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MOTIVATION AND SOCIAL PROCESSES

Teacher-Student Interactions and Teacher Interpersonal Styles: A State Space Grid Analysis

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ABSTRACT

The crucial role of teacher-student relationships has been reported in many studies. Yet, how teacher-student relationships develop from moment-to-moment interactions during lessons remains understudied. The present study combined insights from interpersonal theory and dynamic systems approaches to study indices of interpersonal content and structure in teacher-student interactions and their association with the teacher's interpersonal style. We found that moment-to-moment teacher behavior was indeed related to student perceptions of the teacher's interpersonal style. Indices of variability (structure) in interactions discriminated between teachers with less preferred and more preferred interpersonal styles, while, contrary to earlier research, the indicator of predictableness of interactions could not. Results are discussed considering the expectations, and suggestions made for future research and practice.

KEYWORDS

Classroom observation; continuous assessment of interpersonal dynamics; dynamic systems; interpersonal theory; teacher-student interactions; state space grid analysis; teacher-student relationships

TEACHING IS A complex job (Chang, 2009; Wubbels, Brekelmans, Den Brok, & Van Tartwijk, 2006). The crucial role of teacher-student relationships in education has been reported (see for an overview Wubbels et al., 2006) in a many studies. For example, positive teacher-student relationships are associated with cognitive and motivational learning outcomes for students (e.g., Cornelius-White, 2007; Den Brok, Brekelmans, & Wubbels, 2004; Roorda, Koomen, Spilt, & Oort, 2011) and with teacher well-being (e.g., Spilt, Koomen, & Thijs, 2011).

Teachers early in their career or those experiencing transitions between schools may be particularly vulnerable to problems with developing and maintaining positive teacher-student relationships (e.g., Wubbels et al., 2006). Given that positive teacher-student relationships are important determinants for student as well as teacher outcomes (e.g., Cornelius-White, 2007; Den Brok et al., 2004; Goh, 1994; Henderson & Fisher, 2008; Maulana, Opdenakker, & Bosker, 2014; Wubbels et al., 2006), this is problematic. Why some teachers can establish positive relationships and some cannot, remains understudied. Information about processes underlying relationship development may provide opportunities for teacher professional development or for coaching of teachers that experience problems with establishing and maintaining positive relationships.

An answer to this question may be found in the idea that moment-to-moment interactions are the building blocks of relationships (e.g., Granic & Patterson, 2006; Pincus et al., 2014). This is a

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theoretical premise inspired by dynamic systems (DS) theorists. For example, Guastello, Koopmans, and Pincus (2009) state that social systems (i.e., macro-level, e.g., relationships) create and maintain order (i.e., stabilized type of relationships) through interactions between the social system's components (i.e., micro-level, such as the teacher's and the students' behavior). This means that development occurs on different time scales and that the interplay between these different time scales can and should be studied to promote understanding of change and development (Guastello et al., 2009). Also, according to Kiesler (1996) and Wubbels (2012), focusing on how interactions between teachers and students unfold in time is essential for understanding the development of certain types of (teacher-student) relationships. Their research stresses the need for studying the interplay between interactions and relationships.

Until now only a limited number of (case) studies focusing on the interplay between interactions and relationships in education and using a DS approach are available (i.e., Mainhard, Pennings, Wubbels, & Brekelmans, 2012; Pennings, 2017; Pennings, Van Tartwijk, et al., 2014). In the present study, we wanted to further the knowledge generated in those studies by (a) mapping the micro-level interactional behaviors of secondary education teachers and their students and (b) relating those observations to student perceptions of the teacher's interpersonal style (i.e., macro-level), which is an indicator for teacher-student relationship quality (Wubbels et al., 2006).

Dynamic systems approach

In dynamic systems (DS) approaches development is seen as hierarchically nested in time (Hollenstein, 2007). This means that change and development occur on multiple interrelated timescales. Hollenstein (2013) described *real-time* or moment-to-moment interactions as the micro-level time scale, the *situational* or hourly/daily processes as the meso-level time scale, and the *developmental-time* processes that occur weekly/monthly/yearly, as the macro-level time scale. The largest changes in development occur on the macro-level time scale, but smaller scale processes of change on the micro-level and meso-level time scales are responsible for these larger developmental changes. In turn, the macro-level time scale constrains the processes occurring on the lower levels. This results in a feedback loop, or circular causality, between time scales. The objective of DS research is to study the interplay between time scales to understand development of (social) systems.

There are several key concepts used in DS approaches. Moment-to-moment behaviors that occur in real time are called *states* (Hollenstein, 2013) and the set of all possible behavior states is called the *state space*. Another key concept is the presence of *attractors* in moment-to-moment behavior states (e.g., Granic & Patterson, 2006; Guastello et al., 2009; Hollenstein, 2013). Attractors are stable and recurrent behavior states or behavior sequences that a system (e.g., person, dyad, or group) prefers or tends to get stuck in (Granic & Patterson, 2006; Thelen & Smith, 2006). Attractors develop through repetition and once stabilized they are difficult to change (Thelen & Smith, 2006). According to Granic and Hollenstein (2003), attractors in interactions are related to the quality of macro-level relationships. In contrast to attractors, there is the presence of *repellors*. Repellors are behaviors that are hardly ever displayed by a system (Hollenstein, 2013).

For example, in a classroom an early career teacher starts his or her first lesson. The teacher may struggle to structure and support student activities (see Mainhard et al., 2012). When lessons keep being poorly organized, this might evoke distraction and chatting among students, which in turn may lead to dissatisfied teacher behavior; the more often lessons are poorly organized, the more easily students may become distracted, the more easily aversive teacher behavior may be triggered (i.e., teacher-student attractor), and the less likely friendly teacher or student behavior is triggered (i.e., teacher-student repellor). Eventually, such an attractor may restrict the classroom social climate to relatively low levels of control and friendliness of the teacher, which results in a negative teacher-student relationship, which without specific interventions is hard to change (Thelen & Smith, 2006).

Interpersonal interactions and relationships

Interactions between people can be understood as a process of transactional events that unfold over time (e.g., Pincus et al. (2014)). Interaction partners adapt to each other's interpersonal behaviors in such a way that, over time, patterns in their interactions emerge (Pincus et al., 2014; Sadler, Ethier, Gunn, Duong, & Woody, 2009; Vallacher, Nowak, & Zochowski, 2005) and those patterns are related to the quality of interactional outcomes such as relationships (Kiesler, 1996; Vallacher et al., 2005; Wubbels et al., 2015). The conceptual basis for studying behavior, interactions, and relationships can be found in interpersonal theory (e.g., Horowitz & Strack, 2011; Kiesler, 1996; Leary, 1957; Wiggins, 1991).

Interpersonal theory

Interpersonal theory is used to study aspects of interpersonal communication in various contexts and includes two important aspects of communication. First, interpersonal theory states that every interpersonal behavior can be captured as a distinct combination of two orthogonal dimensions of interpersonal behavior: *agency* and *communion*[1] (e.g., Kiesler, 1996; Wiggins, 1991). The agency dimension manifests in strivings for a certain degree of power and control, whereas the communion dimension manifests in strivings for a certain degree of friendliness and affiliation (Horowitz & Strack, 2011; Gurtman, 2011).

Second, people in interaction constantly decide how agentic and communal they need to be with each other (Kiesler, 1996). Such decisions are usually made unconsciously and are based on how one perceives the other person's interpersonal behavior and on one's own dispositional tendencies (Carson, 1969; Fournier et al., 2011). When interactions follow a certain pattern, which can be described using the *principle of interpersonal complementarity*, it is claimed that interactions will likely stabilize into positive relationships (e.g., Kiesler, 1996; Sadler, Ethier, Gunn, Duong, & Woody, 2009).

This theoretical principle of interpersonal complementarity states that each interpersonal behavior includes a specific interpersonal bid that tends to initiate, invite, or invoke specific interpersonal behavior of the interaction partner. Complementarity on the agency dimension is characterized as oppositeness (i.e., dominance begets submissiveness and vice versa), and complementarity on the communion dimension is characterized as sameness, such that friendliness begets friendliness and unfriendliness begets unfriendliness (e.g., Carson, 1969; Horowitz & Strack, 2011; Kiesler, 1996; Sadler et al., 2009).

