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ORIGINAL RESEARCH

# Exploring turn-taking patterns during dialogic collaborative problem solving

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## Abstract

This study investigated students' turn-taking patterns during dialogic collaborative problem solving, with analysis based on the participation-shift analytical framework. 168 primary fourth-grade students were assigned to 42 groups and worked on three mathematical problems for a total of 30 minutes. Group-level analysis revealed that most students accessed the conversational floor by receiving it from the last speaker. Usurping a floor offered to another person and claiming a floor opened to the whole group were positively associated with the intensity and the balance of group discussion. Individual-level analysis further identified four latent profiles of individuals with distinct turn-taking styles: turn-receivers (i.e., receiving the floor assigned by the last speaker) (15%), turn-usurpers (20%) (usurping the floor when it was offered to another person), turn-claimers (10%) (claiming the floor when it was opened to the whole group) and turn-balancers (55%) (no strong turn-taking tendency). Individual participation rates and prior Chinese grades proved to be the two most significant unique predictors of individual membership in the turn-usurper profile. The findings suggest ensuring students' equitable access to the conversational floor and provide teachers with several specific turn-taking related approaches to promote equity and respect in peer talk.

**Keywords** Turn-taking · Collaborative problem solving · Pattern · Participation shift

## Introduction

Collaborative problem solving can enhance students' social skills, cognitive development and acquisition of disciplinary knowledge (Blatchford et al., 2003; Johnson & Johnson, 2016; Slavin et al., 2014). However, in many cases these potential benefits cannot be realised without well-structured dialogue during the problem-solving process (Gillies, 2019; King, 2008).

Numerous studies have used coding and counting approaches to explore the cumulative features of productive peer talk (e.g., Fu et al., 2016; Saab et al., 2007; Stegmann et al., 2012). For example, questioning frames and sentence openers such as 'Why do

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you think …?', 'An alternative theory is …', and 'Do you agree or disagree …?' have been found to promote productive peer talk (e.g., Avcı, 2020; King, 2008; Noroozi et al., 2013). However, such coding and counting approaches cannot address how these discursive moves unfold over time, or how they gradually shape the quality of group solutions (Csanadi et al., 2018). The temporal heterogeneity of the collaboration process has been well-established (Kapur et al., 2008; Leenders et al., 2016). In recent years, increasing numbers of studies have focused on temporal analysis of talk (e.g., Chen et al., 2017; Csanadi et al., 2018). In all of these prior studies, the turn-taking structure of the collaboration process forms the basic chronological sequence of both the micro-time context that considers the impact of recent turns (e.g., Chen et al., 2012, 2020; Molenaar & Chiu, 2014) and the meso-time context that considers the impact of recent dialogue segments (e.g., Dyke et al., 2012; Siebert-Evenstone et al., 2017; Wise & Chiu, 2011).

However, to the best of our knowledge, existing studies have not fully addressed the question of how students in collaborative problem solving groups access the conversational floor and whether individuals have various styles of turn-taking. This study specifically aims to explore the turn-taking pattern in dialogic collaborative problem solving contexts. In the following, we briefly introduce the theoretical background, review the previous relevant studies, elaborate the analytical framework, and then clarify the specific research questions.

## Theoretical background

Bakhtin (1999, p. 6, italics in original) views that there is no fixed and final knowledge or truth, but that truth emerges from unlimited dialogue involving "*a plurality of [opaque, non-transparent] consciousnesses*, with equal rights and each with its own world, [that] combine but are not merged in the unity of the event". Therefore, to Bakhtin, genuine learning happens in genuine dialogue and truth is an emergence but not the end of a dialogic trip (Mercer et al., 2019). Bakhtin emphasizes the *equal rights* of consciousnesses in dialogic interaction which distinguishes dialogic to monologic. Such emphasis on equity also reflects the underlying ethical considerations of dialogism (Matusov et al., 2009) and its intrinsic requirement on equity in dialogue.

Following the epistemological assumptions of Bakhtin's dialogism (1999), the present study defines dialogic collaborative problem solving as a complex dynamic process whereby two or more consciousnesses, with equal rights and each with its own world, combine but are not merged in the unity of solving a shared problem. Students' verbal engagement is an essential end in dialogic collaborative problem solving. Joint solutions emerge from and exist in the dialogue whereby group members open themselves to each other's voices and augment their own.

Turn-taking describes how participation on the conversational floor flows among speakers over time. Students verbally engage in dialogic collaborative problem solving by taking the conversational floor which is an evolving and socially negotiated space where individuals are allowed to make contributions (Clark & Schaefer, 1989; Engle et al., 2014). Thus, examining turn-taking structure is essential for understanding the interanimation of various voices in a group.

## Turn-taking as the sequential structure of human talk

A turn, during which only one speaker holds the conversational floor, is a distinctive feature of peer talk (Levinson, 1983). It can be represented by the turn-holder's identity. Accordingly, a turn-taking sequence can be represented as a temporal series of speaker identities. Previous studies have also described turn-taking structures as participatory or interaction structures (De Laat et al., 2007; Kapur et al., 2008). These types of structures not only determine the chronologically sequential structures of human talk, but also affect the degree of opportunity that different individuals have for influencing group discussions through verbal and accompanied non-verbal contributions (Lemke, 1990).

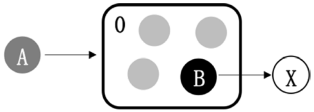
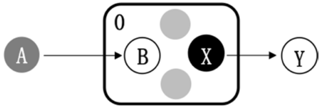
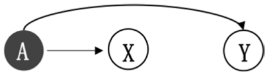
In the broad field of studies on turn-taking, one of the major lines of research across disciplines has focused on the organisational mechanism of turn-taking, which determines who should talk next and when (e.g., Sacks et al., 1974; Schegloff, 2007). In group work, the quality of turn-taking organisation, as shown by clues such as whether group members can smoothly finish each other's sentences, has been identified as an important feature that indicates the level of synergy of the collaborative problem solving process (Liu et al., 2015).

To date, a great deal of fruitful research on turn-taking patterns has been conducted on teacher–student talk (e.g., Mayer, 2012; Molinari et al., 2013). However, very few studies have specifically addressed peer talk (e.g., Kapur, 2008; Martínez et al., 2003). Existing studies mostly focus on inferring the social structure of peer talk by examining turn-taking patterns. One essential construct that is related to turn-taking in peer talk is participation equity, or participation inequity (Boaler, 2008; Shah & Lewis, 2019). Participation equity refers to "a condition where opportunities to participate–and participation itself–are fairly distributed among all students involved in a learning interaction" (Shah & Lewis, 2019, p. 428). Most existing studies that tried to quantify participation equity mainly focused on participation itself (e.g., Cela et al., 2015; Kapur et al., 2008). For example, Kapur et al. (2008) adopted the standard deviation of individual participation rates as an index of participation inequity. They found that this index tended to reach a plateau at a very early stage of group discussion and was a significant negative predictor of group solution quality. Some scholars suggested that participation inequity may lead to information loss, to dominance by a majority of the team members or to limitations on a team's potential to perform various tasks (Borge & Carroll, 2014; Woolley et al., 2010).

