



Research Article

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The complex dynamics of adaptive teaching: observing teacher-student interaction in the language classroom

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Abstract: Real-time verbal interactions between foreign language teachers and their students are of vital importance for language development, but classroom interactions are also multi-faceted and complex. The way a teacher understands and responds to learner utterances can be a powerful pedagogical strategy to scaffold learner language development. In this paper we present the Questions and Answers in English Language Teaching coding scheme which can be used to observe and describe the dynamics of teacher questions and student responses in language classrooms. We piloted the instrument in English as a foreign language lessons of four experienced teachers teaching 16 lessons in total. State Space Grids were used to visualize classroom dynamics and quantify intra-individual variability of each lesson. The results show that interactions between teachers and students have the tendency to self-organize and stabilize in one specific area of the grid. Lessons taught by three of the teachers revealed a dominant pattern formed by closed questions and short student responses. One teacher taught lessons in which more complex question and answer sequences were prevalent. These patterns of variability and stability show that teacher-student interactions have the properties of a shallow attractor state. The analysis of moment-to-moment turns in

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classroom interaction indicate that students in this study generally adapt their response to the level of teacher questions, but that teachers do not seem to adapt their questions to the level of the previous student answer. This suggests that, even for experienced teachers, scaffolding and adaptive teaching might be easier said than done.

Keywords: classroom interaction; co-adaptation; complex dynamic systems; L2 pedagogy; observation; state space grids

1 Introduction

In a globalized world in which English is used as a lingua franca and digital out-of-school exposure to this language is virtually everywhere, language teachers are facing several challenges (The Douglas Fir Group 2016). The first is to create classroom conditions for meaningful language use at the appropriate level of challenge (Snow 2014). A second challenge is to encourage students to participate actively in the language lesson (Larsen-Freeman and Cameron 2008). The third challenge is that language is both the content of the foreign language lesson and the tool to master this content (Gibbons 2015). Eventually, the main goal of language teaching is that students can comprehend, use and produce the foreign language to learn, study or work in diverse sociocultural contexts (Council of Europe 2018).

A language lesson can be a sheltered and structured space in which students can practice the skills which are needed to achieve this goal (Thornbury 2011; Walqui and van Lier 2010). Opportunities for rich and meaningful classroom interaction are essential elements in a language lesson. This includes frequent student participation and shared meaning-making (Gao 2019; Lyster and Saito 2010). Many researchers agree that successful teachers foster student learning when they activate engagement (Hattie and Yates 2014; Mercer and Dörnyei 2020). Insights from cognitive psychology show that a cognitive contribution from the learners is needed for them to benefit from teacher support (Kirschner et al. 2006; Long and Doughty 2009). The way teacher and learners respond to each other and the way this varies or stabilizes during the learning process is called co-adaptation (Larsen-Freeman and Cameron 2008; van Geert and Steenbeek 2005a). Understanding the characteristics of co-adaptation is important in the process of shared meaning-making at an appropriate level of challenge (Larsen-Freeman and Cameron 2008; van de Pol et al. 2010; Wood et al. 1976).

Classroom observations can help us better understand the dynamics of co-adaptation in real-time teacher-student interactions. The present study looks at a

common type of micro-level interaction in the language lesson: the use of teacher questions and student answers.

2 Literature review

2.1 The role of questions in the language classroom

Questions play an important role in verbal classroom interaction because they can serve as a pedagogical and a cognitive tool (Walsh and Sattes 2015). When asking and answering questions, teachers and learners are engaged in a process that is intended to help learners develop a foreign language (Mercer and Dörnyei 2020). Question and answer sequences can be used to test knowledge, but more importantly, can operate as ways to guide understanding. Asking questions is a common way of eliciting language and thoughts from the students (Mercer and Dawes 2014). However, a teacher who uses questions as a tool for learning does not only teach a specific subject, but engages students in the process of co-construction (Menninga et al. 2017). In this process language, content, context, communication and cognition are intertwined (Coyle et al. 2010).

The type of questions a teacher asks in real-time interaction affects the level of challenge for the learners. Language teachers can ask questions that are primarily language-oriented: focusing on structures, forms, morphology or translations to the students' mother tongue (hence L1). Teachers can also ask questions that are meaning-oriented. These can be aimed at eliciting pre-defined answers, but they can also be focused on verifying if learners have understood the subject of the lesson or whether they can express their own thoughts and opinions about the lesson content (Menninga et al. 2017; van Vondel et al. 2017). A communicative language lesson focuses on getting students to use the foreign language in a way that simultaneously supports language development and thinking (Mercer and Dörnyei 2020; Walqui and van Lier 2010).