According to Carson (1969) and Kiesler (1983) complementarity in interactions is important for developing positive and healthy relationships. However, based on a review study conducted by Orford (1986), the effect of complementarity on developing positive and healthy relationships is somewhat nuanced. Complementarity in terms of friendliness is more evident than complementarity in terms of hostility, and the former is more likely associated with positive outcomes than the latter type of complementarity (Sadler, Ethier, & Woody, 2011). To illustrate this, in conflictual teacher-student interactions, when students are hostile toward the teacher and this is reciprocated with hostility from the teacher, this pattern of interaction may follow a downward spiral into negativity. Such negativity in interactions could result in a negative teacher-student relationship if such situations occur regularly (Doumen et al., 2008; Wubbels et al., 2015). Yet, if in a similar situation, the teacher reacts to hostile student behavior with more agentic yet communal behavior (e.g., in a normal tone of voice talking to the students, telling the students to calm down and by actively listening to the students), the teacher's ability to refrain from negativity may bend the interaction into a positive one, resulting in a positive teacher-student relationship. In several studies, it was indeed found that teachers who developed positive teacher-student relationships were better able to refrain from reacting with hostility to hostile student behaviors

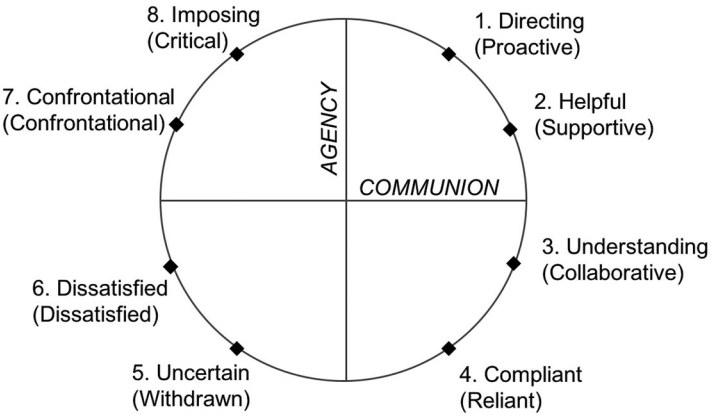

Figure 1. Interpersonal circle to describe teacher and student (in brackets) behavior.

than teachers with more-negative teacher-student relationships (Thijs, Koomen, Roorda, & Ten Hagen, 2011; Pennings et al., 2018).

Agency and communion can be used to describe moment-to-moment interpersonal behaviors and dyadic interactions but also to describe a person's more general interpersonal style (Horowitz & Strack, 2011). An interpersonal style is a general description of how a person, according to others, usually behaves interpersonally on the micro-level (e.g., second-to-second) or the meso-level (e.g., day-to-day) time scales. In educational research, a teacher's general interpersonal style is an important indicator for the quality of the teacher-student relationship (Wubbels et al., 2015). To study interpersonal behaviors and interpersonal styles usually the interpersonal circle (IPC) is used (Gurtman, 2011; Horowitz & Strack, 2011; Kiesler, 1983, 1996).

The interpersonal circle

The IPC is a Cartesian coordinate system consisting of the two dimensions—agency and communion (Gurtman, 2011; Horowitz & Strack, 2011). There are several ways to use the IPC to study interpersonal communication. The most common way in educational research is to divide the IPC into octants to describe certain types of behaviors (Figure 1; Wubbels et al., 2006). The IPC presented in Figure 1 is the IPC used in the educational context (Mainhard, 2015; Wubbels, 2017). The anchor words along the circumference of the circle are prototypical words to describe teacher behaviors located in that area of the IPC (IPC-T). In brackets, we provided the prototypical words that are used to describe interpersonal student behaviors and styles (IPC-S).

The associations between the octants follow a circumplex ordering. This means that the octants are related to each other following a specific kind of ordinal structure that is circular. This means that the association between the octants adjacent to each other is more strongly positive than octants opposite from each other (which are correlated negatively). For example, the association between octant 1(directing) and octant 8(imposing) is stronger than the association between octant 1 (directing) and octant 3 (understanding) or octant 1 (directing) and octant 5 (uncertain). In the latter example, the octants are complete opposites of each other. Therefore, the correlation between octant 1 and 5 should be the most strongly negative, whereas the strongest negative correlation of octant 8 should be with octant 4 (Horowitz & Strack, 2011; Wubbels et al., 2006).

The second way to use the IPC is to plot the scores for agency and communion onto the coordinate system to visualize where in the IPC interpersonal behavior or the interpersonal style is located. Note that based on this location, the corresponding octant can also be identified but that this is not a necessity.

In the present study, we use both methods of representing agency and communion in the IPC. The first method is used to code observed teacher and student *interpersonal states* (i.e., interpersonal behavior). A combination of the first and second methods is used to identify the teachers' *interpersonal styles* (i.e., an indicator of teacher-student relationship quality). How we study teacher interpersonal styles is explained in the following paragraph.

Teacher interpersonal styles

Teacher interpersonal style can be measured by administering the Questionnaire on Teacher Interaction (QTI; Wubbels et al., 2006) to students, which measures student general perception of the levels of agency and communion in teacher behavior. These perceptions are used to map a teacher's interpersonal style by aggregating the perceptions of all students in a class (Mainhard et al., 2012). The aggregated agency and communion scores can be placed in the IPC. Often the interpersonal style is then described in terms of the level of agency and communion. For example, a teacher's interpersonal style could be characterized by high levels of agency and communion. The second step in determining the interpersonal style is to identify the corresponding octant based on the angular location and the vector length in the IPC, which may be easier to interpret.

Since Wubbels, Creton, and Hooymayers (1985) first published about teacher interpersonal styles,[2] many studies have been conducted across the world that investigated the importance of the teacher's interpersonal style for student outcomes, such as student achievement and student motivation (e.g., Cornelius-White, 2007; Den Brok et al., 2004; Goh, 1994; Henderson & Fisher, 2008; Maulana, Opdenakker, & Bosker, 2014; Wubbels et al., 2006). However, in those studies, another typology of teacher interpersonal styles was used, which was identified by Brekelmans (1989).

Based on more-recent insights and advances in interpersonal theory (e.g., as described in Horowitz & Strack, 2011), a new typology of nine interpersonal styles was identified (Mainhard, 2015; Pennings et al., 2018; Wubbels, 2017). This new typology is based on the octants of the IPC, hence eight interpersonal styles, complemented by a ninth interpersonal style that is located at the intersection of the two dimensions in the IPC. Teachers with this ninth interpersonal style do not show positive or negative levels of agency and communion. In previous research these teachers have been described as disorganized and struggling (Brekelmans, 1989; Wubbels et al., 2006; Wubbels et al., 2015). Therefore, this ninth interpersonal style is called struggling.

More-preferred or less preferred interpersonal styles

In the present study, we compared the results for teachers with more-preferred (MP) interpersonal styles to the results for teachers with less preferred (LP) interpersonal styles. In various studies, it was shown that better student academic and emotional outcomes are associated with teachers that have interpersonal styles characterized by high levels of both agency and communion (e.g., Brekelmans, 1989; Den Brok et al., 2004; Ertesvag, 2011; Goh, 1994; Henderson, 1995; Walker, 2009; Wentzel, 2002; Wubbels et al., 2015). Furthermore, research has shown that teachers with an interpersonal style characterized by high levels of agency and communion are most preferred by teacher and students (Wubbels et al. 2006).

To study whether the identification of interpersonal styles as MP or LP still holds for the new typology, Pennings et al. (2018) reanalyzed a data set with measurements of 7,958 teachers' perceptions of their ideal interpersonal style (Wubbels et al., 2006). The results presented in Pennings et al. (2018) confirmed that with this new typology of interpersonal styles, the interpersonal styles located in the upper right part of the IPC (directing and helpful) were most preferred by teachers. The other styles are seen as less preferred by teachers. Thus, in the present study MP

interpersonal styles located in the upper right part of the IPC (i.e., directing and helpful), and the LP interpersonal styles are all other interpersonal styles.

Research on teacher-student interactions (using a DS approach)

There is substantial research on teacher-student interactions (e.g., Mainhard, Brekelmans, & Wubbels, 2011; Buyse, Verschueren, Doumen, Van Damme, & Maes, 2008; Booren, Downer, & Vitiello, 2012; Pennings, Brekelmans et al., 2014). In some of these studies teacher-student interactions are measured using retrospective self-reports of teachers or observed only teacher or even only student behavior. The term *interaction* inherently means that there are always two components present and that those should be studied together (Carson, 1969). Thus observations of both actors in the interaction are necessary.

There are several studies using a DS approach on teacher-student interactions that incorporated observations of both teacher and student behaviors to study interactions. For example, Turner, Christensen, Kackar-Cam, Trucano, and Fulmer (2014) studied the effect of teacher-student interactions after an intervention to enhance student self-efficacy. Several other studies focused on scaffolding in teacher-student interactions (e.g., Kupers, Van Dijk, & Van Geert, 2015; Vauras, Kinnunen, Kajamies, & Lehtinen, 2013). In another study Kupers, Van Dijk, Van Geert, and McPherson (2015) studied the degree to which autonomy of students was co-regulated in teacher-student interactions during music lessons. Also Van Vondel, Steenbeek, Van Dijk, and Van Geert (2017) studied how scientific understanding of students was co-constructed during teacher-student interactions. All of these studies were focused on the effect of interactions on a specific educational outcome instead of on studying the association between interactions and relationships over time.

Roorda, Koomen, Spilt, Thijs, and Oort (2013) were among the first to study moment-to-moment teacher-student (kindergartners) interactions using observations of agency and communion with a larger sample in a natural classroom setting. However, they also did not explicitly study the interplay between micro-level and macro-level variables in terms of relationship quality.