## The analytical framework of participation shifts

This study aims to shed light on the mechanisms underlying the emergent features of participation equity, and to do this by investigating how students gain access to the conversation floor. The analytical tool applied for this task is the participation-shift framework. This framework is focused on how turns shuffle among speakers (Leenders et al., 2016), and it describes 'the way in which people move themselves and one another onto and off the floor' (Gibson, 2005, p. 1566). The participation-shift framework differentiates between the various speakers, targets and third parties in human interactions, and it further identifies four categories of participation shifts (see Table 1). These participation shifts cover all possible micro turn-taking motifs, and they can thus describe how turns shift from one speaker to the next.

**Table 1** Participation shifts as defined by Gibson (2003, 2005)

| Participation shift | Formula[a] | Illustration | Description |
|---|---|---|---|
| Turn-receiving | AB-BX |  | A talks to B, then B talks to X (X could be A or the group) |
| Turn-claiming | A0-BX |  | A talks to the group, then B talks to X (X could be A or the group) |
| Turn-usurping | AB-XY |  | A talks to B, then X (X is not B or A) talks to Y (Y could be A, B or the group) |
| Turn-continuing | AB-AX |  | A talks to X (X could be the group), then A continues to talk to Y (Y could be the group) |

[a]The formula denotes the following: (speaker) (target)—(third party) (target of third party). The group is denoted as 0. X and Y represent people other than the neighbouring speaker and target

Turn-receiving happens when a target takes the floor offered by a speaker. Such receiving of a speaking opportunity reflects the reciprocity of human interaction (Blau, 1964; Gergen et al., 1980), because the target provides instant feedback in response to the speaker's invitation. The participation-shift framework can also be used to investigate individual turn-taking styles (Gibson, 2005). For example, in a turn-receiving shift, a third party (who is also a target) serves as an agent enabling the shift. Therefore, this third party can be viewed as a turn-receiver.

Turn-claiming happens when a speaker addresses the whole group, and a third party responds to this open invitation. The speaker opens the floor to every group member. Then, a third party who actively claims the floor can be characterised as a turn-claimer. Compared with a turn-receiver, a turn-claimer is more active in taking turns at speaking.

Turn-usurping happens when a third party usurps the floor of the target who was assigned by the speaker. Such interruptive turn-taking intensifies the disorder among interactions. Usurping may thus either enhance the animation or create tension in a group discussion. A third party who usurps the floor is defined as a turn-usurper. Such a usurper overlooks the speaker's allocation of the floor to the next target and interrupts the normal turn-taking organisation. Thus, a turn-usurper possesses stronger agency in turn-taking than a turn-claimer or a turn-receiver.

Turn-continuing occurs when a speaker continues to occupy the floor while talking to various other individuals. A turn-continuer shows a certain control of the floor. He/she may play a special role in the group interaction, such as that of a facilitator or a leader. For example, a turn-continuer may provide feedback for one peer, and then invite another peer to express his/her view.

Regarding the degrees of freedom of participation, both turn-receiving and turn-continuing tend to reduce the diversity of participation by limiting identity shuffling. Both turn-claiming and turn-usurping, however, strengthen the diversity of the participation structure, and thus they tend to increase the complexity of turn-taking patterns.

To the best of our knowledge, little research has investigated whether individuals who prefer different types of turn-taking may have different individual characteristics. One exception was a relevant study by Tsvetkova et al. (2016), who investigated how individual status, as indicated by a person's volume of activity on Wikipedia, was related to the different types of reverts of article edits to Wikipedia. The authors identified six two-event temporal motifs to describe various behavioural patterns among the reverters and the reverted users. They found that the reciprocal motif (A reverts B, and B reverts A back, AB–BA) usually happened between participants of equal status. Senior Wikipedia editors tended to perform continuous reverts (A reverts B, and A reverts C, AB–AC), and were likely to be reverted by either low-status editors or by others of equal status (A reverts B, and C reverts A, AB–CA).

## The present exploratory study

This study aims to explore students' turn-taking patterns during dialogic collaborative problem solving, and to do so using the participation-shift framework, which offers a means to gain understanding of how these patterns might relate to group performance and individual characteristics. Specifically, this study sought to answer the following two research questions. It is exploratory in nature due to the lack of empirical and/or theoretical contributions from which hypotheses could have been derived.

*RQ 1.* What is the distribution of participation shifts in dialogic collaborative problem solving, and how does this distribution relate to group performance in dialogic collaborative problem solving?

Bakhtin's dialogism views dialogue as an important end of education itself but not simply a medium for learning (Mercer et al., 2019) and emphasizes the equity in dialogue (Matusov et al., 2009). Therefore, group performance in this study not only concerns the quality of group solution but also the equity of dialogue.

*RQ 2.* Do underlying profiles emerge from individual turn-taking styles in dialogic collaborative problem solving, and if so, how can individual profile membership be predicted?

To predict possible individual profile membership, this study mainly considered student status features and their self-perceived competence. Previous studies suggested that status is linked to the structure of group participation. Cohen and Lotan (2014) suggested several indicators of status: academic status (i.e., the order in academic performance), peer status (the attractiveness or popularity in peers formed when students interact with each other within and out of school), and social status (the status distinction concerning social class, gender race, and ethic group). This study therefore collected data concerning students' previous academic performance (recent mathematics and Chinese grades), their friendship with each group member, gender, and parents' education background.

Also, students' interest, comprehension, and confidence are likely to be linked to their participation (Blue et al., 1998). Students tend to participate less if they are not able to formulate their ideas, lack knowledge with the subject, or fear to look unintelligible in front of peers or instructors (Jin, 2012). In this regard, this study also collected data concerning students' self-concept and enjoyment in mathematics.

## Method

### Participants

This study was conducted at a high-ranking primary school in a third-tier city in mainland China. The participants were 168 fourth graders from five classes (41% females, 59% males; see Online Resource 1 for detailed characteristics of the participants). Participants were organized into groups of four in their own classroom without computers during regular schooltime. Gender and prior mathematics grades were balanced across groups with the help of teachers. Specifically, we categorised students into three levels based on their previous academic performance (high, middle, and low) and then assigned one high-level student, one low-level student, and two middle-level students into a group with gender considered at the same time. The mathematics teachers then helped slightly adjust the preliminary grouping based on their knowledge of student personality, relationship, and leadership.

### Procedures

Before the test, all participants were informed of the overall project background (i.e., to study their collaborative dialogue) and the major task of this study (i.e., to finish three challenging mathematical problems) in class. Participants were also required to write down the names of their group members and report their willingness to collaborate with their assigned group members on a scale from 1 to 10, with 10 representing the highest degree of willingness. This study adopted such score of willingness to reflect students' friendship with each other in a group.

Groups were then instructed to collaboratively solve three structured open-process mathematical problems within half an hour and were told not to discuss with other groups or touch the recorder in the middle of their table. To facilitate the identification of speakers, students were required to introduce themselves following a structured format before working on the problem. During the test, teachers or the researcher did not moderate group discussions except for clarifying task instructions or maintaining classroom discipline. All groups' discussions were audiotaped.

