A Climate of Support: A Process-Oriented Analysis of the Impact of Rapport on Peer Tutoring

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Abstract: Prior work has found benefits of interpersonal closeness, or rapport, on student learning, but has primarily investigated its impact on learning outcomes, not learning processes. Moreover, such work often analyzes the direct impact of dyadic features like rapport on learning, without considering the role played by individual factors, such as learners' prior knowledge and self-efficacy. In this paper, we investigate the intertwined impact that rapport, self-efficacy, and prior knowledge have on the process and outcomes of peer tutoring. We find that peer tutors in high-rapport dyads offer more help and prompt their tutees to explain their reasoning more than low-rapport dyads, with tutees in such dyads verbalizing their problem-solving process and proposing more steps and answers. Meanwhile, rapport is associated with increased procedural performance, but tutees' self-efficacy and prior knowledge moderate the effect of rapport on tutees' conceptual performance.

Introduction

As decades of scholars have argued, learning is a socially-mediated process, embedded in relationships between students and their teacher, and between students and their peers. The interpersonal components of classroom talk - those focused on building and maintaining social relationships - are inextricably intertwined with the interactional process of providing feedback, hints, and instructions (Wentzel, 1999; Parr and Townsend, 2002; Madaio et al., 2017). Though teachers and schools may primarily promote educational goals, students arrive in the classroom with relational goals, which may include developing relationships and friendships with each other (Wentzel, 1999). They also arrive with individual resources for and attitudes towards learning that may impact the ways that they establish and respond to both the educational and social environment of learning. Prior research has particularly targeted reciprocal peer tutoring as a form of learning likely to result in learning gains due to relational factors (Parr and Townsend, 1992; Webb and Mastergeorge, 2003). As students are asked to learn in increasingly collaborative learning environments, and as one of the most touted 21st century job skills is the ability to collaborate, it is important to understand whether and how the rapport learners build with one another impacts learning. Specifically, there remain questions about how the social bond among students intersects with the individual resources and beliefs of each student to impact the process and outcomes of peer tutoring.

Educational technologies are increasingly designed to mediate students' collaborative learning (Carmien et al., 2007), or to take on the role of a teacher or peer. In prior work, we have treated the question of how the social relationships between peers in collaborative learning (here, peer tutoring) impact learning gains. Here we ask how rapport's impact on learning gains might be mediated by the student's own academic ability and beliefs about learning (which we operationalize here as self-efficacy; Pajares, 1996). We have argued that rapport is a phenomenon that must be understood – and designed for – as taking place over time (Zhao et al., 2014). For that reason, in this paper we look not just at learning gains, but also at the process-oriented mechanisms by which social factors interact with individual cognitive and socio-cognitive factors to influence the peer tutoring process. Specifically, in this work we investigate how rapport between peer tutor and tutee influences the learning-related behaviors that each participant engages in, moderated by tutees' prior knowledge and self-efficacy. We contribute to the larger learning science community by (1) Shedding light on how the impact of social factors like rapport on learning is moderated by individual cognitive and socio-cognitive factors like prior knowledge and self-efficacy, respectively; (2) Identifying the core sequences of tutor and tutee behaviors associated with moments of high and low rapport, to shed light on the peer tutoring process as it plays out over time; and (3) Teasing apart the intertwined influences of rapport, self-efficacy, and prior knowledge on tutors' help-provision and tutees' verbalization of problem-solving.

Related work

Rapport has been described as a "harmonious, coordinated interaction based in mutual attention, respect, understanding, and openness", characterized in learning interactions by nurturance on the part of a teacher and

increased engagement in classroom activities on the part of students (Wentzel et al., 1999). However, in contrast to prior work on teacher-student rapport, the impact of *student*-student rapport on peer learning interactions has been less well-studied. Work in our own lab suggests that rapport is beneficial for learning outcomes in peer tutoring settings (Zhao et al., 2014; Sinha and Cassell, 2015), but that work did not look at whether or how individual factors mediated the impact of rapport on learning *processes*. Work on differences in learning dynamics between dyads of friends and non-friends (often a proxy for rapport) found that learning interactions between friends are characterized by a warm, supportive climate favorable to exploration and problem-solving, a more elaborated learning discourse, and greater expectations for assistance and support from the other, (Wentzel, 1999), as well as greater tolerance for direct challenges and differences of opinion (Azmitia and Montgomery, 1993). Prior work suggests that the supportive climate engendered by relational closeness may constitute a motivational support that mitigates anxieties around self-explanations, help-seeking, and problem-solving attempts, encouraging more participation and engagement in learning (Wentzel, 1999). However, these findings were based on groups of self-defined friends, which may mask a great deal of variation in the nature or duration of those friendships. To unpack these nuances, we focus on students who have never met before.