Many researchers have found that the closed, directive question is the most prevalent question type in lessons (Dalton-Puffer 2007; Sinclair and Coulthard 1975). Although closed questions are efficient to check understanding, a frequent use of this question type carries the risk for classroom interaction to stall (Cullen 2002; Larsen-Freeman and Cameron 2008). Moreover, closed questions encourage learners to give short and simple answers and offer very few opportunities for students to practice language use (van Vondel et al. 2017). This pattern of closed questions and short answers might limit the possibilities for teacher and students to engage in dialog (Mercer and Dörnyei 2020). According to Walqui and van Lier (2010), changes in the amount and quality of student participation over time are an

indicator of learning. During meaningful classroom interaction students show high levels of participation in terms of richness of ideas expressed in the target language and in terms of utterance length. Limited or hardly any verbal student participation could signal a lack of student understanding, although affective factors might also play a role (MacIntyre et al. 1998).

2.2 The language classroom as a complex dynamic system

Language development, teaching and learning can all be conceptualized as complex dynamic systems in their own right (van Geert and Steenbeek 2005a, 2005b). Complex dynamic systems theory is a process theory and focuses on how the current state of a system transforms into the next state (Kupers et al. 2018). Processes can be studied on a macro-timescale, a longer period of time for instance a school year or a term, but also on a micro-timescale. Concrete situations such as the duration of a classroom activity or lesson can form a micro timescale of a learning process (van Vondel et al. 2017). In a complex dynamic system, micro and macro timescales are connected (van Geert and Steenbeek 2005b). Likewise, the interactions within a time-scale, for instance between teacher and learner behavior, are also connected. This means that the way teacher-student interactions develop and change over time cannot be attributed to either the teacher or the student (Kupers et al. 2018; Menninga et al. 2017; Pennings and Mainhard 2016).

Currently, the dynamics of moment-to-moment classroom interactions in language classrooms are understudied (Larsen-Freeman 2016; van Geert and Steenbeek 2005a). An important reason for this is the lack of instruments to systematically observe teacher-student interaction dynamics at the micro-level. A previous example of an observational study of teacher-student interaction can be found in the work of Larsen-Freeman and Cameron (2008). These authors shift the focus away from either the learners or the teacher and put the learning *process* centerstage. In this interactive process, managing dynamics of learning in the language classroom is highly important, but the authors also argue that language teachers have varying degrees of sensitivity to their students' verbal utterances (Larsen-Freeman and Cameron 2008). Whereas some teachers respond in a way that helps learners pick up new language or communication skills, other teachers respond less aptly to limited student output, for instance by ignoring the student response (van de Pol et al. 2010).

Classrooms are multi-faceted and any observer could focus on a multitude of variables and characteristics. Larsen-Freeman and Cameron (2008) used the "interaction differential" collective variable to gauge the development of interaction over time. We share the underlying assumptions these authors make

about the language classroom as a complex dynamic system. Our study, however, uses a different collective variable. The Questions and Answers in English Language Teaching (QAELT) coding scheme was designed to observe teacher-student interaction. This paper presents a methodology to observe and quantify question and answer interactions. QAELT was applied to a series of lessons ($n = 16$) in secondary school EFL classrooms to explore patterns of variability and flexibility of teacher-student interactions.

2.2.1 Attractor states

In a complex dynamic system view of classroom interaction, teacher and student behavior during the lesson is a real-time and self-organizing process in which interaction moves from one “state” to another over time (van Geert and Steenbeek 2005a, 2005b). We define a state of the system as a combination of teacher and student behavior. The interactive state of the system in any given moment in time is influenced by the system’s behavior on the previous moment. In theory, in the initial stages in which a teacher and a newly combined group of individual students are formed, all states in the dynamic system can occur: there are no routines and no fixed patterns yet.

In a complex dynamic system, flexible or rigid interaction patterns might emerge from moment-to-moment interactions (Kupers et al. 2018; van Geert and Steenbeek 2005a). This also means that some potential interaction patterns might occur less often. The most stable or often recurring behavioral patterns can result in fixed classroom routines which might evolve into attractor states (de Bot et al. 2007; Hollenstein 2013). A common interaction pattern in the language classroom is the sequence of closed questions asked by the teacher (“So, what is the answer to question three?”) and short learner answers (e.g., “Blue”) while discussing a gap-fill exercise, for instance. This sequence could evolve into an attractor state.

Attractor states in the classroom can be shallow or deep. A shallow attractor state is the most frequent behavioral pattern, while variability in the system still exists. A deep attractor state is a dominant pattern that is hard to break (de Bot et al. 2007). An attractor state can be a positive upward interaction pattern in which teacher and students are enthusiastic and engaged, but could also be formed by more negative patterns in which the teacher may become increasingly active and students become passive. Whether the attractor state is a positive or a negative pattern, a key characteristic is that it takes little effort to stay or enter this state, but substantial effort to leave. This implies that attractor states are often self-sustaining.