After the test, the students independently completed a questionnaire concerning their demographic backgrounds, mathematics learning enjoyment, mathematics self-concepts and their levels of social anxiety. Mathematics self-concept and mathematics learning enjoyment were measured using items adapted from the TIMSS 2015 questionnaire for fourth graders in Taiwan (Mullis & Martin, 2013), with students being asked to indicate their agreement with each statement on a four-point Likert scale (1 = *strongly agree*, 2 = *somewhat agree*, 3 = *somewhat disagree*, and 4 = *strongly disagree*). Social anxiety was measured using the 10-item Chinese version of the Social Anxiety Scale for Children–Revised (La Greca & Stone, 1993). The students were asked to indicate the frequency of specific behaviors on a three-point Likert scale (1 = *always do this*, 2 = *sometimes do this*, 3 = *never do this*). The measures had a relatively high internal reliability, as indicated by Cronbach's alpha values for social anxiety ($\alpha = 0.835$), mathematics enjoyment ($\alpha = 0.734$) and mathematics self-concept ($\alpha = 0.882$) (Tavakol & Dennick, 2011). The students were also asked to evaluate their own and their group's performance. The whole process of data collection took around 50 min for each class.

## Materials

The levels of difficulty increased across the three problems (featuring *ice cream*, a *snake* and a *bridge*) (see Online Resource 2 for the translated English versions). The *ice cream* (item ID: M041132) and *snake* (item ID: M051006) problems were adapted from the trends in international mathematics and science study (TIMSS) that was conducted in 2015 (TIMSS & PIRLS International Study Center, 2015). The *ice cream* required students to calculate the unit prices of an ice cream and a popsicle based on costs of two children who bought different numbers of ice creams and popsicles. The *snake* problem required students to estimate the number of stones that a curled snake would occupy when it straightened its body. The *bridge* problem was the most difficult and was adapted from the junior mathematical olympiad (Database of Mathematical Olympiad, n.d.). It required students to design a bridge-crossing plan for four people with different walking speeds that would take the least time. To promote collaborative peer talk, all problems had no explicit routine for students to follow, although each problem had a unique correct answer. In addition, solutions to these problems mainly required students' reasoning ability (rather than their specific content knowledge) which helped ensure that the students with high levels of prior knowledge were not at an advantage.

## Data analysis

Written solutions submitted by the groups were graded by the first author according to a standard scoring criterion that considered the correctness of the final solution first and then awarded partial credits for solution steps informed by group discussion audios if the final answer was wrong (see Online Resource 3 for details on the scoring criteria of three tasks).

Group discussions were transcribed by turns. Overlapped talk was transcribed for separate speakers and in an order of their speaking time. If a speaker paused and then continued to speak, her utterances were viewed as happening in one turn. Therefore, turn-continuing was not considered in the present study. All transcripts of group discussions were coded by two trained coders, in accordance with the participation-shift framework. The decision tree for identifying the target interlocutor was as follows:

Does the speaker explicitly name the target interlocutor?

Yes, code it as the named interlocutor.

No. Does the speaker use *you* in the utterance?

Yes. Is there any clue indicating *you* not representing the last speaker?

Yes, code it as the inferred target.

No, code it as the last speaker.

No. Does the speaker use *we* in the utterance?

Yes. Is there any clue indicating *we* not representing the whole group?

Yes, code it as the inferred target.

No, code it as Group.

No. Does the utterances belong to a flow of discussion (at least 4 turns) with one specific interlocutor?

Yes, code it as the specific interlocutor.

No, code it as Group.

In addition, for utterances that contained multiple targets, the target was coded as the major addressee or "Group" when there was no obvious major target. For utterances which were difficult to infer the target according to the decision tree, the target was coded as "Group". The type of participation shifts was automatically generated through Excel after

**Table 2** Sample data coding

| Turn | Speaker | Target | Content | Participation shift type |
|---|---|---|---|---|
| 42 | Gan | Group | 8 divided by 2 equals 4 | |
| 43 | Gu | Gan | Why? Their prices may not be the same | Claim |
| 44 | Gan | Gu | 8 divided by 2 equals 4. Listen to me *(5-s pause)*, 8 yuan … | Receive |
| 45 | Xun | Gan | Gan, I wanna ask a question … *(muffled sound)* | Usurp |
| 46 | Gan | Xun | It means 8 equals one popsicle and one ice cream | Receive |
| 47 | Gu | Group | So, how can we calculate the prices of one popsicle and one ice cream? | Usurp |
| 48 | Gan | Gu | One popsicle … | Claim |
| 49 | Si | Group | I think we can calculate like this | Usurp |
| 50 | Gan | Si | Say it | Claim |
| 51 | Si | Gan | 2, 8, 16. That is two popsicles and two ice creams. Then 22 minus 16 equals two popsicles. Then divide by 2. It is one popsicle | Receive |

target interlocutors were determined (see Table 2). Both coders finished three of the groups separately and achieved an acceptable level of inter-rater agreement [*Kappa* = 0.692; Landis and Koch (1977): 0–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial, and 0.81–1 as almost perfect]. All disagreements over coding were resolved through discussion. One coder then finished the coding of the left groups.

Three sets of variables were involved in the analysis (see Table 3). First, the outcome variables included both the group-level performances (indicated by solution quality, self-reported group assessment, interaction intensity and participation inequity) and the individual level performances (indicated by self-assessed performance and possible individual turn-taking profile membership). Second, the explanatory variables comprised the three kinds of participation shifts (turn-usurping, turn-receiving, and turn-claiming), which were identified on the basis of the participation shift analysis framework, and individual participation rates. Third, the control variables concerned relevant individual characteristics that could affect the students' turn-taking styles, including their friendship ties, social anxiety, mathematics learning enjoyment, mathematics self-concept, prior grades in mathematics and in Chinese, and parents' education levels. Individual friendship refers to an individual's average willingness (a score from 1 to 10) to collaborate with his/her three assigned group members. Accordingly, group friendship refers to the average willingness to collaborate with each other for all group members. All the other individual characteristics were averaged for the group-level analysis.

Latent profile analysis (LPA) is a person-based approach that is suitable for identifying subtypes within populations where various traits may co-occur (Gibson, 1959; Lubke & Muthén, 2005; Sterba, 2013). This study thus adopted LPA to detect latent individual turn-taking profiles and group performance profiles with use of the R programming language (Rosenberg et al., 2019). The best-fitting profile model was selected by iteratively estimating various models with different numbers of profiles. These profiles were based on multiple criteria, including the Bayesian information criterion (BIC), the Akaike information criterion (AIC), entropy and the bootstrapped likelihood ratio test (BLRT) (Nylund et al., 2007). Lower values of the BIC and AIC, an entropy value closer to 1, and a significant *p*-value in the BLRT indicated a higher-quality model classification.

## Results

### Research question 1

The results for the first research question indicated that turn-receiving was the major form of participation shift across the various groups. The distribution of participation shifts had an impact on group interaction intensity and participation inequity, but not on subjective group assessment or final solution quality.