From the tutor's perspective, prior work suggests that more capable peer tutors support their partners' needs for "positive face", or desire to be approved of by others (Brown and Levinson, 1987), particularly when they lack the relational closeness of friendship or rapport (Madaio et al., 2017). Peer tutors may do this by modifying the behaviors that may threaten the other's face, such as overly direct instructions or knowledge monitoring, while increasing "face-boosting" behaviors, such as positive feedback. Other work has argued that close, "integrative" social relationships among peers are characterized by greater resource provision (Wentzel 1999) and unsolicited advice- or help-giving, which may be perceived as face-threatening without a sufficient relationship (Feng and Magen, 2013). However, prior work suggests that tutors' provision of the correct step or answer to a problem without providing deeper conceptual support may be not only unhelpful, but may actually be harmful for tutees' learning (Webb and Mastergeorge, 2003). The best tutors, therefore, prompt their students to provide elaborated explanations of the concepts and reasoning either through explicitly requesting explanations or by prompting them with leading questions (Webb and Mastergeorge, 2003).

While this work demonstrates that relational closeness has a positive influence on students' participation and engagement in learning, other prior work has uncovered competing influences at work: namely, students' self-efficacy, or their beliefs in their ability to successfully complete a task, and their prior knowledge (Webb and Mastergeorge, 2003; Wentzel, 2016). Students with lower self-efficacy or prior knowledge may be more likely to avoid publicly engaging in the problem-solving process by verbalizing fewer self-explanations and attempts of the problems, due to fears of judgment or negative evaluations from their peers (Wentzel, 1999), which may conflict with the motivating influence of rapport. Such students might not only be reluctant to attempt the problems for fear of failure but, worse, they might engage in what Newman (2002) describes as "nonadaptive" or "dependency-oriented" help-seeking, or, help requests designed to elicit the answer from a partner to avoid the risk of failing. Therefore, it is critical to understand how the help provided by peer tutors is influenced by their rapport with their tutees, and how *tutees'* responses to tutors' help are influenced by their rapport with their partner, their self-efficacy and their prior knowledge.

In sum, prior work argues that interpersonal closeness between tutor and tutee is likely to lead to increased tutor helping behaviors and increased tutee engagement in the learning process. However the nature of that interpersonal closeness has primarily been treated as a dichotomous measure of friendship, which may mask variation in the nature and strength of those friendships. We thus investigate the rapport established between strangers, to identify how peers without an existing relationship negotiate between their relational and their task goals. Further, prior work suggests that learners' self-efficacy and prior knowledge may moderate the pathway from social support to improved learning outcomes (Wentzel, 2016), but it leaves open the question of how rapport, self-efficacy, and prior knowledge interact to impact tutoring processes and learning outcomes. This leads us to investigate the following research questions:

RQ1: To what extent does the rapport between peer tutors and their tutees, when they first begin their relationship, interact with those tutees' prior knowledge and self-efficacy to impact their learning outcomes?

RQ2: How does the rapport between peer tutoring dyads impact the learning *process*, as it plays out over time?

RQ3: To what extent does the rapport between newly formed tutoring dyads interact with tutees' prior knowledge and self-efficacy to impact tutees' help-seeking and self-explanations, and tutors' help provision?

Methodology

Data corpus and dialogue annotations

The corpus described here was collected as part of a larger research program on the effects of rapport-building on reciprocal peer tutoring. Participants were assigned to 20 dyads that alternated tutoring one another in linear algebra equation solving for two hour-long sessions, a week apart. though data from only 15 dyads were usable due to issues with recording, participant retention, or a pre-existing relationship between partners, for a total of ~30 hours of data. Each session was structured such that students engaged in two brief periods of getting to know one another interleaved with two longer periods of tutoring, where each student was randomly assigned to be the tutor for one of the tutoring periods in each session. The peer tutor was not assumed to have any greater prior knowledge than their partner for the problems they were tutoring them on and, as such, all tutors were provided with instructions on how to teach the problems for which they were assigned the role of tutor.