2.2.2 Variability

In a complex dynamic system, variability may be a source of information rather than noise (de Bot et al. 2007). Moreover, inter- and intrapersonal variability is crucial for development in general and for language development in particular. Variability in the behavior of a language teacher could take the form of adjusting pace, type, level and number of questions based on the information the teacher receives from listening carefully to their students' responses. Variability in teacher behavior might stimulate student participation and foreign language use. Flexibility in the teacher question and student answer dynamics could be an indicator of successful adaptation of the complex dynamic system (Hollenstein 2013). The process of co-adaptation between teacher and students can be observed in dense time series data. It is, however, important to note that a large amount of variability in classroom interaction does not necessarily entail successful co-adaptation of the teacher and students (Menninga et al. 2017).

2.3 Aims and research questions

The first aim of this paper is to present a coding scheme that can be used to quantify question and answer interactions between teacher and students. The second aim of this paper is to test the instrument and analyze micro-interactions in the classrooms of four different English as a foreign language (EFL) teachers. The research questions which guide this study are:

- (1) What are the most frequent question and answer patterns in EFL lessons?
- (2) How variable are teacher question and student interaction patterns during the lesson?
- (3) Do students and teachers adapt to each other in question and answer sequences?

3 Method

3.1 The QAELT coding scheme

The Questions and Answers in English Language Teaching (QAELT) coding scheme can be used to describe interactions between teacher questions and student answers. Coding schemes are indispensable for an observer to focus their attention on what is going on in the classroom, but any coding scheme is inevitably selective and limited (Cohen et al. 2011). Teachers know that learners differ, which

is why they support and structure their students' learning in many different ways (Smit et al. 2017). The QAELT scheme looks at the role of teacher questions in this interactive process. It can be used to analyze time-series data of two synchronous interaction variables. The scheme's underlying assumption is that classroom dynamics and language learning are cognitive processes that take place through social-interaction in a specific context over time (Ellis 2019; Gibbons 2015). QAELT helps to identify the number and level of teacher questions and learner answers in the social context of a lesson over a period of time.

The QAELT coding procedure consists of two rounds. In a first coding round, a timestamp is given to all teacher questions and student responses uttered from lesson start to finish. A set of coding rules defines (1) what qualifies as a question and (2) what marks the start of a new event. The combination of teacher question and student answer form an event, which is the unit of analysis used in this paper (Hiver and Al-Hoorie 2016). QAELT records the response from any student as a response from the group as a whole. An event finishes as soon as one or more students have answered the question or when a new classroom event starts (e.g., new question, group work or individual work). A follow-up question or the repetition of a teacher question is coded as a new event. Turn-taking, a special form of repetition (e.g., "Kevin?"), is also coded as a new question. Lesson episodes that are not related to teacher-student question and answer patterns (e.g., group work, unintelligible utterances, watching a video) are excluded from the analysis.

In a second coding round teacher questions and students' responses are categorized on an ordinal scale as displayed in Table 1. The underlying dimension of the teacher question variable is the level of cognitive complexity (Cummins 1984; Gibbons 2015). Four levels of questions are defined: (0) non-elicitation, (1) closed question, (2) clarification and (3) open-ended question. These codes are mutually exclusive. The second variable is that of learner level of complexity. The codes for student utterances range from (0) off task/none, to simple (1), complete (2) and complex (3).

After coding, the teacher questions and student answers were synchronized and analyzed with GridWare (Hollenstein 2013; Lamey et al. 2004; Lewis et al. 1999). The State Space Grid technique is a data visualization technique for complex dynamic systems research and takes the shape of a two-dimensional scatterplot. We used State Space Grids to gauge moment-to-moment variability of question and answer interaction patterns within each lesson. The teacher question and student answer variables of QAELT were displayed in a 4×4 grid. One cell in the grid represents one state of the system, which is formed by a combination of two variables. The State Space Grid technique also offers a set of quantitative measures that can be used to analyze interaction dynamics in terms of rigidity or flexibility (Lamey et al. 2004). For this study we used number of events, cell range and

Table 1: Summary of QAELT coding scheme.^a

Teacher Question	Code	Student Answer
Non-elicitation The teacher does not really want an answer Example: <i>“That usually feels really good right?”</i> ^b	0	None learners do not answer
Closed question The teacher expects a certain answer Example: <i>Last time, what did we watch?</i>	1	Simple the learner understands the question and gives a very short answer (1–3 words) Example: <i>“A song.”</i>
Clarification question The teacher wants to know if the student understands Example: <i>“How do you deal with a multiple-choice question?”</i>	2	Complete The learner answers the question by giving information that can be derived from the lesson content Example: <i>“Yeah, errr, yeah, there is always an unlogical* one.”</i>
Open-ended question The teacher wants to know what the student thinks Example: <i>“How does Art feel about his brother?”</i>	3	Complex responses are long (>1 sentence), extensive and/or learner adds a new perspective to the lesson Example: <i>“Errr, he feels jealous of him. Errr, there is sort of competition between them. But the competition is non-existent. Because, well, err, his future is imaginary.”</i>

