I. Project Summary

Project Title: How Nonverbal Communication Supports Abstract Thinking Development

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Other Personnel: John Black, Ph.D., Professor; Joshua Friedman, Ph.D. Student; Department of Human Development, Teachers College, Columbia University

Abstract: One of the greatest strengths of the Columbia education is the opportunity for students to develop an awareness and capacity for in-depth thought across disciplinary boundaries. Abstraction, or the ability to identify and describe common patterns between different phenomena at various levels of complexity, is a necessary cognitive skill underpinning this development. The ability to integrate meaning across contexts is often challenging but essential, as it enables the transfer of learning from the classroom to life after graduation. This project seeks to understand how nonverbal behaviors in teacher-student communication impact the capacity for abstract thinking skills to develop. Our central hypothesis is that the opportunity to communicate in small group settings over time enhances abstract thinking development through increased nonverbal understanding, which in turn supports efficient teaching and learning interactions between teachers and students. Understanding the meaning behind gestures, speech tones, and facial signals subconsciously eases the burden on conscious verbal interpretation, freeing the mind to construct abstract models of experience. In other words, being able to predict a teacher’s meaning through their nonverbal communication relaxes effort to understand their verbal communication, and frees the student’s mind to engage in transfer-oriented thinking (e.g., this phenomena within a previous or potential future context). By inviting teacher-student dyads to complete tasks together in a custom built online portal, we will be able to apply a novel data-driven approach to address the question: how do teacher-student relationships and communication patterns jointly contribute to the development of students’ discipline-based abstract thinking skills?

II. Project Scope

Framing & Participants: Transferring knowledge and skills developed in one context (e.g., the classroom) or one discipline (e.g., physics) to another (e.g., the workplace, biology) remains a steep challenge for traditional education and pedagogy models. Our objective in this study is to explore how historically positioned non-cognitive aspects of cognition such as affect, emotion, and social bonding support and enable abstract thinking, previously shown to support such transfer. By recruiting teacher-student dyads from Core Curriculum seminar classes at the end of the semester and randomly assigning them to a ‘matched’ vs. a ‘mismatched’ condition to complete two teaching & learning tasks, we will be able to compare: 1) the impact of having a previous relationship built on small seminar interpersonal interactions vs. not having interpersonal experience, 2) across simple vs. complex problem solving contexts, on the development of students’ abstract thinking skills. Thus, this experimental study will explore how nonverbal communication between teachers and students impacts abstract thinking skill development across two levels of social bonding: previous relationships vs new relationships; and two levels of abstraction: simple pattern identification (represented by a logic task related to chains of gears) vs. complex theoretical development (represented by an experimental design and interpretation task).

We plan to recruit 60 dyads from the Frontiers of Science courses during the Fall 2022 term through in-person classroom presentations of the study, its central aims, and the benefits for...
participants (chances to win large sum cash prizes, and first informant rights to the results of the study). Impact on participants will be restricted to 60 minutes of their time for students, and 20-30 minutes per student for teachers between the end of the Fall 2022 and the beginning weeks of the Spring 2023 semester, when participating dyads will meet on the online portal to complete the two tasks together. Through the project’s novel data-driven approach, future Core Curriculum course instructors and students will be empowered with specific knowledge about nonverbal communication and intentional relationship building strategies applicable to 1-on-1 interactions in seminar, office hour meetings, and feedback moments to amplify interpersonal understanding and thus, abstract thinking development.

**Research Question (RQ) 1**: How does the development of social relationships impact abstract thinking skills? **Hypothesis (Hyp) 1**: Both the matched and mismatched conditions will score equally well on the simple problem solving task; **Hyp 2**: Students in the matched condition will score higher on the complex problem solving task than students in the mismatched condition. **RQ2**: How does nonverbal communication increase the capacity for abstract thought? **Hyp 3**: The degree of facial movement reciprocity, measured as the multivariate distance between facial muscle group movements between teacher-student pairs, will be directly correlated with student performance in both tasks. **Hyp 4**: Students in the matched condition will show more facial movement reciprocity with the teacher overall, spend less time to find solutions, and provide a more complete solution during complex problem solving compared to students in the mismatched condition.