The students took a pre-test before the first session and a post-test after the final session to assess their prior knowledge and their learning gains. Both tests included procedural (problem-solving) and conceptual items (multiple choice items on algebraic concepts). The participants (mean age = 14.3, min=13, max=16) came to a lab on an American university campus in a mid-sized city for the study. Half were male and half female, assigned to same-gender dyads, so that, as in other work with this corpus, any gendered differences in the social, rapport-building behaviors of the participants could be identified. To control the baseline level of interpersonal closeness, we paired students with a partner they had not met before (and removed two dyads that we later discovered to have already met), similar to the dyads of "strangers" in Madaio et al., (2017). Audio and video were recorded, and audio transcribed and segmented into clauses. Participants were provided with survey items to assess their self-efficacy for algebra, following (Pajares et al., 1996), and their perceptions of the rapport in the dyad. As part of a larger research program on the relationship between rapport and peer tutoring, this corpus was annotated for a set of social, rapport-building verbal and nonverbal behaviors, following Zhao et al., (2014), and for a set of tutoring and learning behaviors, following Madaio et al. (2016)'s work on knowledge-telling, knowledge-building, procedural and conceptual questions (though here we additionally annotated for subtypes of each of those categories, as shown in Table 1, with Krippendorff's alpha for all categories > 0.75). In this paper, we describe analyses of behaviors likely to be impacted by relational closeness: two types of tutor behaviors: tutors' *help-offering* and *explanation-prompts*; and five types of tutee behaviors: tutees' *help requests, answer-checking, step-level procedures, answers-proposed;* and *evidence-based reasoning*.

Table 1: Tutoring and Learning Strategies Annotated

Role	Low-Level Strategy	Abbreviation	Example
Tutor	Help-Offering	HO	"Let me know if you need any help with this one"
Tutor	Explanation Prompting	EP	"Why did you say to divide it by 5?"
Both	State Step-Level Procedures	SP	"Ok so I'm gonna add three to both sides here."
Student	General Help Requests	HR	"Wait, how do I do this kind again?"
Student	Answer Checking	AC	"Is that right?"
Student	Answer Proposing	AP	"I think x is 7."
Student	Explain Reasoning	ER	"I divided by 5 because it needs to be reduced."

Rapport rating

Rapport between dyad participants was evaluated using a "thin-slice" approach (Ambady and Rosenthal, 1992), where the corpus was divided into 30-second video slices provided to naive, third-party raters, following Sinha & Cassell (2015) where three raters rated the rapport in each slice on a Likert scale from 1-7, and a single rating was chosen for each slice using a bias-corrected weighted majority vote approach. From the 120 30-second slices in each session, we calculated a summary rapport score for each session, the "utopy" (Sinha, 2016), which we use in this paper as our rapport measure. Prior work has shown that statistical summaries such as a measure of central tendency or proportion of high and low ratings of rapport collapse the temporal dimension and are not as robust as more stochastic-based models which capture the evolution of rapport over time (Sinha, 2016). We thus fit a Markov chain of order 1 to the sequence of 120 rapport ratings for each session, and used the resulting transition probability matrix to generate a measure of the "utopy", or likelihood of the dyad being in a high-rapport state, which is the sum of each transition probability weighted by the distance of the transition (e.g. rapport 2 to 5) (Madaio et al., 2017; Sinha, 2016).

Sequence mining and clustering

To better understand how the rapport between tutor and tutee impacts the tutoring and learning process over time, we adopt a sequence mining approach. We used the USpan algorithm to mine "high-utility" sequential patterns, where "utility" in this case is the rapport value of the thin-slice window in which a given behavioral sequence occurred (Fournier-Viger et al., 2016). However, most sequential pattern mining algorithms produce large outputs with many similar patterns that make interpretation of the resulting sequences difficult. To resolve this, we developed a sequence summarization approach, based on Patel et al.'s sequence clustering technique (Patel et al., 2017). A directed weighted graph was constructed to represent a set of sequences as a cluster, with each annotated behavior represented by a node, and the number of times each multiple-node behavior sequence occurred represented by the weights of the edges, similar to (Patel et al., 2017). We differ from Patel et al. by then summarizing each sequence cluster into a single "core sequence" which reflects the most representative behavior sequences for that cluster. For each graph, we first simplify the result by removing unrepresentative edges (those with very small weights). We then identify the "core sequence" of each sequence cluster, defined as the longest simple path between any two nodes on the graph to find the most common sequences.