^aThe full QAELT coding scheme can be downloaded from IRIS repository <https://www.iris-database.org/>.^bExamples used here are all transcripts from our data.

dispersion. Dispersion is a measure that compensates for biases in the cell range measure due to long or repeated visits. The dispersion measure signifies the extent to which interactions are variable over time, and can take a value between 0 and 1. The value of 0 indicates that all interactions are in one cell, 1 indicates that all interactions are spread out evenly across the grid (Hollenstein 2013).

3.2 Participants

The QAELT scheme was piloted in a non-probability convenience sample. Four EFL teachers, Amy, Beth, Claudia and Doris (pseudonyms) were recruited from the network of the first author. The teachers taught communicative language lessons in different Dutch secondary schools. Their teaching experience ranged from 2 to 25 years (see Table 2).

Table 2: Teacher characteristics.

Teacher	Amy	Beth	Claudia	Doris
Age group	35–40	25–30	35–40	55–60
Experience (years)	9	2	16	38

All teachers consistently spoke English throughout the lessons. Amy spoke English 97.7% of the time. Beth, Claudia and Doris used the English language all the time (100%).

3.3 Procedure

Sixteen lessons were video-recorded between December 2015 and February 2016. The micro-timescale of the interactional data in this study was the lesson. Lesson duration was defined by the school timetable and varied between 45 and 60 min, which is typical for Dutch secondary education. Ethical clearance was given by the Ethics Committee of the Department of Teacher Education and informed consent was obtained from both teachers and parents for all participants in the study.

The teachers were asked to teach “business-as-usual” lessons in which teachers decided on lesson content, classroom organization, activities and type of instruction. Depending on the school curriculum, the teachers either taught a reading lesson in which they used fiction (literature) or non-fiction text (Table 3). For every teacher, two lessons in two different groups were recorded, resulting in four lessons per teacher. Amy, Claudia and Doris taught groups of 22–30 students, aged 15–17 years old. The average language level of the learners was CEFR B2. Beth, a teacher working in a CLIL school, taught groups that were smaller (10–18 students). This means that the coded student utterances in Beth’s lessons were produced by a smaller number of students.

Table 3: Group and lesson characteristics.

Teacher	Group	# students	Topic
Amy	year 4	24	19th century literature
	year 5	27	20th century literature
Beth	year 5	12	20th century literature
	year 4	18	Non-fiction genre analysis
Claudia	year 5 A	30	Non-fiction news articles
	year 5 B	24	Non-fiction genre analysis
Doris	year 4	22	Non-fiction reading comprehension
	year 5	24	Non-fiction reading comprehension; Shakespeare

Data was coded by the first author and a trained research assistant. In order to establish inter-observer reliability, four videos were coded independently. Cohen's Kappa for the dimension teacher question was high with an average of $\kappa = 0.77$ (agreement range 0.69–0.89) and average $\kappa = 0.78$ (range 0.68–0.87) for the students' responses. Agreement for teacher language was almost perfect with an average $\kappa = 0.99$ (agreement range 0.94–1.00) and for students' language it was strong with an average $\kappa = 0.86$ (range 0.79–0.89). Lesson episodes with group work, student presentations and watching a video were excluded from analysis. This resulted in a set of 16 lessons with a duration that varied between 13 and 41 min. The average lesson duration was 22 min.

4 Results

State Space Grids visualize which teacher question and student answer patterns occurred most frequently (RQ1) and revealed a unique picture for every lesson. In our sample ($n = 16$), interaction in every lesson seemed to self-organize with a preference for a particular region. The average number of cells visited was 9.7, but the range of cells visited during a single lesson varied from 7 to 12. Figures 1 and 2 illustrate how differences in lesson variability was visualized with State Space Grids.

Figure 1 displays a lesson taught by Claudia on a Monday morning. The horizontal axis shows the level of teacher questions; the vertical axis shows the level of

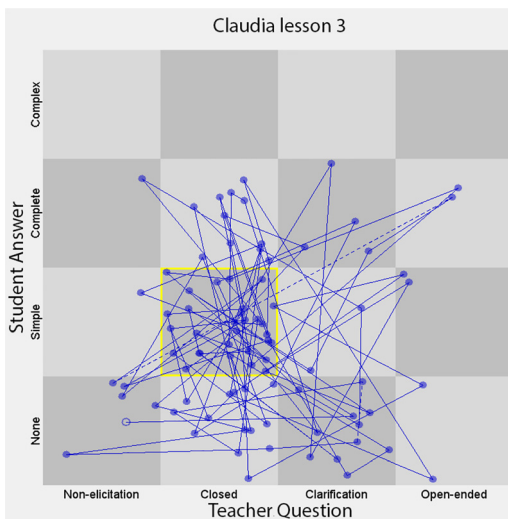


Figure 1: State space grid of a lesson Claudia taught on Monday morning.