Kiesler (1996), Wubbels et al. (2012), and Wubbels (2017) both stress the need for more research on moment-to-moment interactions and the association with relationships. In the present study, we are specifically interested in studying the interplay between teacher-student interactions (micro-level) and student perceptions of the teacher interpersonal style as an indicator for the quality of the teacher-student relationship (macro-level).

Only a few studies exist that systematically studied moment-to-moment-teacher-student interactions (in secondary education) using observations of agency and communion and related those observations to the teachers' interpersonal styles that also used DS approaches (e.g., Mainhard et al., 2012; Pennings, Van Tartwijk et al., 2014). Even though those studies were small-scale studies (i.e., $N = 2$ designs), the findings of those studies offered important insights in how the interplay between teacher-student interactions and interpersonal styles could be examined in larger-scale studies.

First, the results of those studies (Mainhard et al., 2012; Pennings, Van Tartwijk et al., 2014) indicated that for most teachers, the average level of observed moment-to-moment teacher behavior was related to the level of agency and communion characterizing the teacher interpersonal style (as perceived by students). This is consistent with the assumption that interactions are the building blocks of relationships (Mainhard et al., 2012) and with the findings of studies in interpersonal contexts other than the educational context (e.g., Markey, Lowmaster, & Eichler, 2010; Sadler et al., 2009).

Second, the results of those studies indicated that interactions of teachers with MP interpersonal styles were more stable and predictable than those of teachers with LP interpersonal styles. For example, Pennings, Brekelmans et al. (2014) found that the teachers with

uncertain, dissatisfied, or confrontational interpersonal styles showed a larger variety in teacher behaviors than teachers with directing and helpful interpersonal styles. They also found that behavior sequences of teachers with uncertain, dissatisfied, or confrontational interpersonal styles were less predictable than those of teachers with directing and helpful interpersonal styles.

The results of those studies show that using a DS approach is useful for gaining insight into the interplay between interactions and relationships. Those studies pointed toward a direction in which we can start understanding that interactions are the building blocks of relationships. Therefore, in the present study, we included observations of a larger sample of 35 teachers with their 746 students.

The present study

In the present study we investigated the dynamics of teacher-student interactions by visualizing and analyzing the interactions' trajectories with State Space Grid (SSG) analysis (Hollenstein, 2013; Lewis, Lamey, & Douglas, 1999). SSG analysis was developed by Lewis et al. (1999) to study infant behavior and was quickly adapted to the study of parent-child interactions (e.g., Granic, O'Hara, Pepler, & Lewis, 2007; Hollenstein & Lewis, 2006; Lougheed & Hollenstein, 2016). To visualize interactions, the SSG analysis generates a state space of dyadic behaviors. For the present study, we defined this state space using the octants of the IPC as characterizations of interpersonal behavior, which we will refer to as *interpersonal states* throughout the manuscript. To study interactions in terms of states (especially attractors) and variability, Granic and Hollenstein (2003) introduced the terms *content* and *structure*.

Interpersonal content refers to indices that describe *which* behavior states unfold in interactions over time. In other words interpersonal content described what behavior looks like and which behaviors are most frequently occurring in interactions. In the present study, we described interpersonal content (a) in terms of the degree of agency and communion in behaviors of teacher and students (i.e., we correlated the *average level* of agency and communion in moment-to-moment teacher and student behavior) and (b) in terms of octant scores, which is a representation of both agency and communion in the IPC at a given moment in time (i.e., the frequency of occurrence during an interaction indicates *attractors*). The average level of agency and communion and attractors are two indices of interpersonal content.

Structure of interactions refers to the indices of the variability and predictableness of interactions. This means that interpersonal structure describes the processes of behavioral change in interactions (e.g., Hollenstein, 2013)—that is, *how* interpersonal behavior unfolds in time. We will derive several indices of interpersonal structure using SSG analysis: (a) the number of *transitions* (changes in behavior), (b) the *range* of dyadic states (i.e., number of unique dyadic behaviors shown by the teacher and their students), (c) *dispersion* (i.e., the scatteredness of behavior across the state space, and (d) *entropy* (i.e., the degree of predictableness). All indices will be explained further in the analysis section.

Furthermore, in the studies of Mainhard et al. (2012), Pennings, Brekelmans et al. (2014), and Pennings, Van Tartwijk et al. (2014), the results for moment-to-moment agency and communion were analyzed separately instead of as blend of agency and communion. In the present study, we entered observations of teacher and student behavior as a confluence of agency and communion into the SSG analysis, instead of analyzing the results for agency and communion separately. This fits better to the central aspect of interpersonal theory, that both agency and communion are present in every interpersonal behavior (Horowitz & Strack, 2011).

We combined observations of teacher behavior states and student behavior states in the analysis to study the dynamics of teacher-student interactions in terms of the content and structure and to answer the following research questions:

1. *Do interpersonal content and interpersonal structure characterize moment-to-moment-teacher-student interactions?*
2. *Are indices of interpersonal content and interpersonal structure of moment-to-moment-teacher-student interactions related to the teacher's interpersonal style?*
3. *Are indices of interpersonal content and structure different for teachers with more preferred and teachers with less preferred interpersonal styles?*

Since the studies of Mainhard et al. (2012), Pennings, Brekelmans et al. (2014), and Pennings, Van Tartwijk et al. (2014) were, to our knowledge, the only studies that concerned the content and structure of interactional teacher behavior or teacher-student interactions, we based our expectations mainly on the results of those small-scale studies. Also, some expectations were based on findings of studies that were conducted in different contexts but that used similar observations of agency and communion to study the interplay between interactions and interpersonal styles (e.g., Markey et al., 2010; Sadler et al., 2009).

In previous studies, Markey et al. (2010) and Sadler et al. (2009) found moderate correlations between levels of agency and communion in interactions and levels of agency and communion in perceptions of interpersonal styles of unacquainted males and females. Therefore, we expected that the level of observed agency and communion in moment-to-moment teacher behavior would be related to the student perceived level of agency and communion characterizing the teachers' interpersonal style.

The indices of interpersonal content studied by Mainhard et al. (2012) and Pennings, Van Tartwijk et al. (2014) indicated that the interactions in their studies followed a pattern of complementarity. Based on these findings, for the present study we expected that attractors and average levels of agency and communion in teacher-student interactions would also indicate patterns of complementarity.

Last, based on the findings of Mainhard et al. (2012), Pennings, Brekelmans et al. (2014), Pennings, Van Tartwijk et al. (2014), we expected that the interactions of teachers with MP interpersonal styles would show less variability in terms of different types of dyadic behaviors or changes in dyadic behaviors, and that these teachers' interactions would be more predictable than those of teachers with LP interpersonal styles.

Method

Participants

For this study, 36 secondary school teachers were selected from a larger sample of 189 teachers participating in a three-year longitudinal study on classroom climate in the Netherlands. We selected these 36 teachers, because they participated in the most extensive version of the longitudinal study (i.e., including interviews and videotaped lessons at each wave of the study). The present study is based on the data of the first wave of the longitudinal study (i.e., the interviews and videotaped lessons of wave 2 and 3 were not included). One of the classrooms was removed prior to analyses because in the first 10 minutes of the videotaped lesson, hardly any interaction occurred due to students taking a written test. Therefore, only 35 teachers (746 students, 27 schools) were included in the present study.

The teachers (ages 22–59 years, M = 42.4, SD = 10.7; 14 female) had different levels of teaching experience (1–35 years, M = 11.3, SD = 11.4) and taught different subjects (i.e., languages, science, history, geography, economy, and art). Their classes of students were from different educational levels (i.e., preparatory secondary vocational, senior general secondary, university preparatory) and different grades (grades 7 to 12; ages 12–18 years).

Procedure

Video recordings of the lessons were made in the spring of the 2010–2011 academic year. For each teacher, we recorded a lesson with two cameras: (a) a camera positioned in the back of the classroom to record teacher behavior and (b) a camera in front of the classroom to record student behavior.

Teachers were provided with consent letters for parents to return if they objected to their child being filmed; none of the parents objected. After data collection was finished, teachers received the video recordings and a written report on their interpersonal style and other measures included in the study.

Instruments

Teacher-student interactions

Teacher-student interactions were observed during the first 10 minutes of a lesson[3] with Continuous Assessment of Interpersonal Dynamics (CAID; Sadler et al., 2009; Lizdek, Woody, Sadler, & Rehman, 2016). With CAID, interpersonal behaviors, in terms of agency and communion, are continuously coded using a computer joystick apparatus and corresponding software (i.e., Joymon[4]). Joymon generates a Cartesian plane representing the IPC. By moving the joystick in the desired direction, behavior coordinates (i.e., communion on the *x*-axis and agency on the *y*-axis) are automatically recorded every half second (i.e., default setting of the CAID software). The behavior coordinates range from −1000 = very low agency/communion to +1000 = very high agency/communion (i.e., to ensure maximum sensitivity of the computer joystick device).[5] The resulting observational data are continuous time series data of 1,200 time points.

