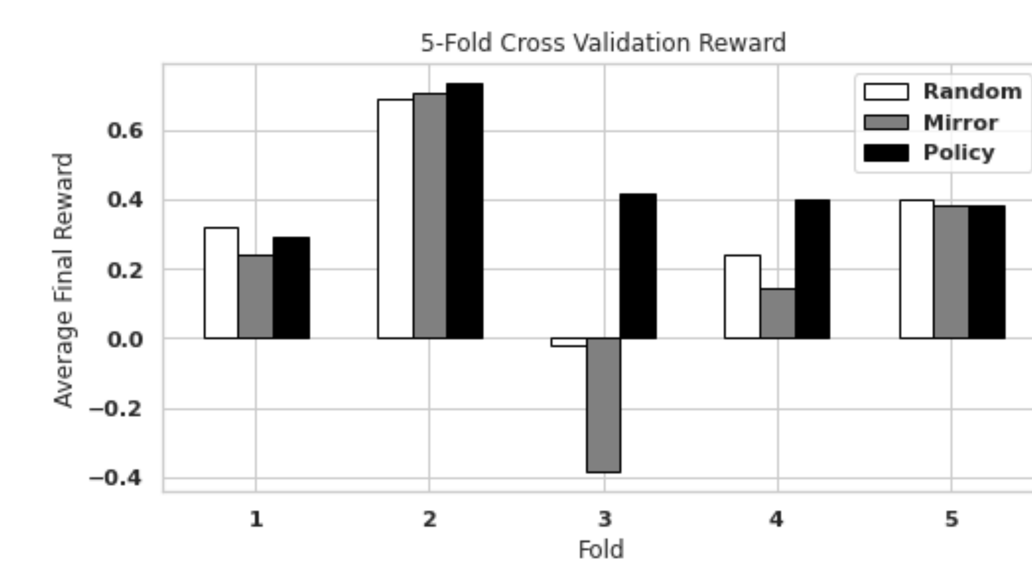
Tuned and validated using policy that mirrors actions taken by Emma during data-collection.



High-level overview of the reinforcement learning environment.

Learned RL policy outperforms baseline "Mirror" policy and random policy.

Learned RL achieves more consistent results across student groups.



Results of evaluation comparing learned policy to mirror policy and random policy.

Next Steps

Bring together project strands to run RL experiments on factors identified as important in data collection. Add gesture and gaze as modalities for interaction.

Proposed Computer Science Impacts

Apply reinforcement learning to human-robot interactions to automatically acquire social behaviors. Success paves the way for co-robots in school environments.

Proposed Learning Sciences Impacts

Understand how robot multimodal communication influences collaboration and learning. Success informs best practices for human facilitation of collaboration.

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