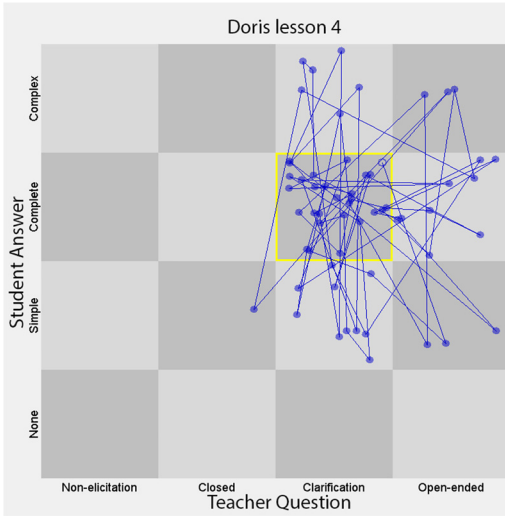


Figure 2: State space grid of lesson Doris 4

the student responses. Every dot in the grid represents a combination of a question and an answer. This example shows that the number of coded interactions for this lesson is 86. The figure shows that students mostly respond to teacher questions with a simple answer, no answer or a complete answer, and that complex answers do not occur in this lesson. The grid also illustrates that the teacher varies the type of questions. The cell which is highlighted is the most frequently occurring type of teacher-student interaction: an attractor state emerging from simple questions and simple answers (27% of the interactions). The lines in the figure show how the interaction moves from one state to another.

Figure 2 shows a lesson taught by Doris. The number of teacher questions and student responses in this lesson was 53. The highlighted cell, a combination of a clarification question and a complete student answer, is the cell which is visited most often. The number of states (cells) visited during this lesson was 7, which was the lowest number of visited cells in our sample. The grid reveals that Doris receives an answer to every question she asks. The teacher asked mainly clarification and open-ended questions and the majority of the students' answers were complete and complex.

The most frequent question and answer interactions during the lesson can form an attractor state. Figures 1 and 2 show that, despite some variation, teacher-student interaction is concentrated in a specific area of the grid, and can be defined as a shallow attractor. The attractor is shallow because besides the dominant pattern there is still variation.

Figure 3 displays question-answer interactions in all 16 lessons. The lines showing the transitions between the dots are hidden for clarity. This example

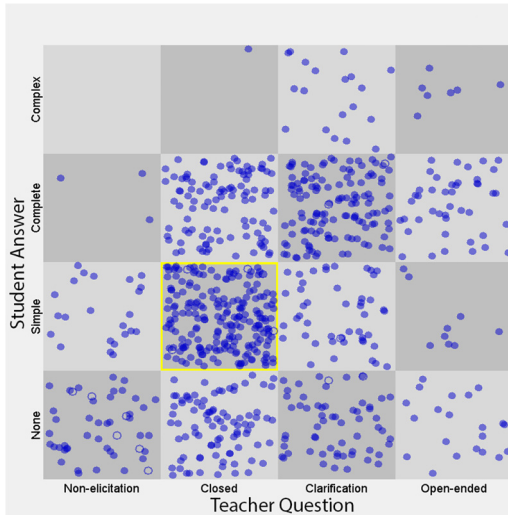


Figure 3: State space grids of all lessons ($n = 16$).

indicates that the most frequently observed interaction pattern was the combination of closed teacher question and simple student answer (RQ2).

The average number of question and answer interactions per lesson was 53. The closed question was the most common question type, with a mean number of 25 closed questions per lesson, which accounts for 49% of the questions asked during a lesson. The simple answer was the most prevalent student response, with 13 simple answers per lesson on average.

We will now look more closely at the characteristics of the entire sample. Table 4 gives an overview of the question and answer interactions during the lesson and indicates the position of the attractor state.

Teacher-student interaction patterns in lessons taught by Claudia were the least flexible. The mean number of teacher questions in these lessons was 59, which is a higher number than in the lessons of the other teachers. As can be seen from Table 4, dispersion for the lessons in our dataset varied between 0.7 and 0.9. Considering that the maximum value for dispersion is 1, these values suggest that the attractor states were not strong but shallow. The cell range, dispersion and lesson time spent in the attractor state, indicate that teacher-student interaction in all lessons moved in and out of the attractor throughout the lesson. The lesson which had the lowest dispersion (0.658) and was the least flexible, and showed a high number of display questions to which students gave no answers or simple answers. This was lesson 4 taught by Claudia.