The first 10 minutes of each teacher and student video were coded by two out of four trained observers. We chose to observe the first 10 minutes only because this part of the lesson is most important to set the stage for an effective teaching and learning environment (Van Tartwijk, Brekelmans, Wubbels, Fisher, & Fraser, 1998). Also, this part of the lesson is most comparable between teachers because each lesson has a specific start when the teacher class-level dynamics are most apparent, and according to Van der Want et al. (2015), this part of the lesson is especially demanding regarding such class-level dynamics. Furthermore, according to Sadler et al. (2009), a period of 10 minutes is of sufficient duration to identify adaptive patterns in moment-to-moment interactions.

The observers coded interpersonal behavior representing the class-level dynamics. Class-level dynamics are very complex (Wubbels et al., 2006). In a whole-class setting, the teacher in general interacts with the entire class of students and the behavior of the teacher, whether it is focused on the entire class or on a specific student, affects all students' perceptions of their teacher. In turn, the classes' collective behavior and the behavior of each individual student affect how the teacher interacts with the entire class. Such teacher-class interactions are a typical example of what Kenny, Kashy, and Cook (2006) call a one-with-many interaction. Because we wanted to study the class-level dynamics and not individual teacher-student dynamics, observers took a shared student perspective when coding teacher behavior and coded behavior states of the entire class of students as a whole. However, one exception was made when one specific student's interpersonal behavior would stand out from the entire class. In such situations, one student's behavior influenced the teacher-class dynamics substantially (i.e., such student's behavior influenced how the teacher interacted with that class and that specific student). In those instances, this student's behavior would weigh heavier in coding than if the entire class were interacting in more harmonious ways. This means that observers took a teacher perspective and pooled agency and communion in coding students' behavior.

Joystick training

Observers received a four- to eight-hour joystick training by the first author who was trained by Pamela Sadler. This training was based on the guidelines described by Lizdek, Sadler, Woody, Ethier, and Malet (2012), who stated that behavior should be coded as a continuous stream or flow of behavior.

After the initial training, the coders practiced and discussed (also with the first author and with several other experts in the field of interpersonal communication in education) how to code interpersonal teacher and interpersonal student behavior in terms of agency and communion.

In general, to code agency it is important to keep in mind the amount of control the teacher or class has in the interaction. To code communion it is important to keep in mind how friendly the teacher and students are toward one another. For example, it is known from previous research by Van Tartwijk (1993) that the amount of teacher's control can be determined by whether the teacher is walking through the classroom (high levels of agency), standing (high levels of agency) or sitting at a desk (lower agency; not necessarily submissive). Furthermore, a teacher's friendliness can be determined by the teacher's facial expressions, such as smiling (higher levels of communion) or frowning (lower levels of communion; not necessarily unfriendly).

For some ambiguous situations, however, it was necessary to establish some specific guidelines together with the experts. For example, the joystick movement goes down on agency (not necessarily agency) when a teacher turns her back completely toward the students to write on the blackboard for a long period. Since such teachers cannot oversee what is happening with the class, the amount of teacher control is thus lower than the amount of control when facing the class, only turning their back for only a short period, or when keeping their bodies turned halfway towards the students while writing on the blackboard. A coding guideline was that students' compliance with teacher requests was coded as low agency and high communion.

After 10 hours of training interrater reliability (intraclass correlations, ICC; k = 2) was established and indicated strong agreement between the observers (LeBreton & Senter, 2008), *mean* ICC for observations of teacher agency =.84 (*SD* =.09), *mean* ICC for observations of teacher communion =.74 (*SD* =.11), *mean* ICC for observations of student agency =.88 (*SD* =.09), and *mean* ICC for observations of student communion =.81 (*SD* =.14).

Preparing the Joystick data for SSG analysis

The time series of agency and communion were averaged across the two observers at each time point separately for the teacher observations and for the class observations. This procedure resulted in two behavioral trajectories for each teacher and two trajectories for each class of students. To analyze interpersonal teacher and student behavior as a blend of agency and communion, the continuous observations of both were combined and, at each time point, recoded into the corresponding octant of the IPC. For example, a teacher that was asking for the students' attention while standing in front of the classroom using a friendly but firm tone of voice was observed as having more agency and communion than a teacher who was demanding the students' attention in a strict and almost angry tone of voice. The first teacher's behavior was recoded as *directing*, whereas the second teacher's behavior was recoded as *imposing* or *confrontational*.

We did this using a vector-based method that calculates the angular position of the agency and communion score (i.e., the location in the IPC), as described by Gurtman (2011). At each time point, we recoded the coordinates (representing the level of agency and communion) as angles that correspond to the octants of the IPC-T and IPC-S (Gurtman, 2011) using the following formula:

$$Angle = \tan^{-1}\left(\frac{Agency}{Communion}\right) * \frac{180}{\pi}$$

When the resulting angle lies between 45 and 90 degrees this corresponds to the first octant, when the angle lies between 0 and 45 degrees this corresponds to the second octant. When the angle is greater than 315 degrees this corresponds to the third octant. When the angle lies between 270 and 315 degrees this corresponds to the fourth octant. When the angle lies between 225 and 270 degrees this corresponds to the fifth octant. When the angle lies between 180 and 225 degrees this corresponds to the sixth octant. When the angle lies between 135 and 180 degrees this corresponds to the seventh octant. When the angle lies between 90 and 135 degrees this corresponds to the eighth octant.

This eventually results in two, "10-minute" time series, one for the teacher and one for the students, consisting of octant scores at every half second (for 10 minutes). Because the trajectories are exactly coordinated in time, they can be combined to study their moment-to-moment interrelation, as teacher-student interactions. To study the duration of each interactional behavior, the sequence of time points in which the teacher and student continued in the same octants we combined into one event that changed only when either the teacher or student changed behavior. Otherwise in SSG analysis, each half-second would be a new event, even though behavior did not change. For the remainder of this article we will refer to octants representing the observed moment-to-moment behaviors of teachers and students as *IP states*.

Teacher interpersonal style

To measure the teacher interpersonal style, we used the class-aggregated student perceptions of their teacher's interpersonal behavior using the Dutch 24-item Questionnaire on Teacher Interaction (QTI; Wubbels et al., 2006). Examples of items are "this teacher has humor" and "this teacher is dissatisfied." Every item is rated on a five-point scale (1 = *never* and 5 = *always*). Each item loads on the two dimensions agency and communion. Consequently, agency and communion dimension scores could be derived from the QTI results by weighting the items based on their position on the IPC (Gurtman, 2011; Locke, 2011). For example, the item "this teacher has humor" corresponds to the second octant of the IPC (i.e., helpful) and is moderately positive associated to agency and highly associated to communion. Therefore, this item receives a weight of .38 on agency and .92 on communion. The item "this teacher is dissatisfied" corresponds to the sixth octant of the IPC and, therefore, loads moderately negative on agency and highly negative on communion. This item therefore receives a weight of -.38 on communion and a weight of -.92 on agency. For an elaborate explanation of the calculation of agency and communion using these weights we refer to Locke (2011).

The reliability of the dimension scores was good: Cronbach's α for agency was .89, and. 95 for communion. Pearson r between agency and communion was .13. Class consensus (ICC; k = class size; Lüdtke, Robitzsch, Trautwein, & Kunter, 2009) was high and varied in the 35 classrooms for agency from .95 to .98 (M=.97, SD=.01) and for communion from .93 to .97 (M=.96, SD=.01).

To derive a single value that represents the teacher's interpersonal style, we used the vector-based method that calculated the angular position of the agency and communion score (i.e., the location in the IPC). Note that this is the same method we used to prepare the Joystick coordinates for SSG analysis. However, one extra step was taken to identify teachers with the struggling interpersonal style, by calculating the vector length corresponding to the angular location of agency and communion in the IPC with the following Pythagorean formula:

$$Vector\ length = \sqrt{Agency^2 + Communion^2}$$

Based on insights from previous studies (e.g., Horowitz & Strack; Wubbels et al., 2006), teachers whose vector length lay between 0 and .20 were characterized as struggling. For the remainder of the article we will use *IP style* when referring to the teacher's interpersonal styles. In Table 1 (results section) the IP styles per teacher are provided.

Analysis

To analyze the dynamic aspects of teacher-student interactions we used State Space Grid analysis and the corresponding program GridWare (Lamey, Hollenstein, Lewis, & Granic, 2004). SSG analysis can be used to study the dynamic association between two or more mutually exclusive and exhaustive categorical variables, which are graphically presented in a grid (see Hollenstein, 2013, for examples from a large array of research fields, or Pennings & Mainhard, 2016, for examples specifically for education).

Figure 2 shows a hypothetical example of how the trajectories of teacher and class/student IP states in the IPC look when they are combined in an SSG. The open node marks the start of the interaction. The larger the nodes, the longer that specific IP state was shown at the corresponding moment in the interaction. The teacher IP state trajectory in this example showed that the teacher's behavior changed from directing, to helpful, to imposing, and back to directing. The student trajectory showed that the students' behaviors changed from reliant to collaborative, to supporting and back to being reliant. However, how the teacher's and the students' IP states were linked to each other in time cannot be derived from the separate trajectories in the IPCs. Combining both teacher and class IP state trajectories in an SSG provides a dyadic trajectory of how changes of the teacher and class go together in time. This interaction starts in cell 14 (i.e., the cells are referred to following an *xy* convention), which indicates *directing* teacher behavior and *reliant* student behavior. Then moves through the SSG following the arrowed lines and ends again in cell 14 (directing-reliant). Note that the grid consists of categories that follow a circumplex ordering, not a regular ordinal ordering. The lines are included only to mark how the teacher-class interaction trajectory moves through the SSG; they do not indicate the strength of behavior changes.