#### Participation shifts and group-level outcomes

The students were divided into 42 groups. Each group produced an average of 286 turns ($SD = 116$) within the half hour testing period. Turn-receiving ($M = 43\%$, $SD = 10\%$) was the most common type of participation shift within the groups, followed by turn-usurping ($M = 29\%$, $SD = 8\%$) and turn-claiming ($M = 28\%$, $SD = 8\%$). The groups achieved an average solution score of 6.41 ($SD = 1.76$). Around 90% of the groups successfully worked out

**Table 3** Summary of the variables and corresponding descriptions

| Category | Variable name | Description (measures) |
|---|---|---|
| Group-level outcome variables | Solution score | A total score measuring the quality of the solution, based on standard scoring criteria. The maximum score is 10 |
| | Group assessment | At the end of the task, each student was asked to score the group's performance from 1 to 10 |
| | Interaction intensity | The total number of turns produced by one group during collaborative problem solving |
| | Group performance profile | Groups were assigned to one performance profile through latent profile analysis, based on their solution scores and levels of interaction intensity |
| | Participation inequity | The standard deviation of individual participation rates |
| Individual level outcome variables | Individual assessment | At the end of the task, each student was asked to score their own performance from 1 to 10 |
| | Individual turn-taking profile | Each student was assigned to one turn-taking profile through latent profile analysis, based on his/her turn-taking style |
| Explanatory variables | Turn-receiving | Percentage of the number of turn-receiving shifts divided by the total number of turns |
| | Turn-usurping | Percentage of the number of turn-usurping shifts divided by the total number of turns |
| | Turn-claiming | Percentage of the number of turn-claiming shifts divided by the total number of turns |
| | Individual participation rate | The aggregated degree of individual vocal engagement through dividing number of individual turns by the total number of turns |

**Table 3** (continued)

| Category | Variable name | Description (measures) |
| --- | --- | --- |
| Control variable | Friendship | Students' willingness (a score from 1 to 10) to collaborate with their assigned group members |
| | Social anxiety | Chinese version of the Social Anxiety Scale for Children–Revised (La Greca & Stone, 1993) (three-point Likert scale) |
| | Mathematics learning enjoyment | Adapted from TIMSS 2015 questionnaire for fourth graders in Taiwan (Mullis & Martin, 2013) (four-point Likert scale) |
| | Mathematics self-concept | Adapted from TIMSS 2015 questionnaire for fourth graders in Taiwan (Mullis & Martin, 2013) (four-point Likert scale) |
| | Prior Chinese grade | Students reported their recent Chinese grades in the mid-term examination. The maximum score was 120 |
| | Prior Mathematics grade | Students reported their recent mathematics grades in the mid-term examinations. The maximum score was 120 |
| | Mother's education level | Students indicated their mother's educational level (1: primary school or below; 2: middle school; 3: high school or technical high school; 4: junior college; 5: undergraduate; 6: graduate or above; 7: I don't know) |
| | Father's education level | Students reported their father's educational level, choosing from the same seven options |

the *ice-cream* problem. Around half of the groups solved the *snake* problem, and only 10% of the groups successfully solved the *bridge* problem (see Online Resource 4 for detailed descriptive statistics of the group-level features).

Regarding group-level outcomes, correlation analysis indicated that turn-taking patterns affected interaction intensity but not solution score or subjective group assessment. Turn-usurping was positively related to interaction intensity ($r(42)=0.46$, $p<0.01$) and negatively related to participation inequity ($r(42)=-0.53$, $p<0.001$) (see Fig. 1). In contrast, turn-receiving was negatively related to interaction intensity ($r(42)=-0.52$, $p<0.001$) and significantly positively related to participation inequity ($r(42)=0.62$, $p<0.001$). Participation inequity was negatively related to interaction intensity ($r(42)=-0.40$, $p<0.01$). Solution score was not significantly correlated with the percentage of turn-claiming ($r(42)=-0.15$, $p=0.33$), turn-receiving ($r(42)=-0.01$, $p=0.95$), or turn-usurping ($r(42)=0.16$, $p=0.33$). However, the correlation coefficient between turn-usurping and solution score was positive and the largest for the three participation shifts. Meanwhile, interaction intensity was positively related to solution score but did not reach significance ($r(42)=0.18$, $p=0.25$). Participation inequity was negatively related to solution score but did not reach significance neither ($r(42)=-0.11$, $p=0.48$).

Hierarchical regression analysis was conducted to determine the impact of participation shifts on group-level outcome variables. Turn-receiving was automatically removed, due to its collinearity with turn-usurping and turn-claiming. No significant regression models were found concerning solution score (see Table 4). A significant regression equation on subjective group assessment was found ($F(8, 29)=6.32$, $p<0.001$), with an $R^2$ of 0.64. Average friendship among the group members significantly predicted subjective group assessment, standardised as $\beta=0.82$, $t(37)=5.46$, $p<0.001$. The incidence of turn-usurping shifts was found to be a significant predictor of interaction intensity, after accounting for all of the control variables (standardised $\beta=0.54$, $p<0.01$). Groups with more turn-usurping shifts produced more conversational turns. Furthermore, turn-claiming and turn-usurping significantly predicted participation inequity, after controlling for the control variables (turn-claiming standardised $\beta=-0.38$, $p<0.01$; turn-usurping standardised

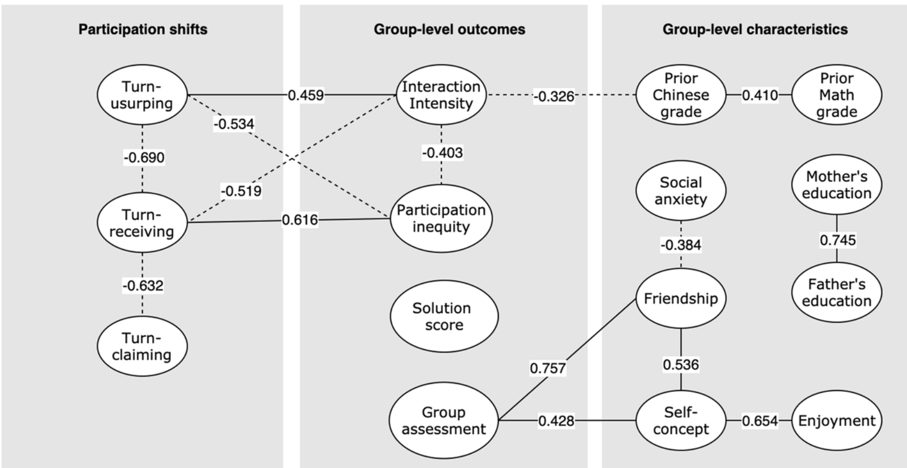



**Fig. 1** Significant correlations ($p<0.05$) among group-level variables (solid lines denote positive correlations; dashed lines denote negative correlations)