Table 4: Descriptive statistics of lessons ($n = 16$).

	# observations	# valid	cell range	attractor (teacher-student)	% in attractor	dispersion
Amy 1	48	39	10	Closed – None	29.8	0.779
Amy 2	34	33	11	Clarification – Complete	25.0	0.893
Amy 3	49	48	10	Closed – None	23.4	0.931
Amy 4	39	31	11	Clarification – Simple	18.4	0.85
Beth 1	50	43	10	Closed – Simple	26.5	0.825
Beth 2	52	51	12	Closed – Simple	26.0	0.805
Beth 3	63	58	9	Clarification – Simple	33.3	0.848
Beth 4	49	41	12	Closed – Simple	19.1	0.91
Claudia 1	62	58	10	Closed – Simple	44.3	0.737
Claudia 2	44	41	12	Closed – None	17.5	0.914
Claudia 3	89	86	11	Closed – None	27.1	0.794
Claudia 4	51	50	8	Closed – Simple	44.9	0.658
Doris 1	68	65	11	Clarification – Complete	29.7	0.86
Doris 2	63	59	12	Clarification – Simple	20.3	0.867
Doris 3	32	30	7	Clarification – Complete	24.1	0.813
Doris 4	60	53	7	Clarification – Complete	44.1	0.846

In three out of four lessons taught by Doris, the attractor state was formed by a teacher clarification question in combination with a complete student response. Beth also taught a lesson (Beth 3) in which the average level of teacher questions was higher, but student responses in this lesson were at a low level. Amy's fourth lesson had two shallow attractor states. The level of the teacher questions varied between 1 and 2 (closed and clarification), but the level of the student answers (level 1 – simple answer) was the same for both question types.

To discover whether there was a relation between the level of the student answer and the level of the next teacher move (RQ3), the original time serial data were transformed into lagged time-series. This was done by synchronizing the score for the previous student response and the score for the teacher's follow-up question (TQ-lag 1), by removing the score for the first teacher question and shifting the scores for the teacher questions up. The lagged time serial data were analyzed under the assumption that a student response which was followed by for instance group work or a video could not be related to the next teacher question. Therefore, before synchronization, all interactions with no meaningful follow-up were excluded from the analysis. These transformations resulted in a new dataset with events that in which the teacher question was combined with the previous student response.

Table 5: Correlations and lag-correlation between teacher question and student answer.

	Correlations TQ and SA		Correlations SA to TQ-lag 1	
	ρ	p value	ρ	p value
Amy 1	0.422*	0.003	-0.222	0.173
Amy 2	0.310	0.079	-0.082	0.676
Amy 3	0.356*	0.013	0.349*	0.017
Amy 4	0.177	0.281	-0.394	0.028
Beth 1	0.371*	0.008	-0.032	0.840
Beth 2	0.230	0.105	-0.025	0.870
Beth 3	0.046	0.730	-0.104	0.466
Beth 4	0.248	0.089	-0.022	0.891
Claudia 1	0.171	0.183	0.116	0.385
Claudia 2	0.341*	0.029	-0.064	0.715
Claudia 3	0.002	0.988	-0.055	0.630
Claudia 4	0.194	0.176	0.236	0.122
Doris 1	0.449*	0.000	0.367	0.782
Doris 2	0.455*	0.000	0.000	0.999
Doris 3	0.248	0.187	0.310	0.122
Doris 4	0.117	0.979	0.004	0.980

TQ = teacher question. SA = student answer.* correlation is significant at $p < 0.05$.

For our ordinal time-series data we used the Spearman rank-order correlation coefficient (ρ) to calculate correlations between the teacher's question and the students' responses. The first column of results in Table 5 shows the correlation between the teacher question and the student answer; the second column shows the correlations between the student answer and the follow-up teacher question (the lagged time series). The correlations give an indication of how teacher and students adapt to each other (RQ3).

The results in Table 5 suggest that there is a relation between the level of the teacher's question and the level of the students' response. Table 5 shows that 6 out of 16 correlations between teacher question and student answers reached significance. For every teacher there was at least one lesson with a significant correlation between the teacher question and the student response. Correlations between teacher question and student response for these lessons are positive, but low to intermediate. The correlations for the other lessons were low and not significant. Correlation analyses (TQ and SA) of the original time series suggest that students adapt the level of their answer to the level of the teacher question (RQ3).

Correlation analyses of the TQ to SA lag-1 time series indicate that in these lessons there was a weak relation between the level of the previous answer and the

follow-up question. This suggests that teachers do not adapt their next question to the previous student answer. The only positive significant correlation in our sample was found in lesson Amy 3. These results suggest that this is the lesson in which there was a relation between how the students responded and the teacher's next interactive move. From the observations we do not know whether it was a conscious decision from the teacher whether or not to take the previous student answer into account when asking a follow-up question.