**Rationale and Literature Review**: This project furthers CU’s Strategic Directions by: 1) advancing knowledge and inspiring inquiry through investigating the overlap between the frontiers of educational psychology, cognitive science, and computer vision with state-of-the-art machine learning tools; 2) catalyzing discovery through working vertically from real students in real classrooms to the latest theories surrounding neuroscience and cognitive development; and 3) shaping discourse through opening new avenues around what it means to improve Core Curriculum practices - from content to be learned to the context it is learned through: meaningful teacher-student communication.

Teachers and students stand to benefit from understanding social and emotional dynamics inherent to communication. One intriguing possibility is that 1-on-1 teacher-student interactions, made possible by small class sizes in seminar and during office hours, especially at the beginning of the year, enhance nonverbal understanding, feelings of relatedness, and personalized intervention and feedback strategies throughout the year. The Interactive Brain Hypothesis suggests that human brains evolved to understand others through interactive nonverbal communication (i.e., reciprocal movements of the face, body, and voice). This understanding of nonverbal behavior minimizes effort and energy costs of social interaction and improves our ability to interpret another. It may also help explain why enhancing beliefs of similarity between teachers and students (e.g., each being told they both like a particular hobby or quality in other people) fell short of expectations for performance improvement.

Belief-based interventions may be too psychologically distant from what matters: mutual understanding. While a professor’s introduction to a large lecture hall may provide context for authority and opportunities for relatedness, it may not enhance listeners’ ability to understand them. In contrast, reciprocal nonverbal communication improves learning in and out of the classroom, especially for teachers and students who already have high quality relationships. Additionally, spending dedicated time to communicate face-to-face (e.g., in small seminars) may improve interpersonal understanding and performance, as well as teacher-student relationships. In other
words, a complex positive feedback loop seems to emerge: nonverbal communication reciprocity improves relationship quality, nonverbal reciprocity and relationship quality increases successful joint performance, and successful joint performance improves reciprocity and relationship quality.\(^\text{20}\)

Finally, theories of learning and cognition hypothesize that the empathic processes that make our relationships successful (e.g., theory of mind) may be intricately involved in developing abstract thinking skills.\(^\text{21,22}\) Children’s theory of mind skills appear to enhance their divergent thinking capacity,\(^\text{23}\) and imagining what another is thinking or feeling appears to rely, at least in part, on similar neural networks for imagining the cause of, or pattern between, objective phenomena.\(^\text{24}\) Spending time to understand teachers’ reciprocal interpersonal coordination with students deserves close attention if we are to optimize the necessary and complex interplay between “social” and “non-social” cognition in learning environments.\(^\text{25}\) Pedagogical structure and praxis that values and facilitates changing oft-overlooked social, emotional, and cultural dynamics in classrooms requires it,\(^\text{26,27}\) and engaging practices so naturally human seems an intriguing remedy.\(^\text{28}\)

**Assessment and Evaluation Plan for Specific Aims:** To test hypotheses 1 and 2, accuracy and reaction time in the gear task (scored by the portal) and quality of the solution as well as thinking vs. explanation time in the experimental design task (assessed by qualified raters blind to condition) will be compared across matched vs mismatched conditions. To test hypotheses 3 and 4, an open source machine learning algorithm\(^\text{29}\) will quantify movements of the teachers’ and students’ faces from recorded video, including 17 muscle groups and the direction of their eye gaze, and then a multivariate distance between all parts of the teacher’s and student’s faces within each dyad will be calculated through a state-of-the-art dynamic time warping analysis\(^\text{30}\) and regressed on performance measures by condition. Each task has been designed to isolate foundational cognitive processes required for higher level abstract development based on previous research and practitioner input, so we will be able to assess whether facial movement reciprocity has differential effects on pattern recognition, experimental design, hypothesis generation, data interpretation, and theoretical integration, each scored on objective criteria by qualified raters.