**Table 4** Hierarchical regression analysis of the predictors of the group-level outcome variables

| Predictor variables | Solution score | | Group assessment | | Interaction intensity | | Participation inequity | |
|---|---|---|---|---|---|---|---|---|
| | Model[1] | Model[2] | Model[1] | Model[2] | Model[1] | Model[2] | Model[1] | Model[2] |
| Control variables | | | | | | | | |
| Chinese grade | −0.03 | −0.02 | 0.03 | 0.04 | −0.38 | −0.18 | 0.34 | 0.12 |
| Mathematics grade | 0.13 | 0.13 | −0.03 | 0.03 | 0.07 | 0.02 | −0.18 | −0.12 |
| Mother's educational level | −0.18 | −0.14 | −0.20 | 0.31 | 0.26 | 0.04 | −0.40 | −0.14 |
| Father's educational level | 0.001 | −0.01 | 0.10 | 0.26 | −0.04 | 0.11 | 0.40 | 0.23 |
| Friendship | −0.14 | −0.08 | 0.82*** | 0.15 | −0.13 | −0.21 | −0.28 | −0.16 |
| Mathematics enjoyment | 0.33 | 0.37 | −0.30 | 0.77 | 0.14 | −0.11 | −0.37 | −0.07 |
| Mathematics self-concept | 0.19 | 0.11 | 0.19 | 0.85 | −0.01 | 0.18 | 0.19 | −0.05 |
| Social anxiety | −0.12 | −0.12 | 0.16 | 1.16 | −0.10 | −0.01 | 0.03 | −0.06 |
| Participation shift | | | | | | | | |
| Turn-claiming | | −0.23 | | 3.21 | | 0.26 | | −0.38** |
| Turn-usurping | | 0.01 | | 2.81 | | 0.54** | | −0.60*** |
| $R^2$ | 0.27 | 0.31 | 0.64 | 0.66 | 0.18 | 0.45 | 0.32 | 0.69 |
| $\Delta R^2$ | 0.27 | 0.06 | 0.64 | 0.02 | 0.18 | 0.27 | 0.32 | 0.38 |
| $\Delta F$ | 1.32 | 0.89 | 6.32*** | 0.76 | 0.79 | 6.71** | 1.66 | 16.46*** |

*$p<0.05$; **$p<0.01$; ***$p<0.001$

$\beta=-0.60$, $p<0.001$). Groups with more turn-claiming and turn-usurping shifts had a lower participation inequity.

## Latent profiles of group performance

This study further adopted LPA to identify latent profiles among the 42 groups, based on their interaction intensities and solution scores. The four-profile model was found to be the best. This model showed the lowest AIC (244.21), the lowest BIC (266.80) and the highest score for entropy of profiles (0.83). Two emerging levels regarding the numbers of turns were found among the four profiles (i.e., more and less), and four levels of solution scores were identified (i.e., bad, average, above-average and good). The four profiles were accordingly named *more-above-average*, *less–bad*, *less–average* and *less–good* (see Online Resource 5 and Fig. 2). The three *less* profiles had fewer turns than the *more-above-average* profile and differed in solution quality. The *more-above-average* profile fit 40% of the groups ($n=17$), and the students in this profile achieved an average solution score that fell between that of the *less–average* and *less–good* profiles. The *less–good* profile fit 24% of the groups ($n=10$). This profile was characterised by fewer turns but better outcomes than the *more-above-average* profile. Around 31% ($n=13$) of the groups were considered to fit the *less–average* profile, because they had middle-level solution scores among the three *less* groups. Only 5% of the groups ($n=2$) were considered to fit the *less–bad* profile, as they showed the poorest performances.

The study further compared the participation shifts and the students' basic characteristics between groups fitting the *more-above-average* profile and those fitting the *less–good* profile. For the participation shifts, the percentage of turn-usurping shifts in the *less–good* profile groups ($M=27\%$, $SD=10\%$) was significantly lower than

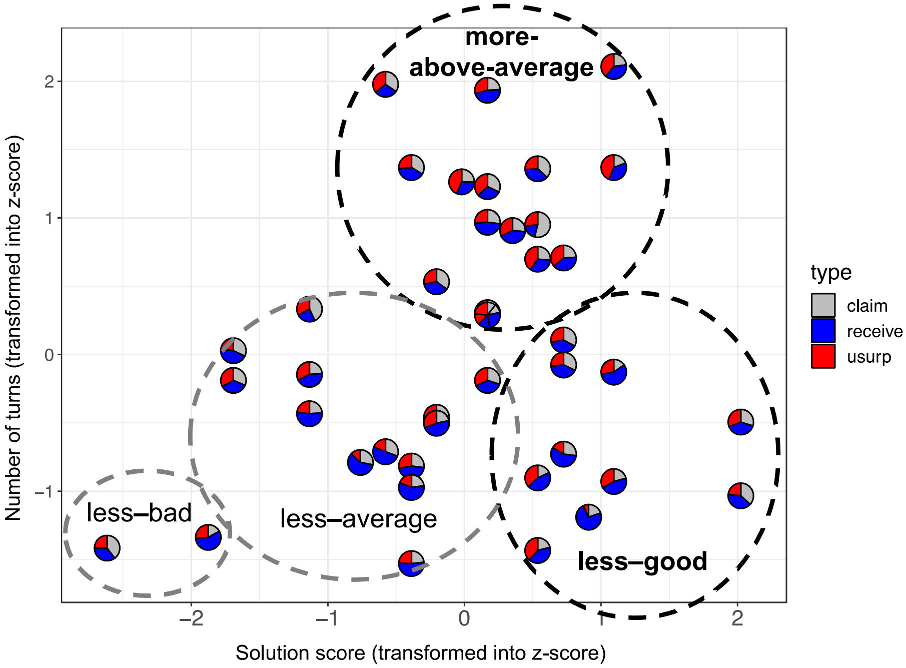



**Fig. 2** Four latent group profiles based on the number of turns and the group outcome. The small pie charts illustrate the distributions of the three types of participation shift

that in the *more-above-average* profile groups ($M = 34\%$, $SD = 7\%$), $F(1, 25) = 4.87$, $p < 0.05$). However, the percentage of turn-receiving shifts in the *less–good* profile groups ($M = 48\%$, $SD = 11\%$) was significantly higher than that in the *more-above-average* profile groups ($M = 37\%$, $SD = 7.8\%$), $F(1, 25) = 8.79$, $p < 0.01$). The participation inequity in the *less–good* profile groups ($M = 0.12$, $SD = 0.05$) was significantly higher than that in the *more-above-average* profile groups ($M = 0.08$, $SD = 0.04$), $F(1, 25) = 4.82$, $p < 0.05$).

Concerning the group characteristics, no significant differences were found between the *more-above-average* profile and the *less–good* profile in terms of characteristics such as prior mathematics grades, prior Chinese grades, parents' education levels, subjective assessments, friendships, mathematics learning enjoyment, mathematics self-concept and social anxiety.

## Research question 2

The results concerning the second research question revealed four latent turn-taking profiles in dialogic collaborative problem solving, namely, the turn-usurper, turn-receiver, turn-balancer and turn-claimer profiles. The individual participation rates and prior Chinese grades were identified as the significant predictors of individual membership in the turn-usurper profile, rather than the other types of profiles.

### Latent individual profiles concerning turn-taking styles

The second research question concerned subgroups of individuals with similar turn-taking styles. LPA showed that the four-profile model behaved best, as it had the lowest AIC (1241.02), the lowest BIC (1297.25), the highest level of entropy among profiles (0.86) and a significant BLRT score ($p < 0.05$). Speakers who strongly preferred to usurp rather than receive or claim turns made up 20% ($n = 33$) of the sample, i.e., Profile 1 (see Fig. 3). Individuals in this profile were therefore labelled 'turn-usurpers'. Individuals in Profile 2, who comprised around 15% ($n = 25$) of the sample, mainly received turns from previous speakers. Accordingly, they were named 'turn-receivers'. Around half of the individuals belonged to Profile 3 (55%, $n = 93$). These students did not reveal a strong turn-taking style. Individuals in this profile took turns in a relatively balanced way and were thus labelled 'turn-balancers'. A few individuals (10%, $n = 17$) belonged to Profile 4. These students preferred to claim turns when a speaker opened the floor to the whole group and were thus named 'turn-claimers'.