5 Discussion and conclusion

We have presented a complex dynamic system method for analyzing teacher-student interactions on the micro timescale of the language lesson. Lessons were analyzed from moment-to-moment with a QAELT coding scheme and the State Space Grid technique. The data in this paper revealed classroom interactional patterns in which the teacher asked many questions to which students gave very short answers. We also observed that students tend to adjust the level of their response to the level of the teacher question in several lessons, but saw only one lesson in which the teacher adjusted the level of follow-up question to the previous student answer. The results of this study suggest that teacher questions drive the interaction and that the level of the student answers tends to follow the level of the teacher question.

These results raise questions about the complex dynamic process of co-adaptation in EFL lessons. Adaptive teaching requires a teacher to hear and recognize the meaning and intention of a student response, and to use that information to adjust the teachers' follow-up response. These are teacher decisions that are often made instantaneously and intuitively during the lesson. It might be difficult for teachers to teach adaptively, because many complex cognitive, affective and metacognitive factors need to be monitored in interaction and a response is often required immediately.

Closed teacher questions could help to maintain the direction and pace of the lesson. Being able to answer closed questions by giving a short answer could help students feel more competent or at ease. However, closed questions may also result in limited opportunities for students to think, practice, respond and fail. This could lead to frustration or boredom. An indicator of student frustration or boredom could take the form of "I don't know" or no student response. Teacher frustration could manifest itself in interaction patterns formed by an increasing number of questions to which students do not answer. Both teacher and learner frustration might constrain opportunities for learning.

We observed that a “pull” to longer and more complex student answers, for instance stimulated by deliberately asking open-ended questions, does not always take place. In our study, Doris asked a lot of open questions and put a lot of effort in finding out what her students were thinking. This question and answer pattern led to a larger proportion of more extensive student talk. Thus, when students are invited to produce longer and more complex answers, opportunities for meaningful, engaged and active classroom participation might arise. It is important to note that interactions cannot be understood without looking at what happened before and what happens after. Observations of micro-interactions can help to identify fixed, and possibly frustrating, patterns and space for growth, challenge and development. Future research might look into characteristics of lessons in which active student contributions emerge and into characteristics of lessons in which students do not produce longer verbal utterances in the foreign language. Analyses of moment-to-moment interactions can help researchers and teachers recognize opportunities for learning through adaptive questioning strategies.

6 Limitations and suggestions for further research

The results reported in this study are based on 16 lessons taught by four different teachers. An important limitation of the QAELT coding scheme is the data reduction needed for these analyses. Teacher and student behavior are synchronized and chunked into consecutive turns. Another limitation is that we do not go beyond describing the observed interaction patterns. Additional data, for instance from interviews or questionnaires, might help us grasp underlying reasons for teacher and student behavior during the lessons. Other environmental factors, such as the time of day at which the lesson was taught, teacher experience, age of the students and group size might also affect micro-level dynamics. These are research areas that need to be studied in a larger sample of lessons.

Since questions and answers also play an important role in other school subjects, the QAELT coding scheme could also be applied to CLIL subject lessons (e.g., geography, biology, history and mathematics) to gain a better understanding of how language learning and content learning might complement each other. Additionally, it would be interesting to analyze the dynamics of question and answer patterns initiated by students or question and answer dynamics in small-group work. Other potential uses include its applications for teacher education and as a diagnostic tool to gauge intervention effectiveness. These are all promising areas of research to which this methodology might be applied.