Content and structure

To study the content and structure of teacher-student interactions, we derived various indices from the SSG analysis. To study the content, we identified the attractor cells in each teacher-student interaction. According to Hollenstein (2013), there are three methods for this. The first method is to predefine attractors based on theory. The second method is to identify the cells with the longest duration and the highest number of visits as attractor cells (see e.g., Pennings, Brekelmans, et al., 2014, who described certain criteria for duration and number of visits to identify attractors). The third method is the most empirical method but also the most strenuous, the *winnowing procedure* (e.g., Hollenstein, 2013). We used this winnowing procedure.

For an elaborate description of the winnowing procedure including an explanation with examples of data we refer to Hollenstein (2013). But, in short, the winnowing procedure goes as follows: the cells with the highest probability of being an attractor are identified based on the heterogeneity criterion, which is based on the duration of the observations in the cells of the SSG. The cells with the lowest durations are iteratively (step-by-step) eliminated as attractor cells. Based on the observed duration (i.e., the duration that the interaction trajectory resided in the target cell), the expected duration (i.e., calculated by the total duration of the observed interaction divided by the number of cells included in the iteration), and the number of cells included in the iteration, a heterogeneity score is calculated per iteration using the following formula:

Table 1. IP style agency and communion, IP state agency and communion, and SSG measures.

	(Teacher) Interpersonal Style			Interpersonal State				SSG measures					
				Teacher		Student							
Teacher	Agency	Communion	style	Agency	Communion	Agency	Communion	Transitions	Cell Range	Dispersion	Visit Entropy	Duration per visit	Duration per cell
1	-410	200	4	-151	342	-213	-4	59	17	.86	2.54	9.79	34.56
2	280	470	2	583	644	-208	152	76	16	.90	2.55	7.63	36.72
3	140	130	9	-137	577	50	-513	77	16	.90	2.49	7.53	36.72
4	150	110	9	91	170	31	-12	104	33	.95	3.25	5.60	17.80
5	-10	-200	9	176	313	175	365	55	13	.89	2.35	10.49	45.19
6	290	660	2	411	518	157	317	28	13	.86	2.45	20.26	45.19
7	40	440	2	154	710	133	431	32	12	.81	2.20	17.80	48.96
8	330	570	2	570	427	93	338	40	10	.75	2.18	14.33	58.75
9	60	590	2	290	475	-399	405	42	12	.74	2.16	13.66	48.96
10	200	130	1	77	512	-484	334	35	15	.80	2.50	16.32	39.17
11	30	150	9	472	169	-150	0	53	19	.78	2.60	10.88	30.92
12	230	-190	8	243	183	-270	373	42	18	.90	2.62	13.66	32.64
13	420	250	1	406	249	-107	194	46	15	.86	2.43	12.50	39.17
14	450	430	1	517	379	-224	275	42	16	.68	2.64	13.66	36.72
15	-60	520	3	296	514	167	578	20	9	.67	2.09	29.38	65.28
16	310	400	2	466	627	-258	485	39	8	.82	1.94	14.69	73.44
17	-260	320	3	392	428	-213	150	98	18	.85	2.47	5.93	32.64
18	100	520	2	225	604	-229	551	27	9	.71	2.00	20.98	65.28
19	140	-70	9	748	610	-481	309	36	11	.73	2.27	15.89	53.41
20	420	-80	8	285	49	23	213	86	17	.92	2.63	6.75	34.56
21	230	-20	8	420	516	-194	331	53	11	.79	2.19	10.88	53.41
22	150	510	2	427	740	-168	366	34	11	.81	2.10	16.79	53.41
23	50	-30	9	-214	55	365	-321	83	34	.83	3.31	6.99	17.28
24	350	-160	8	508	99	-179	173	102	20	.89	2.73	5.70	29.38
25	90	180	2	164	583	120	170	69	15	.88	2.40	8.39	39.17
26	310	70	1	518	401	-452	538	48	10	.68	1.59	11.99	58.75
27	-80	-120	9	-28	-25	167	−61	138	47	.97	3.69	4.23	12.50
28	270	340	2	442	478	-333	644	51	9	.79	1.75	11.30	65.28
29	140	210	2	214	708	-178	122	45	13	.86	2.25	12.77	45.19
30	-120	160	3	248	515	64	138	64	18	.86	2.44	9.04	32.64
31	-100	60	9	174	369	155	107	58	20	.89	2.67	9.96	29.38
32	-230	40	4	348	167	-64	180	48	16	.91	2.65	11.99	36.72
33	310	40	1	474	413	-784	656	33	8	.59	1.61	17.28	73.44
34	220	360	2	156	397	30	93	54	21	.90	2.83	10.68	27.98
35	370	450	2	278	176	-423	239	42	19	.65	2.70	13.66	30.92
Average	140	210	n.a.	293	403	-122	238	55.97	16.26	0.82	2.44	12.27	42.33

Note. IP style agency and communion are multiplied by 1,000, which makes them comparable to the IP state variables. For convenience we deleted the decimals corresponding to the IP style and state values.

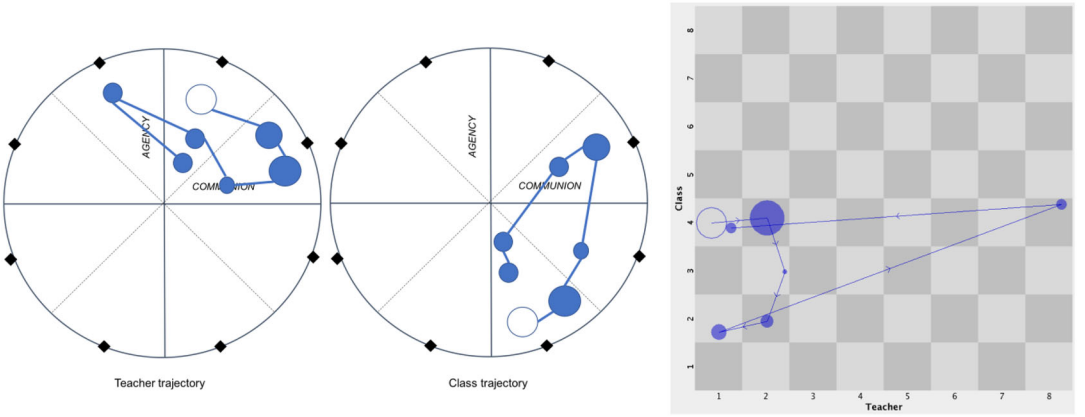

Figure 2. Example SSG. In this hypothetical example, a student-class interaction trajectory is presented. Note that the location of the dots in the IPCs and in the SSG is completely arbitrary; it does not say anything about the location of behavior in the IPC. Note that the numbers on the *x*-axis and *y*-axis correspond to the octants of the IPC-T and IPC-S (in brackets): 1 = directing (proactive). 2 = helpful (supportive), 3 = understanding (collaborative), 4 = compliant (reliant), 5 = uncertain (withdrawn), 6 = dissatisfied (dissatisfied), 7 = confrontational (confrontational), 8 = imposing (critical).

$$\frac{Heterogeneity_j = \Sigma(Observed_i - Expected_j)^2 / Expected_j}{\#\ of\ \ Cells_j}$$

where *i* represents the specific cell targeted in iteration *j*.

The heterogeneity score corresponding to each cell is quantified as a proportion of the heterogeneity score in the first iteration by dividing heterogeneity$_j$ by heterogeneity$_i$. The cell with a drop of >50% in proportion indicates that the remaining cells may be regarded as attractor cells (Hollenstein, 2013; Lewis et al., 1999). If multiple adjacent cells turn out to be attractors, this can be referred to as an attractor region (Hollenstein, 2013). In addition, we derived the duration that the interaction trajectory resided in the identified cells as an indicator for the strength of the attractor. This indicator is called *perseverance*.

To study the structure of the interactions, we derived four structure indices from the analysis: the number of *transitions* (i.e., the number of dyadic behavior changed calculated by the number of visits–1), the *cell range* (i.e., the number of unique cells visited by the interaction; this conceptually refers to the number of different dyadic behaviors that were observed in the interaction), *dispersion* (i.e., indicates to what extent dyadic behaviors are distributed across the SSG). Dispersion is expressed in a value between 0 (no variability) and 1 (maximum variability) and is an overall measure of scatteredness across the SSG controlling for proportional cell durations. Dispersion is calculated by taking the sum of the squared proportional average duration per cell across all visited cells corrected for the total number of cells and inverted (Hollenstein, 2013). *Visit entropy* (i.e., the degree of unpredictability of an interaction trajectory) is calculated using the Shannon and Weaver entropy formula (Hollenstein, 2013).