The individuals in these four profiles differed significantly in their percentages of turns taken in group discussion ($F(3, 164) = 37.38$, $p < 0.001$). Analysis of variance with a post-hoc Tukey's test revealed that the turn-receivers contributed a significantly higher percentage of turns in group talk ($M = 35\%$, $SD = 10\%$) than the turn-balancers ($M = 26\%$, $SD = 6.66\%$), the turn-claimers ($M = 20\%$, $SD = 7\%$) or the turn-usurpers ($M = 16\%$, $SD = 6\%$). Self-assessment scores also differed significantly across the four profiles (Welch's $F$ $(3, 37.98) = 4.52$, $p < 0.01$), with significantly lower scores for the turn-usurpers ($M = 5.52$, $SD = 2.35$) than for the turn-balancers ($M = 6.40$, $SD = 3.29$).

Regarding individual characteristics, the prior mathematics grades differed significantly across the four profiles ($F(3, 140) = 5.20$, $p < 0.01$), with the turn-usurpers ($M = 93.02$, $SD = 12.00$) having significantly lower scores than either the turn-receivers ($M = 107.50$, $SD = 8.08$) or the turn-claimers ($M = 105.16$, $SD = 12.02$).

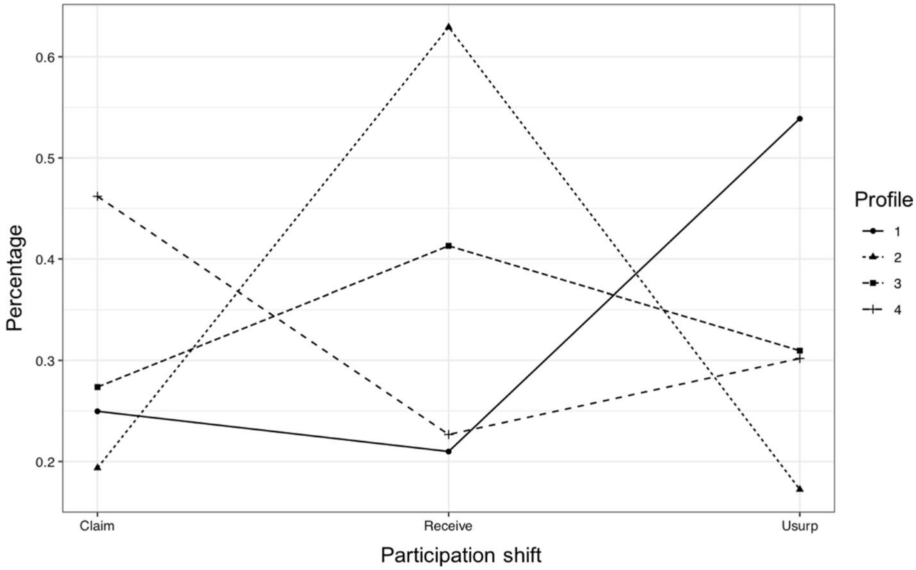



**Fig. 3** Four latent profiles of individuals' turn-taking styles

The prior scores in Chinese also significantly differed across the four profiles (Welch's $F$ (3, 41.83) = 7.34, $p < 0.001$), with the turn-usurpers ($M = 95.24$, $SD = 14.04$) having significantly lower scores than the turn-receivers ($M = 108.39$, $SD = 5.90$) or the turn-balancers ($M = 102.75$, $SD = 8.86$). Mathematics self-concepts also differed significantly across the four profiles ($F$(3, 142) = 5.04, $p < 0.01$). The turn-usurpers ($M = 2.73$, $SD = 0.70$) had significantly lower scores for mathematics self-concept than the turn-receivers ($M = 3.26$, $SD = 0.61$), the turn-claimers ($M = 3.10$, $SD = 0.62$) or the turn-balancers ($M = 3.26$, $SD = 0.55$).

No significant differences were found between the four profiles in terms of gender, mathematics learning enjoyment, social anxiety, parents' education levels, subjective group assessment or individual friendship with peers (all $p$s > 0.05).

## Profile membership prediction

A multinomial logistic regression was performed to model the relationships between individual characteristics and membership in the four turn-taking profiles (turn-usurper, turn-receiver, turn-balancer and turn-claimer). Mother's and father's education levels were not analysed at the individual level, because many individuals either failed to report or did not know their parents' education levels.

The addition of the predictors to a model that contained only the intercept significantly improved the fit between the model and the data, $\chi^2(24, N = 136) = 102.82$, Nagelkerke $R^2 = 0.59$, $p < 0.001$. Significant unique contributions were made by the factors of individual participation rates and prior Chinese grades (see Online Resource 6).

The reference group was the profile of turn-usurper. Accordingly, each predictor had three parameters, for predicting membership in the turn-receiver, turn-balancer, and turn-claimer profiles, in contrast with membership in the turn-usurper profile (see Table 5).

Both the individual participation rates and the prior Chinese grades were found to be significant predictors in comparing the turn-usurper with the turn-receiver profile group. If an individual participated more in group discussion and had a higher prior Chinese grade, then he or she was more likely to be classified as a turn-receiver than a turn-usurper.

Three predictors showed significant parameters for comparing the turn-usurper profile with the turn-balancer profile. Individuals who participated more had higher prior Chinese grades and a higher mathematics self-concept tended to fit the turn-balancer profile rather than the turn-usurper profile. No significant predictor was found to differentiate the turn-usurpers from the turn-claimers.

If we considered only the base rates of individual membership in the turn-usurper profile, our predictions would be only 15% correct. The logistic model would result in an overall 68% rate of correct predictions. Correct predictions were more frequent for the turn-balancer profile (89%) than the turn-usurper (52%) or turn-receiver (52%) profiles. No correct predictions were made for members of the turn-claimer profile.

## Cross-comparison of individual profiles and group profiles

Various combinations of individual profiles across the various group profiles were further examined (see Online Resource 7). The *more-above-average* group profile had a much lower percentage of turn-receivers and a much higher percentage of turn-balancers than the three *less* profiles. The percentage of turn-usurpers was similar across the

**Table 5** Parameter estimates contrasting the turn-usurper profile with each of the other profiles ($N = 136$)

| Predictor | Usurper vs. receiver | | | Usurper vs. balancer | | | Usurper vs. claimer | | |
|---|---|---|---|---|---|---|---|---|---|
| | B | EXP (B) | *p* | B | EXP (B) | *p* | B | EXP (B) | *p* |
| Individual participation rate | 0.44 | 1.55 | 0.000*** | 0.26 | 1.30 | 0.000*** | 0.12 | 1.13 | 0.08 |
| Mathematics self-concept | 0.99 | 2.70 | 0.34 | 1.48 | 4.40 | 0.04* | 0.09 | 1.10 | 0.92 |
| Mathematics learning enjoyment | −0.83 | 0.44 | 0.40 | −0.66 | 0.52 | 0.27 | 0.19 | 1.21 | 0.83 |
| Social anxiety | 0.81 | 2.25 | 0.50 | 0.40 | 1.49 | 0.66 | 0.26 | 1.30 | 0.79 |
| Prior mathematics grade | −0.03 | 0.97 | 0.54 | −0.05 | 0.95 | 0.19 | 0.05 | 1.05 | 0.36 |
| Prior Chinese grade | 0.16 | 1.17 | 0.01* | 0.10 | 1.10 | 0.02* | 0.09 | 1.09 | 0.09 |
| Average friendship | 0.18 | 1.19 | 0.41 | 0.29 | 1.33 | 0.08 | 0.12 | 1.13 | 0.52 |
| Gender [Female = 0] | −0.46 | 0.63 | 0.63 | −0.40 | 0.67 | 0.59 | −0.07 | 0.93 | 0.94 |

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

*more-above-average*, *less–good* and *less–average* group profiles, and the percentage of turn-claimers was similar across all four group profiles.