Findings

We first wanted to validate our use of the "utopy" measure of rapport, or, the likelihood that rapport will be increasing from one "slice" to the next, by understanding its relationship to students' self-reported rapport at the end of each session. Prior work has found a significant correlation between "thin-slice" observer judgments of interpersonal rapport and participants' own self-report (Grahe and Bernieri, 1999). Our data replicates that finding, showing a significant positive correlation between the "utopy" measure of rapport for each dyad and that dyad's average self-report rapport rating ($\rho = 0.49$, p<.005). Other summary measures of the thin-slice rapport data, such as the average value for each dyad, did not, following Sinha's (2016) finding that utopy was a more informative measure of temporally dynamic interpersonal constructs such as rapport than simple measures of central tendency such as the average. For the following analyses, all results are significant after correcting for multiple hypothesis testing using the Benjamini-Hochberg post-hoc correction (Benjamini and Hochberg, 1995).

Rapport and learning outcomes

We first investigated research question (RQ1): how tutor-tutee rapport interacts with tutees' self-efficacy and prior knowledge to predict tutees' learning outcomes. Since prior work suggests that students with lower prior knowledge and self-efficacy will reap the most benefits from the socially supportive environment engendered by rapport (Wentzel, 2016),. we hypothesized that students with lower prior knowledge and self-efficacy will demonstrate greater performance at post-test when they have increasing rapport with their tutors (i.e. high utopy). In order to identify interactions between tutees' prior knowledge (operationalized by their score on a pre-test) and their rapport, we used the post-test performance as the dependent variable rather than a normalized learning gain score. We ran two hierarchical linear mixed-effects models, with two measures of tutees' post-test performance (procedural items and conceptual items) as the respective dependent variables, and interactions between tutees' pre-test percent, their self-reported self-efficacy, and their rapport utopy measure as fixed effects, with random effects for session and dyad. Significant results are reported in Table 2.

Table 2: Coefficients of regressions for pre-test, rapport, and self-efficacy on procedural and conceptual items

Post-test Item Type	Pre-test	Self-Efficacy	Rapport	Rapport*Pre-test	Rapport*Self-efficacy	Rapport*Pre-test*Self-efficacy
Procedural	0.47***	0.28***		0.40***	0.10*	
Conceptual	0.67***				-0.25 **	0.19 **

p<0.05*, p<0.01**, p<0.001***

For the model with the *procedural post-test* items only, rapport was only predictive while interacting with prior knowledge and with self-efficacy. In those two two-way interactions, while tutees in high-rapport dyads did demonstrate greater procedural performance over tutees in low-rapport dyads, unexpectedly, the tutees with high-rapport with their tutors that *also* had greater prior knowledge and greater self-efficacy performed better than their low prior knowledge and low self-efficacy peers on the post-test items. That is, contrary to our hypothesis, tutees that already came to the session with greater prior knowledge and greater self-efficacy benefited the most on procedural test items from having high rapport with their tutors.

The *conceptual post-test* performance tells a different story, however. There was a two-way interaction between rapport and self-efficacy, and a three-way interaction between rapport, self-efficacy, and prior knowledge. In the three-way interaction, the tutees with low prior-knowledge and low self-efficacy demonstrated greater conceptual performance when they had high rapport with their tutor, in line with our hypothesis that students who needed the most support would benefit from rapport (Wentzel, 2016). Unexpectedly, however, tutees with low prior-knowledge and *high* self-efficacy demonstrated *worse* conceptual performance when they had high rapport with their tutor. This same pattern was true for the two-way interaction between rapport and self-efficacy as well. That is, when tutees with lower self-efficacy had increasing rapport with their tutor, they were more likely to have higher conceptual post-test scores, but when tutees with *greater* self-efficacy had higher rapport with their tutor, their conceptual post-test scores were more likely to be lower.