Results

Association teacher IP style with teacher and student IP states

Table 1 shows the results for IP style agency and IP style communion (i.e., student perceptions) and the descriptive statistics (i.e., means, standard deviations, and ranges) for IP state (i.e., observer ratings) and for the structure indices per teacher. Across all teachers, the IP style level of agency was 140 (range -410 to 455) and the level of communion was 210 (range -200 to 660).

For the IP state, on average, the level of teacher agency was 293 (range -214 to 748) and communion was 402.71 (range -25 to 740).

There was a large variety in the degree to which the levels of IP style agency and communion with IP state agency and communion per teacher were comparable. For example, Teacher 5's IP style communion as perceived by the students is -200, but IP state communion was observed in the lesson at 313. Or Teacher 23's IP style communion was -30 and IP state communion was 55. However, the difference for Teacher 23 was not as large as the difference for Teacher 5.

To quantify the association between the IP style and IP state levels of the teacher we calculated correlations between the four variables (Table 2). The correlations between teacher IP style communion and IP state teacher communion (r = .58) and between teacher IP style agency and IP state teacher agency (r = .47) were both positive and indicate moderate associations. For students, the average level of IP state agency was -122.38 (range -784.11 to 364.74), the level of communion was 237.64 (range -513.00 to 656.20). The average levels of teacher and student IP state agency and communion already showed that, on average, the moment-to-moment interactions follow a pattern of complementarity with oppositeness on the agency dimensions (i.e., teachers high in agency and students low in agency) and sameness on the communion dimension (i.e., both the teachers and students high in communion). The correlations between IP style agency and communion and IP style agency and communion of the students show that how students perceived their teacher was not related to observations of how students behaved themselves.

Teacher-student interactions

The IP state behaviors of the teacher were correlated with IP state behaviors of the students. The negative correlation between teacher IP state agency and student IP state agency (r = -.47) and the positive correlation between teacher IP state communion and student IP state communion (r = .35) indicated that patterns of complementarity were present in the interactions.

We also found a statistically significant positive cross-dimensional correlation between teacher IP state agency and student IP state communion (r = .59), indicating that when teachers showed more agency in their behavior students were more friendly in their behavior (i.e., a lower level of moment-to-moment teacher agency was related to a lower level of moment-to-moment student communion).

Table 2. Correlations between the style and state variables.

Variables	IP style communion	IP style agency	IP state T-communion	IP state S-communion	IP state T-agency	IP state S-agency
IP style Com	–					
IP style Ag	.12	–				
IP state T Com	.54**	.01	–			
IP state S Com	.29	.28	.35*	–		
IP state T Ag	.21	.47**	.24	.59**	–	
IP state S Ag	-.02	-.30	-.19	-.49**	-.47**	–
Transitions	-.48**	-.19	-.55**	-.62**	-.34*	.33
Cell Range	-.40*	-.24	-.67**	-.66**	-.54**	.44**
Dispersion	-.38*	-.28	-.27	-.59**	-.42*	.57**
Visit Entropy	-.34*	-.21	-.65**	-.74**	-.51**	.52**

Note. IP style = interpersonal style; M-to-M = moment-to-moment; T = teacher; S = students.
*$p < .05$
**$p < .01$
**$p < .001$

Interpersonal content of interactions

The left part of Figure 3 shows the dyadic behaviors of all 35 teachers in one SSG. Visual inspection of this SSG showed that all dyadic behaviors were observed (i.e., there are dots in all cells of the SSG), but some behaviors occurred rarely. For example, uncertain teacher behavior ($x5$) rarely combined with dissatisfied student behavior ($y6$); thus, those dyadic behaviors can be identified as repellors.

The large or densely clustered plot points in the SSG show that interactions mostly consist of directing-collaborative (cell 13), directing-reliant (cell 14), helpful-collaborative (cell 23), and helpful-reliant (cell 24) teacher-student behaviors. There are also some large (i.e., long duration) nodes in the cells that represent understanding-critical (cell 38) and compliant-critical (cell 48) teacher-student behaviors.

The empirically identified attractors that represent the predominant content of each teacher-student interaction derived from the winnowing procedure (see analysis section) are presented in Table 3. Per teacher, the single attractors and the corresponding perseverance (duration in those cells) are listed. Also, if the single attractor cells were adjacent to each other, those cells formed an attractor region and are presented in the attractor region columns of Table 3. The frequency with which attractors were identified across all 35 teachers is presented in the right side of Figure 3.

We identified up to four attractors per classroom, with varying degrees of perseverance for each attractor. For half of the teachers, multiple cells formed an attractor region. There are three cells of dyadic behaviors that were identified as attractors relatively often: Directing-reliant (cell 14) was identified as an attractor for 16 out of 35 teachers (46%); helpful-reliant (cell 24), for 10 teachers (29%); and directing-collaborative (cell 13), for eight teachers (23%). Also, for seven teachers (20%), combinations of these three cells were identified as attractor regions.

These most frequently occurring attractor cells indicated patterns of interactions where the teachers' IP state agency and communion were both high and student IP state agency was low

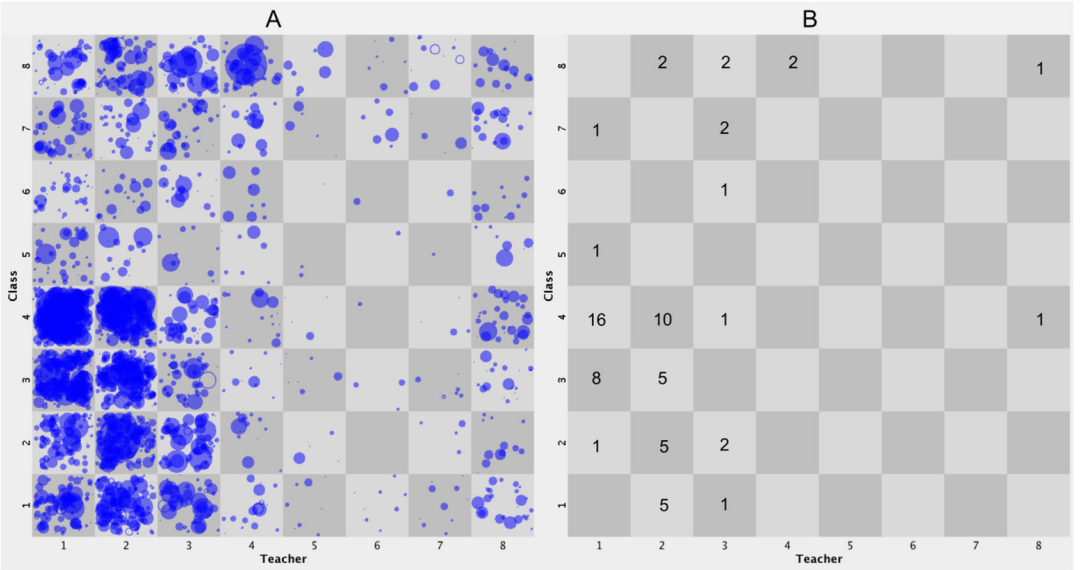

Figure 3. Content of teacher-student interactions. Illustration of all the IP states of the 35 teacher-student interactions (Figure 3A). The SSG on the right displays the frequencies with which each cell was identified as an attractor (Figure 3B). Note that the numbers on the *x*-axis and *y*-axis correspond to the octants of the IPC-T and IPC-S (in brackets): 1 = directing (proactive). 2 = helpful (supportive), 3 = understanding (collaborative), 4 = compliant (reliant), 5 = uncertain (withdrawn), 6 = dissatisfied (dissatisfied), 7 = confrontational (confrontational), 8 = imposing (critical).

Table 3. Single attractors cells, attractor regions, and corresponding perseverance.