Each group included various combinations of individual turn-taking profiles. The results showed that there were 17 emergent unique individual profile combinations among the 42 groups. The most common combinations were two turn-usurpers and two turn-balancers ($n=6$); four turn-balancers ($n=6$); one turn-usurper and three turn-balancers ($n=5$); and one turn-receiver and three turn-balancers ($n=5$). These four combinations accounted for around half of the groups. Of the four most common combinations, the combination of one receiver and three balancers yielded the lowest group outcome ($M=6.00$, $SD=1.13$) and the smallest number of turns ($M=216$, $SD=80$).

## Discussion

This study extensively explored students' turn-taking patterns during dialogic collaborative problem solving from both group and individual levels. We used the participation-shift framework (Gibson, 2003, 2005) to analyse how turns were shuffled among speakers. This framework categorised four types of shifts by which participants moved themselves and others onto or off the conversational floor. The types of shifts were turn-receiving (i.e., receiving the floor from the speaker), turn-claiming (i.e., claiming the floor when it was open to the whole group), turn-usurping (i.e., usurping the floor when it was offered to another person) and turn-continuing (i.e., continuing to hold the floor). Specifically, we mainly investigated the distribution of participation shifts in peer talk during dialogic collaborative problem solving, its impact on group performance, emergent profiles concerning individual turn-taking styles, and the prediction of individual profile membership.

### Participation shifts and group performance

The group-level analysis revealed that turn-receiving was the major form of participation shift in dialogic collaborative problem solving, accounting for around 40% of the turns on average. This finding reflects the reciprocal nature of human interaction, which has been well documented in the literature (Blau, 1964; Gergen et al., 1980). In human conversation, feedback from a target is always expected.

Various researchers have shown considerable interest in exploring why some groups are more successful than others (Barron, 2003; Kapur et al., 2008; Schnaubert & Bodemer, 2019). In this study, participation shifts did not significantly predict solution scores or subjective group assessments. Instead, these shifts significantly predicted interaction intensity and participation equity. Structural level features of dialogue are usually not enough to predict group outcomes. For example, previous findings have established that intense social interactions do not necessarily lead to high-quality group performance (Choi & Kang, 2010; Heo et al., 2010). The quality of interactions also matters. Participation shifts, as a kind of structural feature of dialogue, were also not found enough to significantly predict solution quality. Therefore, researchers seeking to predict the outcomes of dialogic collaborative problem solving should simultaneously consider turn-taking patterns and other metrics for assessing the quality of talk, such as joint knowledge construction (Chi et al., 2018; Fu et al., 2016) and group regulation (Borge et al., 2018; Järvelä et al., 2019).

Although studies have shown the benefits of participation equity to group outcomes (Kapur et al., 2008; Stevens, 2012; Wilshire et al., 2018; Woolley et al., 2010), the association between participation inequity and group solution score did not reach significance in the present study. This was possibly because the benefits of participation equity might not be strong in short-term tasks. Groups could also achieve a good solution score through trusting members who have relatively high academic status even when solving a challenging task. This may further limit the impact of participation shifts on solution quality.

It is worth noting that the distribution of participation shifts was essential from the dialogism perspective due to their impact on participation equity. In this study, participation inequity was significantly and negatively predicted by both turn-usurping and turn-claiming. As previous studies have shown, it is common for groups to trust members who are deemed to have high intellectual status, and to grant these members more opportunities to participate (Cohen & Lotan, 2014). Such inequity in assigning participation opportunities has been found to be stronger when group members focus on the speed of collaborative problem solving (Lewis & Shah, 2015). Reciprocal turn-receiving shifts indicated the popularity of specific students. Therefore, turn-usurping and turn-claiming shifts, which competed for turns with turn-receiving, might be more highly related to equitable dialogue in collaborative problem solving.

## Individual turn-taking profiles

The second research question concerned the profiles arising from individual turn-taking styles in dialogic collaborative problem solving, and the predictions of individual membership in each profile. The study revealed four latent profiles of students: turn-usurpers (20%), turn-receivers (15%), turn-balancers (55%) and turn-claimers (10%). Turn-usurpers fought for most of their turns in the discussion. Turn-receivers mainly received turns from previous speakers. Turn-balancers, who did not show a specific turn-taking style, made up the largest proportion of the students. Turn-claimers were the least common. These students actively responded to peers when the floor was opened to the whole group.

Many studies have shown that group-level entropy is beneficial to group success (Stevens, 2012; Wilshire et al., 2018). This study extended this argument by helping specify the major population who contributed to group interaction entropy. As indicated by the participation analysis framework, turn-usurping intensifies the interaction disorder by breaking the dominant reciprocal turn-taking sequence. Therefore, turn-usurping shifts could be assumed beneficial to group success. The group-level analysis in this study suggested that turn-usurping shifts also tended to increase the intensity of group interaction. The individual-level analysis further revealed that turn-usurping shifts were mainly enabled by academically disadvantaged students who also showed the weakest mathematics self-concepts and participated the least in group discussion. Thus, it could be inferred that the participation of turn-usurpers who were basically academically disadvantaged students seemed to be essential to group outcomes.

Compared with the turn-usurpers, the turn-receivers had higher academic status in terms of their prior mathematics or Chinese grades. Turn-receivers also demonstrated stronger mathematics self-concepts and took more turns in group discussions. This study also found that the *more-above-average* profile was characterised by a smaller percentage of turn-receivers, but a larger percentage of turn-balancers than the three *less* profiles. These findings indicate that the turn-receivers were relatively popular addressees, who were frequently nominated by their peers in group discussions. Successful collaboration requires individuals to feel responsible for realising collective goals and to actively undertake their share of the work to achieve group success (Wang, 2009). Social loafing, free-rider behaviour and the diffusion of responsibility may all jeopardise individual and/or group outcomes (Webb et al., 2009). The results suggest that turn-receivers tended to take up most of the discussion time, which might lead to free-rider behaviour and inhibit a group's effectiveness.