Unfolding processes over time: Core sequences for high and low rapport

To understand how the rapport between tutor and tutee impacted their respective contributions to the intertwined, dyadic *process* of tutoring and learning (not just the learning outcomes on the post-test), we conducted a sequence mining and clustering analysis to identify the most common sequences of tutoring and learning behaviors. We will discuss here the most commonly occurring "core sequences" of dyadic behaviors associated with high-rapport and low-rapport values in the 30-second "thin-slice" windows (RQ2).

The core behavioral sequence cluster associated with *high rapport* (rapport values above 4), which occurred a total of 151 times in our corpus (out of a possible 834 sequences), contained the behavioral sequence {Tutee States Procedures, Tutee Explains Reasoning, Tutor Help-Offering}. That is, the tutee first verbalized some step-level procedure, then explained their reasoning for doing so, and only then did the tutor offer to help. Such a process is characterized by self-explanations from the tutee and the subsequent provision of help offered by the tutor, as in Wentzel (1999). One example of this from our corpus is the tutee saying, "Wait, so it's k plus k plus two" (SP), then "Cause I need to get all the k's on one side" (ER), followed by the tutor, "Does it make sense what you need to do after that?" (HO). It is significant that we see this order to the sequence, rather than the opposite: tutors offering help prior to the tutee attempting the problem, (which was not one of the core sequences associated with high rapport), as that sort of anticipatory help-offering may imply a lack of confidence on the part of the tutor for the tutees' ability to solve the problem on their own, rather than offering support *after* the tutee attempts to solve it first (Webb and Mastergeorge, 2003).

The core behavior sequence associated with *low rapport* (rapport values below 4), which occurred 268 times in our corpus, contained the behavior sequence {Tutee Proposes Answer, Tutee Checks Answer, *Tutor States Procedure, Tutee States Procedure*}. That is, we see a problem-solving process characterized by tutees proposing an answer, requesting confirmation of the correctness of that answer, and then the tutor providing the next step, which is then stated by the tutee. In our corpus, one instance of this is the tutee saying, "y is equal to negative five" (AP), "Is that right?" (AC), and the tutor responds with "Try adding the 10 to both sides instead." (SP), followed by the tutee: "Ok, so ten plus five is fifteen." (SP). Here, the tutee is explicitly requesting the help or feedback that may instead be provided by the tutor unsolicited if they had greater rapport between them. This also suggests the type of nonadaptive, dependency-oriented help-seeking described by Webb and Mastergeorge (2003), where the tutee requests feedback and validation throughout the problem-solving process that they may not need, rather than trusting in their ability to solve the problems or in their tutor to provide help.

Impact of rapport on tutoring and learning behaviors

Given the surprising impact on learning outcomes from the interaction between rapport and individual tutee factors (prior knowledge and self-efficacy) in RQ1, we wanted to understand how those factors jointly impacted each individual tutee and tutor behavior, to complement our sequential analysis of those intertwined behaviors (RQ2). Specifically, we wanted to understand how dyadic rapport interacts with tutees' self-efficacy and prior knowledge to influence tutees' learning strategies (i.e. self-explanations and help-seeking behaviors) and tutors' instructional behaviors (i.e. help-offering and explanation-prompting). We hypothesized (RQ3a) that *tutors* will do more explanation-prompting and help-offering when rapport is increasing, based on prior work that suggests that friendship, or a social relationship, allows for the kinds of probing questions (Azmitia and Montgomery 1993) and unsolicited advice-giving (Feng and Magen, 2013) that might be seen as face-threatening without that relationship. We also hypothesized (RQ3b) that *tutees* with lower prior-knowledge and lower self-efficacy will generally request help and check their answers more often in dyads with high rapport, based on prior work that suggests that students' willingness to seek help may be inhibited without a sufficient social relationship with peers (Newman, 2002). We also hypothesized that tutees in high-rapport dyads will verbalize their problem-solving more readily than in low-rapport dyads, particularly those with greater self-efficacy, following prior work suggesting that friends (a proxy for high-rapport) are more likely to take risks in learning due to a reduced

fear of failure (Azmitia and Montgomery, 1993), and prior work in peer tutoring that found that tutees who were friends with their tutors engaged in more "knowledge-telling" (Madaio et al., 2016).