		Single Attractor Cells				Attractor Region
Teacher ID	IP style	Attractor 1 (perseverance)	Attractor 2 (perseverance)	Attractor 3 (perseverance)	Attractor 4 (perseverance)	Cells (perseverance)
1	4 (LP)	34 (140.5)	24 (137.5)	48 (86.5)	–	34/24 (178.0)
2	2 (MP)	24 (130.0)	23 (98.5)	–	–	24/ 23 (228.5)
3	9 (LP)	36 (124.0)	37 (91.0)	–	–	36/37 (215.0)
4	9 (LP)	14 (79.0)	37 (59.0)	17 (54.5)	–	–
5	9 (LP)	13 (107.0)	32 (101.5)	–	–	–
6	2 (MP)	14 (164.5)	38 (116.0)	–	–	–
7	2 (MP)	22 (179.5)	32 (166.5)	–	–	22/32 (346)
8	2 (MP)	13 (212.5)	12 (194.5)	28 (85.5)	–	13/ 12 (407.0)
9	2 (MP)	24 (260.5)	14 (138.5)	–	–	24/ 14 (399.0)
10	1 (MP)	24 (235.5)	–	–	–	–
11	9 (LP)	14 (257.5)	–	–	–	–
12	8 (LP)	14 (142.5)	13 (83.0)	–	–	14/13 (225.5)
13	1 (MP)	14 (166.5)	11 (107.0)	21 (94.0)	–	11/21 (201)
14	1 (MP)	14 (324.0)	–	–	–	–
15	3 (LP)	22 (318.5)	–	–	–	–
16	2 (MP)	23 (174.0)	24 (130.0)	13 (104.0)	31 (85.5)	23/24/13 (408.0)
17	3 (LP)	14 (189.0)	–	–	–	–
18	2 (MP)	23 (298.5)	–	–	–	–
19	9 (LP)	14 (289.0)	–	–	–	–
20	8 (LP)	13 (88.5)	21 (83.5)	–	–	–
21	8 (LP)	14 (235.5)	–	–	–	–
22	2 (MP)	24 (214.5)	–	–	–	–
23	9 (LP)	48 (233.0)	–	–	–	–
24	8 (LP)	14 (141.5)	13 (105.5)	84 (78.0)	–	14/13/84 (325.0)
25	2 (MP)	22 (121.5)	21 (105.0)	–	–	22/ 21 (226.5)
26	1 (MP)	13 (238.0)	14 (232.5)	–	–	13/14 (470.5)
27	9 (LP)	48 (80.5)	88 (56.5)	–	–	–
28	2 (MP)	13 (226.0)	23 (132.5)	–	–	13/23 (358.5)
29	2 (MP)	24 (161.0)	22 (122.5)	–	–	–
30	3 (LP)	24 (160.0)	21 (126.0)	–	–	–
31	9 (LP)	22 (117.0)	21 (113.0)	23 (88.5)	28 (69.5)	22/ 21/ 23 (318.5)
32	4 (LP)	14 (113.0)	15 (83.5)	–	–	14/15 (196.5)
33	1 (MP)	14 (301.0)	24 (229.5)	–	–	14/24 (530.5)
34	2 (MP)	14 (102.0)	38 (100.0)	24 (99.5)	–	14/24 (201.5)
35	2 (MP)	14 (343.0)	–	–	–	–

Note. The cells are presented following an *xy*-convention; 14 means teacher octant 1 and student octant 4. The individual cells in the attractor regions are separated with/and are also presented as single attractor cells. Perseverance is the duration (in seconds) that the interaction resided in the cell. MP = more-preferred IP style. LP = less preferred IP style.

and student IP state communion was high. This indicates that in those interactions dyadic behaviors mainly followed the principle of complementarity.

We also identified attractors that characterized dyadic behaviors that to a lesser extent followed the principle of complementarity or did not follow this principle of complementarity at all. For example, there were dyadic behaviors showing complementarity on only one dimension; this is called a-complementarity (Orford, 1986). An example of a-complementarity is the IP state imposing-critical (cell 88) in which both the teacher IP states and the student IP states were characterized by high levels of agency and low levels of communion (i.e., sameness on the agency and communion dimension). There were also dyadic behaviors that showed oppositeness on both dimensions, such as compliant-critical (cell 48).

Considering that the principle of complementarity is associated with the development of positive relationships, such attractors might be associated with teachers who have less preferred IP styles. As shown in Table 3, most of these noncomplementary attractors or those attractors that are characterized by a negative IP state communion of the teacher and/or the student behavior were associated with less preferred IP styles.

Structure of interactions

The correlations between the IP state variables and the structure indices are presented in Table 2. For teacher IP state agency and communion and for student IP state communion, the correlations with transitions, cell range, dispersion, and visit entropy were negative. This indicates that higher levels of agency and communion in teacher behavior and higher communion in student behavior were related to lower variability (as indicated by transitions, cell range, and dispersion) and greater predictability (as indicated by visit entropy) of dyadic behavior in the interactions. The positive correlations between student IP state agency and the structure indices indicate that interactions in which students were more dominant (high levels of agency in IP state behavior of students) showed higher variability and lower predictability.

Structure differences between teachers with more and less preferred IP styles

In Figure 4, the SSGs are presented for the teachers with less preferred (LP) and more preferred (MP) IP styles separately. The cells that are visited in the LP group's interactions are more scattered across the SSG (all cells are visited); whereas in the SSG of the MP group, the visited cells are more concentrated in only a few areas, especially cell 14 (directing-reliant) and cell 24 (helpful-reliant). Many dyadic behaviors shown in the interactions of the LP group were not shown in the interactions of the MP group.

To study the differences in structure indices between teachers in the MP group and teachers in the LP group, we used the nonparametric two-independent sample Kolmogorov-Smirnoff test (K-S test) because the number of participants in each group was smaller than 25 (Field, 2018, p. 292). In Table 4, the means and standard deviations for the IP style, IP state, and structure indices are presented separately for both groups along with the results for the K-S tests (i.e., the resulting *K-S* (*Z*) statistic and effect size (*D*)).

The MP group had significantly higher IP state communion than the LP group. Furthermore, dispersion, transitions, and cell range were significantly higher in the LP group than in the MP group. Indicating higher variability in teacher-student interactions in the LP group than in the MP group. Surprisingly, we did not find a significant difference in visit entropy, thus interactions in both groups were comparable in predictableness.

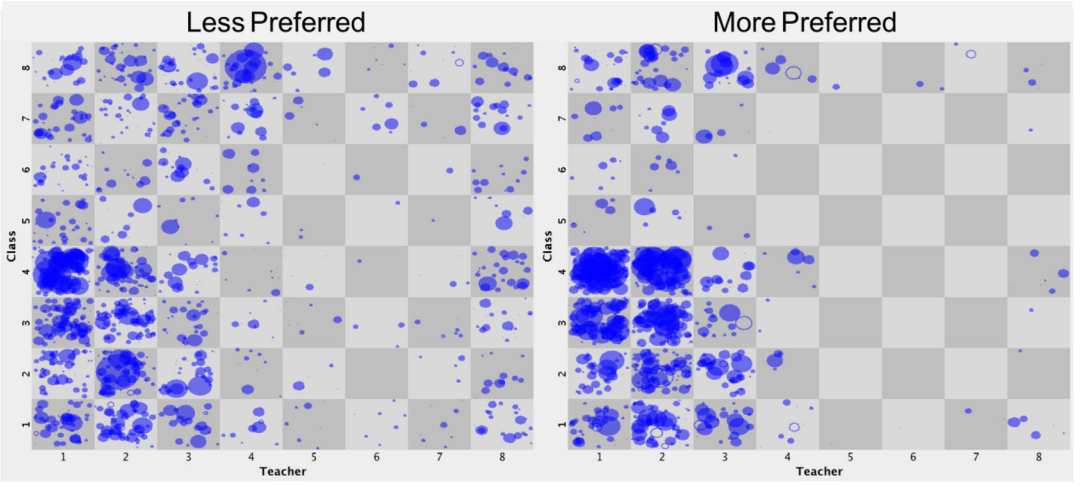

Figure 4. SSGs corresponding to the interactions of all more-preferred (left) and less preferred (right) IP styles. Note that the numbers on the *x*-axis and *y*-axis correspond to the octants of the IPC-T and IPC-S (in brackets): 1 = directing (proactive). 2 = helpful (supportive), 3 = understanding (collaborative), 4 = compliant (reliant), 5 = uncertain (withdrawn), 6 = dissatisfied (dissatisfied), 7 = confrontational (confrontational), 8 = imposing (critical).

Table 4. Descriptives separate for the less preferred and most preferred IP styles.

	Less preferred		More preferred		Kolmogorov-Smirnov test ($df = 35$)	
	M	*SD*	*M*	*SD*	*Z*	*D*
IP style agency	0.03	0.22	0.24	0.12		
IP style communion	0.05	0.19	0.37	0.18		
IP state teacher communion	297.18	204.49	502.38	156.52	1.59*	.54
IP state teacher agency	227.67	257.09	353.89	160.37	.95	.32
IP state student Communion	118.06	262.80	350.57	174.38	1.27	.43
IP state student agency	-33.38	212.87	-206.42	252.68	1.13	.38
Transitions	69.12	29.77	43.50	12.97	1.77**	.60
Cell range	19.82	9.65	12.89	3.72	1.60*	.54
Dispersion	0.86	0.08	0.78	0.09	1.42*	.48
Visit entropy	2.65	0.42	2.24	0.36	1.30	.44

*$p < .05$
**$p < .01$

Discussion

We studied how interpersonal structure and content in observed teacher-student interactions were associated with student perceptions of the teacher IP styles and whether indices of interpersonal structure differed between teachers with MP or with LP IP styles.

The main findings were that (a) in general the observed level of teacher agency and communion shown in the interactions corresponded to generalized student perceptions of their teacher's agency and communion characterizing their IP style; (b) the content of these interactions in terms of attractors of dyadic behaviors largely followed the principle of complementarity; and (c) interactions of teachers with a less preferred IP style showed more variability than those of teachers with more-preferred IP styles but did not differ in predictableness of interactions. In the following section we will discuss the results in light of our hypotheses.