The study's multinomial logistic regression analysis further revealed that individual participation rates and prior Chinese grades were two predictors with unique, significant capacities for predicting individual membership in the turn-usurper profile. It is interesting that students with lower academic status tended to usurp turns which required stronger agency. This was possibly because these students were marginalized and had to actively fight for their participation opportunities. On the other hand, the open-process tasks designed in current study also enabled them to voice their views in group discussions despite of their poor domain knowledge. Another interesting finding was that individual prior Chinese grades had more impact than prior mathematics grades on the students' patterns of participation for solving mathematical problems. This finding seems consistent with earlier observations that reading ability is a strong indicator of perceived individual academic status among peers (Rosenholtz, 1985) and individuals of relatively higher academic status tended to speak more and to be better trusted by other members (Cohen & Lotan, 2014).

## Practical implications

Despite the great potential of peer talk for promoting individuals' domain-related learning and cognitive development, productive peer talk seldom happens spontaneously in classrooms (e.g., Cohen & Lotan, 2014; Gillies, 2019; Miller & Hadwin, 2015). Thus, students need explicit guidance on how to use language effectively and how to regulate group interactions (e.g., Belland et al., 2013; King, 2008; Näykki et al., 2017).

Turn-taking is an important dimension of collaborative talk. As has been well-established in previous studies, students should be encouraged to listen attentively and to engage with every group member (Boaler, 2008; Shah & Lewis, 2019). This study further investigated students' approaches to taking turns in group discussion. The results indicate that the academically disadvantaged students were most likely to fit the turn-usurper profile. Their participation could help complexify and intensify the group interactions and optimise long-term group productivity during dialogic collaborative problem solving. In contrast, students deemed to have high academic status within their groups were likely to emerge as turn-receivers and talked most though they might not intend to dominate the group discussions. In addition, these turn-receivers were more passive in taking turns than the turn-claimers or turn-usurpers and did not necessarily take roles as facilitative leaders, despite their positions as knowledge experts.

A conversational floor is an evolving and socially negotiated space (Engle et al., 2014). The access to a conversational floor can thus be manipulated through changing the context (Shah & Lewis, 2019). Teachers are therefore urged to ensure equitable access to the conversational floor for each group member. This study informs several specific approaches to help teachers build a peer talk culture that values equity and respect. First, teachers could encourage students to express their viewpoints actively and freely. This study does not agree with assigning students various functional roles (e.g., De Wever et al., 2010) or establishing an order of speaking to promote participation equality but encourages teachers to help students build freedom in voicing their opinions. That is, students could be encouraged to freely usurp floors (not interrupting the last speaker) when they have words to add on and do not need to wait for their turns. Second, teachers could remind students that not only their own active participation is important but also who they talk to. Specifically, teachers could remind students not to speak too frequently to one particular member (such as a student who is the most academically advantaged) or neglecting some partners, especially those with relatively lower intellectual status. Third, teachers could pay more attention to academically disadvantaged students in group discussion. They could help students develop respect especially for the contributions of academically disadvantaged students by acknowledging their contributions, engaging with their ideas, or encouraging their participations. Lastly, teachers are also suggested to monitor the emergence of turn-receivers in group discussions. The popularity of turn-receivers in dialogic collaborative problem solving might inhibit group effectiveness, at least in the long term. We suggest teachers to encourage possible turn-receivers, particularly those of high intellectual status, to take roles as facilitative leaders to encourage each member's contributions, rather than passively taking up most of the discussion time.

## Limitations and future research

Inevitably, this study was limited in several ways. First, a clear limitation of the study is the lack of hypotheses derived from existing research that help guide the investigation. This led to somewhat inefficient exploration around the research questions. However, our specific analysis was not purely data-driven but was partially guided by previous studies. For example, to predict individual turn-taking profile membership, we chose individual characteristics that have been shown associated with individual participation behaviour which may avoid chance predictors from inefficient data exploration. In addition, as one of the first efforts to investigate how students access the conversational floor during collaborative problem solving and whether there are various profiles of turn-taking styles, this study raises a set of reasoned hypotheses for prospective studies to further examine across various contexts. For example, groups with a higher percentage of turn-usurping are likely to have higher participation equality and more intense group interaction; ability-heterogeneous groups with more participation of low-status students might have more intense group interaction and better group outcomes; students with a low intellectual status and a low self-concept tend to participate by usurping turns in group discussions.

Also, due to the exploratory nature, the study had difficulty to draw general conclusions. For example, it remains open whether the group-level distribution of participation shifts and emergent individual turn-taking profiles generalize to other populations (e.g., preschool students, secondary school students, or adults), other subjects (e.g., Chinese, science, or STEM), other tasks (e.g., open-ended, or well-structured tasks) or other contexts (e.g., collaborative learning, long-term team project, or computer-supported environment). Therefore, this study may open a line of inquiry for future studies to further investigate turn-taking patterns across various conditions. The analytical framework also provides an alternative approach to help address relevant research questions.

In addition, this study was somewhat limited by the disadvantages of the traditional coding and counting approach (Csanadi et al., 2018). Although the participation-shift framework for analysis takes adjacency as the psychological unit of analysis, and although this framework extensively addresses contextual and historical factors, this study failed to consider the heterogeneity of turn-taking shifts, especially when identifying individual profiles according to the accumulated percentages of different turn-taking shifts. In addition, our inter-rater agreement on the coding of participation shift did not achieve an almost perfect level because it was challenging for a human to infer the speaking target based on audio data for four-person groups. We therefore suggest future studies collecting video data to enrich the clues of speaking target and hopefully get a higher level of reliability.

It should also be noted that the individual participants were interdependent due to grouping. One member's turn-taking style might have been affected by the turn-taking styles of the other group members. Although every effort was made to randomise the groupings, some groups might not have been comparable in some respects, which could have impacted the observed individual turn-taking styles. Future studies may tackle this issue by investigating the stability of individual turn-taking styles across various tasks, across various groups and over a period of time. This may further lead to insights on how to intervene individual turn-taking approaches by adjusting the task design or grouping principle.

Although this study was limited in these ways, it is expected to stimulate more research on the temporal features of peer talk in dialogic collaborative problem solving. Further prospective studies may formulate hypotheses based on the present exploratory study and further test the validity of the findings. The findings also suggest further directions regarding turn-taking patterns. For example, future studies could investigate how turn-taking patterns relate to student roles, such as those of leader, coordinator and animator (Marcos-García et al., 2015). Another issue to be researched is how turn-taking patterns and other quality metrics can be combined to predict group outcomes. Future research could also explore the characteristics of turn-usurpers, such as their intentions when usurping turns, whether they interrupt previous speakers and how others respond to them (Hu, 2021). Prospective studies could further investigate ways to help turn-receivers facilitate whole-group discussions rather than seeking to dominate them. We call for more efforts to address these open questions.

## Conclusion

This study sought to investigate students' turn-taking patterns during dialogic collaborative problem solving and to explore how these patterns relate to group effectiveness. In particular, it suggested the positive association between active turn-taking and participation equity and demonstrated the existence of individual turn-taking styles. This study took a first and essential step in using Gibson's participation-shift framework towards understanding the temporality of peer interaction pattern in collaborative problem solving. It offers preliminary yet promising insights into the nature and dynamics of participation structure in collaborative problem solving. Though limited by its exploratory nature, this study sheds light on formulating possible hypotheses for future studies and on constructing analytical frameworks to help address relevant questions. We call for more efforts in this line of inquiry.

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s11251-021-09565-2.

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## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

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