To investigate these hypotheses, we ran a set of hierarchical linear models with the frequency of tutor and tutee behaviors of interest in each session as the dependent variables, normalized by their total utterances, and with tutors' and tutees' pre-test percent, their self-efficacy, and the rapport utopy score for that session as the fixed effects, with interaction terms, and with random effects for session and dyad. We ran these models for tutors' *help-offering* (HO) and *explanation prompting* (EP), as well as tutees' *stated procedures* (SP)*, answer-proposing* (AP)*, generic help-seeking* (HS), *answer-checking* (AC)*,* and *explanations of reasoning* (ER) as the DVs for each model. We report significant results from the models in Table 3.

Table 3: Coefficients of regressions for pre-test, rapport, and self-efficacy on tutoring and learning strategies

Tutoring and Learning Strategies	Tutees' Pre-test	Self-Efficacy	Rapport	Rapport* Pre-test	Pre-test* Self-efficacy
Tutor					
Help Offering	-0.43**		0.33*		
Explanation Prompting			0.37*		
Tutee					
General Help Requests	-0.31*				
Answer Checking	-0.38**		-0.36**		-0.23 ·
Answer Proposing		0.43**	0.45**		-0.56***
Stating Procedures			0.40*	-0.40**	
Explain Reasoning				-0.30*	

· p<0.10, p<0.05*, p<0.01**, p<0.001***

For the tutors' *help-offering* and *explanation-prompting*, as we hypothesized, when in sessions with rising rapport (utopy), tutors prompt their tutees for explanations of their reasoning more often (e.g. "wait, why would it be two?") and offer more help to their tutees (e.g. "do you want to see my work?"). This aligns with results from the high-rapport sequences mined. Tutors also offer help more often when tutees' prior knowledge is low, suggesting that peer tutors not only recognize when help is needed (i.e. when their tutees have low prior knowledge), but they are also influenced in their help provision by the rapport they have with their tutee.

For tutees, low prior-knowledge tutees use *general help requests* (e.g. "wait where do I even start?") more often than high prior-knowledge, as was hypothesized, with no effect of rapport or self-efficacy. Similarly, for tutees' *answer-checking* (e.g. "is it nineteen over six?"), tutees with lower prior knowledge check answers significantly more than those with greater prior knowledge. Contrary to our hypothesis about rapport motivating more help-seeking, tutees with higher rapport ask their tutors to check their answers significantly *less* than those with lower rapport with their tutors, which was also seen in the low-rapport sequences mined in RQ2. It may be the case that, given the supportive environment of high rapport, these tutees did not feel the need to explicitly request the help that was freely offered in those high-rapport dyads. Surprisingly, tutees with low prior-knowledge and higher self-efficacy answer-check significantly more than tutees with both low prior-knowledge and low self-efficacy. This increased use of explicit confirmation of answers suggests a dependency-oriented approach to help-seeking exhibited by low prior knowledge tutees, particularly when those tutees also have high self-efficacy, aligning with our findings from RQ1. This also aligns with Williams and Takaku's (2011) finding that middle-school students with high self-efficacy, *despite their low performance*, engaged mostly in non-adaptive help-seeking, which included seeking help when not needed.

For tutees' *answers proposed* (e.g. "p equals 23"), tutees in high-rapport dyads are proposing more answers than those in low-rapport dyads, which may be explained by the reduced apprehension of critical feedback in a socially-supportive environment engendered by rapport. Interestingly, low prior knowledge students with high self-efficacy proposed more answers than all others. That is, these students who have confidence in their algebra ability, despite their low performance on the pre-test are both proposing more answers, and asking for confirmation of those answers (as seen in the previous result). For the tutees' *stated procedures* (e.g. "I think I should add thirteen"), high rapport is associated with more verbalizing of their problem-solving procedures, as hypothesized. For the low prior knowledge tutees, those in high rapport dyads verbalize their problem-solving procedures significantly more than those with low rapport. This aligns with our

hypothesis that students with less prior knowledge who might otherwise feel apprehensive about verbalizing their problem-solving process are more likely to do so when they have greater rapport with their tutor. Similarly, for the *explanations of reasoning* (e.g. "I'm gonna divide cause I'm trying to cancel out")*,* low prior knowledge tutees in high-rapport dyads explain their reasoning more than those with low-rapport.