First, we expected that the level of agency and communion in IP state behavior of teachers would be related to the level of agency and communion IP styles. We indeed found moderate statistically significant positive associations between IP style communion and teacher IP state communion and between IP style agency and teacher IP state agency. This means that the student perceptions of teacher agency and communion (IP style agency and communion) were observable from only 10 minutes of one random lesson. These findings are in line with previous larger scale studies in other contexts, such as the studies of Markey et al. (2010) and Sadler et al. (2009), who found similar correlations between IP states and IP styles in 10-minute observations of unacquainted males and females.

Second, we expected that the attractors in teacher-student interactions would indicate a pattern of interpersonal complementarity. We found that for 63% of the identified attractors this was indeed the case. For some of the noncomplementary attractors we saw that the teachers remained agentic and friendly when students showed dissatisfied, confrontational, or critical behavior. This may be expected from teachers, given their professional role and their responsibility for establishing and maintaining a safe classroom environment (e.g., Carson, 1969; Thijs et al., 2011). Most of the attractors that did not represent complementarity in interactions were observed in the interactions of teachers with less preferred IP styles. This indicates that less complementarity in interactions might be related to having a less preferred IP style.

The degree to which attractors correspond to the teacher IP style and whether they represent complementarity in interaction varied, especially across teachers with LP IP styles.

One explanation could be that although teachers are perceived as having an LP IP style, that does not mean those teachers are not in general quite friendly or do not show agentic behavior during the lesson (e.g., Wubbels et al., 2006). This is supported by the results regarding the

structure of interactions. Especially when looking at variability in behavior, we found that teachers with an LP IP style showed more variation in behavior. Thus, it could be that students attributed that to the teacher's inability to take a consistent lead in class. However, more research into this phenomenon is necessary to explain why attractors in interactions of teachers with an LP IP style vary in their correspondence to the location of their IP style in the IPC.

Concerning structure, we expected that the interactions of teachers with MP IP styles would show less variability in terms of different types of dyadic behaviors (range) or changes in dyadic behavior (transitions) and that their interactions would be more predictable (entropy) than those of teachers with LP IP styles.

We indeed found that variability of behavior was higher in the LP group, but we did not find differences in the predictableness of interactions. It may be that teachers with LP IP styles do change a lot between many different behaviors but that those behaviors follow each other in predictable patterns throughout the course of interaction. This could be studied in more detail, perhaps using other types of analyses such as orbital decomposition analysis (Guastello, Hyde, & Odak, 1998), which can be used to describe patterned sequences in interactions using a DS approach.

Another explanation could be that we observed only the first 10 minutes of the lesson, this includes students entering the classroom and the teacher starting the lesson. This part of the lesson is an important part for setting the stage (Van Tartwijk, Brekelmans, Wubbels, Fisher, & Fraser, 1998; Van der Want et al., 2015). It may be that teachers are aware of this and deliberately make sure that their behavior is more predictable during this part of the lesson, regardless of whether they have an LP or MP IP style. It may be that interactions are more predictable during the lesson start and become less predictable throughout the lesson or in certain situations—for example, for teachers with LP IP styles. We cannot study this using only the first 10 minutes of the lesson.

Limitations and suggestions for research

There are several limitations to this study. First, it should also be noted that the present study's design is correlational and that no causal inferences can be made. That a teacher has an LP style does not necessarily mean that the interactional classroom dynamics are always negative.

Second, in future studies, observations of the entire lesson or certain lesson practices may be included. Observations of longer duration are needed to study whether content and structure are different for different parts of the lesson (e.g., lesson start, main section of the lesson, and the lesson ending) or for different lesson practices or lesson activities that are used (e.g., group work versus whole-class teaching).

Another limitation is that we included only one lesson per teacher, which is rather limited in terms of generalizability. In light of IP styles being the cumulative results of many teacher-student interactions (Granic & Patterson, 2006; Pincus et al., 2014) and because IP styles are also related to a person's personality (Carson, 1969; Fournier et al., 2011), we did not expect to find significant differences between lessons. Also, previous research (e.g., Mainhard et al. 2011; Wubbels et al., 2006; Wubbels, 2017) showed that teacher IP styles are rather stable across and between school years and that differences between teachers (e.g., with the same class) are usually greater than within teachers (e.g., with different classes). Therefore, we did not expect to find significant differences between lessons.

Nevertheless, to study differences between classes and to gain more insight into how a teacher interacts with students in general, more lessons per teacher could be observed (e.g., with the same class or with a different class of students). Then, we could examine a number of new research questions: Which kind of teachers are more interpersonally adept at managing a variety of classrooms? Are some classrooms harder to manage overall? What sorts of interactional

processes seem to contribute to more-positive interactions and the ability to create and maintain positive teacher-student relationships?

The results of the present study indicated important associations between the content and structure of teacher-student interactions in the first 10 minutes of a lesson and the quality of the perceived teacher IP style. To further our understanding of the development of certain teacher-student relationships from moment-to-moment interactions, longitudinal observation studies are certainly needed. Those studies could be situated at the beginning of a school year and include, for example, the first few weeks of a teacher working with a new class, and could then be replicated in several consecutive school years. This is the period in which the teacher-student relationship develops and quickly stabilizes into a certain type of relationship (Mainhard, Brekelmans, Den Brok, & Wubbels, 2011). Furthermore, to study differences between teachers in terms of content and structure, future studies may need to add a more experimental focus to this kind of research. For example, deliberately perturbing the lesson could reveal how the teacher attempts to restore or maintain order during the lesson (Granic & Lamey, 2002). This perturbation could be a principal who enters the classroom to ask the teacher or a student something or a student from another classroom asking to borrow a book. Such situations lead to momentary situations of disorder, and how a teacher deals with such disruptions may tell us something about the relationship with students.

There are ample studies on the quality of teacher-student relationships and teacher IP styles that have been carried out all across the world. Those studies showed that high levels of teacher agency and communion are most positive for student outcomes, such as student motivation and academic achievement (e.g., Den Brok et al., 2004; Goh, 1994; Henderson & Fisher, 2008; Maulana et al., 2014; Wubbels et al., 2006). However, the studies published on the dynamic nature of teacher-student interactions or on the association between teacher-student interactions and teacher IP styles are still very limited. Those that have been published use observations of Dutch teachers and students only (e.g., Mainhard et al., 2012; Pennings, Van Tartwijk et al., 2014; Roorda et al., 2013). To generalize those findings, it is important that similar studies be conducted using different cultural contexts. We are aware of several studies that are currently being carried out in other countries, for example, with Portuguese, Finish, Iranian, and Chinese teachers (Sun, Pennings, Mainhard, & Wubbels, 2018). Still, more studies are needed, especially if results are going to be used in practice.

Implications for practice

The results of this study could be used to develop interventions to improve the quality of teacher-student interactions. First, based on the results of the present study we suggest that such interventions should be focused on the degree of variability in teacher behavior, since the results indicated that high variability in dyadic behavior was related to interactions of teachers with LP IP styles. Second, we found that attractors in dyadic behavior of teachers with LP IP styles more often than those of teachers with MP IP styles did not follow the principle of complementarity. Given that following the principle of complementarity is regarded as positive for the development of good quality relationships (Carson, 1969; Kiesler, 1996; Sadler et al., 2011), we suggest that interventions could be focused on increasing the awareness of the principle of complementarity and providing guidelines on how the principle of complementarity could be actively incorporated into a teacher's behavior repertoire.

Concluding remarks

With SSG analysis we visualized moment-to-moment interactions of teachers and their students and studied the content of such interactions. By relating this content to the student perceptions

of their teachers' IP style, we were able to show that teacher IP styles and teacher-student interactions are related. This study showed that the classroom context is a dynamic social system consisting of teachers and students as subsystems that interact with each other to develop their relationship and learning environment over time.

Notes

1. The terms Agency and Communion are meta-labels (e.g., Fournier, Moskowitz, & Zuroff, 2011; Wiggins, 2003) and depending on the context the two dimensions can be given different names, such as control and affiliation or influence and proximity (e.g., Wubbels, et al., 2012; Wiggins, 2003).
2. Wubbels et al. (1985) referred to interpersonal styles by using the term teacher-student relationships.
3. We restricted our observations to the first 10 min of a lesson of each teacher for several reasons: First, because the first ten minutes (lesson start) is important for establishing an effective teaching-learning environment and has in previous research been found especially demanding regarding class-level dynamics (Van Tartwijk, Brekelmans, Wubbels, Fisher, & Fraser, 1998; Van der Want et al., 2015). Second, observations using CAID are quite demanding for a coder. To make sure that the observations remained reliable and were not influenced by fatigue of the coders, we decided to keep the duration of observation at 10 minutes. Which according to studies by to Sadler et al. (2009) and Pennings et al. (2018) is of sufficient duration to identify adaptive patterns in moment-to-moment interactions, and is our last reason for observing only 10 minutes.
4. The joystick-monitoring software program is available via www.wlu.ca/science/psadler.
5. On the website of Teaching and Teacher Education corresponding to Pennings, Van Tartwijk et al. (2014) a detailed description of the coding procedure and a video of an observation with the computer joystick can be found.

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