Additionally, classical survey methods for measuring relationship beliefs and standardized tests of abstraction skills will serve as covariates for these analyses in order to control for effects of individual students’ intelligence and skills, as well as any representational effects specific to the particular teacher-student pair. This approach allows us to isolate the effect of nonverbal communication on abstract skill development while also comparing its effect on performance to belief-based teacher-student relationship quality.

**Role of Key Personnel:** Tugce Bilgin Sonay will take the lead on pedagogical integration of the cognitive aspects of the developed tasks and current topics and norms within the Frontiers of Science course in the Core, as well as serve as the administrative and budgetary lead and liaison with SOLER, in addition to advising on the data analysis and publication aspects of the project. John Black will serve as the primary advisor on the cognitive psychology aspects of the tasks and assist in theoretical integration from an embodied cognition perspective. Josh Friedman will handle management of the online portal, recruitment of teachers, students, and qualified raters, IRB accreditation, data anonymization and privacy management, the bulk of the data analysis process, and writing the results up for publication. Qualified raters will be recruited from graduate students in the Human Development and Math, Science, & Technology department at Teachers College and will be blind to dyad conditions.
III. Project Timeline

Project Timeline for SOLER Grant Proposal

- Pilot Study of small group (5-10 dyads) for process improvements, initial data analysis design, and final procedure modification (Jun)
- Initial recruitment of teachers to elicit feedback and bandwidth (May - Jun)
- Extend current Teachers College IRB protocol to include CU specific requirements (May - July)

- Complete revisions of online portal to adapt to feedback from pilot study (June - Aug)
- Recruit teachers and students from Frontiers of Science courses (Aug - Nov)
- Distribute and collect consent documentation (Aug - Nov)
- Complete process improvements for data collection period, preregister final study with Open Science Framework (Sep - Dec)
- Recruit volunteer Research Assistants from TC and train on qualitative data analysis methods (Sep - Dec)

- Send out pre-surveys to student and teacher participants to complete before portal participation (Dec - Jan)
- Send out unique session codes for each dyad to complete the online tasks within the first 4 weeks of the Spring semester (Jan - Feb)
- Run planned and exploratory analyses on data to answer hypotheses (Mar - Apr)
- Present findings at AERA, APA, and IEEE conferences (if accepted: Mar - May)
- Write up final report on findings and submit a manuscript to Journal of Educational Psychology (May - July)

IV. Budget Overview and Justification

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<thead>
<tr>
<th>Budget Item</th>
<th>Funds Required</th>
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<tbody>
<tr>
<td>Lottery Prizes for Student Participants</td>
<td>$1000</td>
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<tr>
<td>Compensation for Teacher Participants</td>
<td>$4000</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>$5000</strong></td>
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Justifications:

**Lottery Prizes for Student Participants**
Given the goal of 60 students recruited, each student will have 10 prizes of $100 each given to students chosen at random by a random number generator. This provides a 1 out of 6 chance for student participants to receive the prize, which equates to an expected value of around $16.50 for an hour of the student’s time. We are also considering a scheme of 2 prizes for $200 each and 6 prizes for $100 dollars each.

**Compensation for Teacher Participants**
Given the goal of teacher recruitment, but understanding the limitations inherent to recruiting teachers in a fast-paced university environment, we have a goal of dividing the $4000 dollars evenly among the recruited teachers. Ideally, this will be 10 teachers who each meet 6 students on the portal for 20-30 minutes and receive $400 dollars. This compensation will be equivalent to about $133 per hour.
V. Letter of Support

Currently under review by the department chair – to be submitted shortly.
VI. References


doi:http://dx.doi.org.ezproxy.cul.columbia.edu/10.1017/S0140525X19003212


29. OpenFace 2.0: Facial Behavior Analysis Toolkit Tadas Baltrušaitis, Amir Zadeh, Yao Chong Lim, and Louis-Philippe Morency, *IEEE International Conference on Automatic Face and Gesture Recognition, 2018*