These results suggest that rapport contributes to a supportive climate for learning where help from the tutor is provided more readily and tutees feel encouraged to verbalize their problem-solving process. However, for students whose confidence in their abilities outstrips their actual performance, the increased verbalization of the problem-solving process may contribute to their use of a more dependency-oriented, nonadaptive help-seeking process. While this may lead to improved procedural performance, without engaging in elaborated explanatory discourse, this may cause them to miss opportunities to improve their conceptual understanding.

Discussion

Designers of learning environments, technological or otherwise, are always designing –whether they are aware of it or not –for learners who are imbricated in webs of socio-cognitive relations with other learners, thinking and learning in partnership with other learners and with the technologies they use. Therefore, if designers of learning environments are attempting to intervene to improve the learning process, they must first understand the nature of the existing socio-cognitive processes at work. Carmien et al., (2007) have argued that the "scripts" introduced by collaborative support tools may conflict with the internal "scripts" that students themselves already bring to bear on the collaborative learning process. Prior work suggests that the rapport between teachers and students or between peers benefits learners by creating a warm, socially-supportive learning environment (Wentzel, 1999), while other work suggests that social factors in the interaction impact learning (e.g. Schnaubert and Bodemer, 2016). Until now, however, we have not had a well-defined, process-oriented understanding of how dyadic rapport intersects with individual features like prior knowledge and self-efficacy to impact the process of learning in peer tutoring.

In this paper, we identify a surprising interaction between rapport, prior knowledge, and self-efficacy on learning outcomes, and highlight the influence of each of those factors on tutoring and learning behaviors to shed light on the tutoring process. We find that tutors with greater rapport with their tutees offer more help and prompt for explanations more often, perhaps due to feelings of increased responsibility for their partner's performance (Wentzel, 1999) or to increased freedom to engage in unsolicited help-offering, knowing that it is less likely to be taken as face-threatening (Feng and Magen, 2013). Given these results, it seems the peer tutoring process in dyads with high rapport is characterized by investment of the tutor in the comprehension and problem-solving process of their tutee, wherein learners are motivated by a socially supportive environment to self-explain, without needing to continually request confirmation of their answers. To understand why tutees whose self-efficacy outstrips their prior knowledge might rely more on an answer-proposing and –checking approach, we turn to Williams and Takaku's (2011) finding that such students demonstrated a performance-oriented approach to learning, instead of a mastery-orientation (Williams and Takaku, 2011). For such students, perhaps obtaining the correct answers to the problems is more critical than correctly understanding the concepts, which may support our unexpected conceptual learning result. Webb and Mastergeorge (2003) also argued that dependency-oriented help requests may inadvertently signal to tutors that learners are unmotivated or unable to complete the problem, thus eliciting the steps or answers from the tutor, rather than the deeper conceptual explanations learners may need (Parr and Townsend, 2002).

It is in light of such results that designers of computer-supported collaborative learning (CSCL) tools, intelligent tutoring systems (ITS), or other artificial intelligence in education (AIED) applications should design systems that can help establish this supportive climate of mutual nurturance and support, One example is "socially-aware" virtual tutors or teachable agents that can build rapport with their partners (as described in Walker and Ogan, 2016). Such systems should thus incorporate adaptive socially-aware behavior patterns that elicit feelings of increasing rapport in the human learner, and be ready to deal with tutees' learning behaviors increasingly in line with the findings here (i.e. verbalizing problem-solving steps, explaining reasoning, and proposing more answers).

This study is not without limitations as the small sample size limits the power of the findings. The findings here may also not be generalizable beyond the age group or culture of the participants represented. In addition, these analyses were correlational, as we did not experimentally manipulate the rapport of the dyad. Future work may first explore a causal inference approach such as Granger causality to infer the causal relationship between rapport and learning behaviors. We are also developing a rapport-building virtual peer tutor to attempt to build rapport with students in an experimental study, to identify causal relationships between rapport and learning. Conversely, a teachable agent might strategically build rapport with a student to elicit the supportive helping behaviors seen here. In sum, we intend for this paper to contribute to the growing body of

work understanding the socio-cognitive processes by which learning occurs. In this paper, we offer an analysis of how dyadic rapport built between students meeting for the first time interacts with individuals' self-efficacy and prior knowledge to impact their learning *outcomes* and their tutoring and learning *behaviors*, and we offer one approach to unpacking the sequential process of tutoring and learning as it unfolds over time.

Acknowledgments

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