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References

- Council of Europe. 2018. *Common European framework of reference for languages: Learning, teaching, assessment-companion volume with new descriptors*. Retrieved from: <https://rm.coe.int/cefr-companion-volume-with-new-descriptors-2018/1680787989>.
- Cohen, Louis, Manion Lawrence & Keith Morrison. 2011. *Research methods in education*, 7th edn. London: Routledge.
- Coyle, Do, Philip Hood & David Marsh. 2010. *CLIL content and language integrated learning*. Cambridge: Cambridge University Press.
- Cullen, Richard. 2002. Supportive teacher talk: The importance of the f-move. *ELT Journal* 56(2). 117–127.
- Cummins, Jim. 1984. *Bilingualism and special education: Issues in assessment and pedagogy*. Clevedon: Multilingual Matters.
- Dalton-Puffer, Christiane. 2007. *Discourse in content and language integrated learning (CLIL) classrooms*. Amsterdam: John Benjamins.
- de Bot, Kees, Wander Lowie & Marjolijn Verspoor. 2007. A dynamic systems theory approach to second language acquisition. *Bilingualism: Language and Cognition* 10(1). 7–21.
- Ellis, Nick C. 2019. Essentials of a theory of language cognition. *The Modern Language Journal* 103. 39–60.
- Gao, Xuesong. 2019. The Douglas Fir Group framework as a resource map for language teacher education. *The Modern Language Journal* 103. 161–166.
- Gibbons, Pauline. 2015. *Scaffolding language, scaffolding learning*, 2nd edn. Portsmouth: Heinemann.
- Hattie, John A. C. & Gregory C. R. Yates. 2014. *Visible learning and the science of how we learn*. London: Routledge.
- Hiver, Phil & Ali Al-Hoorie. 2016. A dynamic ensemble for second language research: Putting complexity theory into practice. *The Modern Language Journal* 100(4). 741–756.
- Hollenstein, Tom. 2013. *State space grids: Depicting dynamics across development*. New York: Springer.
- Kirschner, Paul A., John Sweller & Richard E. Clark. 2006. Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist* 41(2). 75–86.
- Kupers, Elisa, van Dijk Marijn & Andreas Lehmann-Wermser. 2018. Creativity in the here and now: A generic, micro-developmental measure of creativity. *Frontiers in Psychology* 9. <https://doi.org/10.3389/fpsyg.2018.02095>.
- Lamey, Alex, Hollenstein Tom, Marc D. Lewis & Isabela Granic. 2004. *GridWare version 1.1 [computer software]*. <http://statespacegrids.org>.
- Larsen-Freeman, Diane. 2016. Classroom-oriented research from a complex systems perspective. *Studies in Second Language Learning and Teaching* 6(3). 377–393.

- Larsen-Freeman, Diane & Lynne Cameron. 2008. *Complex systems and applied linguistics*. Oxford: Oxford University Press.
- Lewis, Marc D., Alex V. Lamey & Lori Douglas. 1999. A new dynamic systems method for the analysis of early socioemotional development. *Developmental Science* 2(4). 457–475.
- Long, Michael & Catherine Doughty. 2009. *The handbook of language teaching*. Chicester: Wiley-Blackwell.
- Lyster, Roy & Kazuya Saito. 2010. Interactional feedback as instructional input: A synthesis of classroom SLA research. *Language, Interaction & Acquisition* 1(2). 276–297.
- MacIntyre, Peter D., Richard Clément, Zoltán Dörnyei & Noels Kim. 1998. Conceptualizing willingness to communicate in a L2: A situational model of L2 confidence and affiliation. *The Modern Language Journal* 82(4). 545–562.
- Menninga, Astrid, van Dijk Marijn, Henderien Steenbeek & van Geert Paul. 2017. Language use in real-time interactions during early elementary science lessons: The bidirectional dynamics of the language complexity of teachers and students. *Language Learning* 67(2). 284–320.
- Mercer, Neil & Lyn Dawes. 2014. The study of talk between teachers and students, from the 1970s until the 2010s. *Oxford Review of Education* 40(4). 430–445.
- Mercer, Sarah & Zoltán Dörnyei. 2020. *Engaging language learners in contemporary classrooms*. Cambridge: Cambridge University Press.
- Pennings, Helena J. M. & Tim M. Mainhard. 2016. Analyzing teacher-student interactions with state space grids. In Koopmans Matthijs & Stamovlasis Dimitrios (eds.), *Complex dynamical systems in education*, 233–272. Cham: Springer.
- Sinclair, John M. & Malcolm Coulthard. 1975. *Towards an analysis of discourse: The English used by teachers and pupils*. London: Oxford University Press.
- Smit, Nienke, Wim van de Grift, Kees de Bot & Ellen Jansen. 2017. A classroom observation tool for scaffolding reading comprehension. *System* 65. 117–129.
- Snow, Catherine E. 2014. Input to interaction to instruction: Three key shifts in the history of child language research. *Journal of Child Language* 41(s1). 117–123.
- The Douglas Fir Group. 2016. A transdisciplinary framework for SLA in a multilingual world. *The Modern Language Journal* 100. 19–47.
- Thornbury, Scott. 2011. Language teaching methodology. In James Simpson (ed.), *The Routledge handbook of applied linguistics*, 185–199. London: Routledge.
- van de Pol, Janneke, Monique Volman & Jos Beishuizen. 2010. Scaffolding in Teacher–Student interaction: A decade of research. *Educational Psychology Research* 22(3). 271–296.
- van Geert, Paul & Henderien Steenbeek. 2005a. The dynamics of scaffolding. *New Ideas in Psychology* 23(3). 115–128.
- van Geert, Paul & Henderien Steenbeek. 2005b. Explaining after by before: Basic aspects of a dynamic systems approach to the study of development. *Developmental Review* 25(3–4). 408–442.
- van Vondel, Sabine, Henderien Steenbeek, van Dijk Marijn & van Geert Paul. 2017. Ask, don't tell; A complex dynamic systems approach to improving science education by focusing on the co-construction of scientific understanding. *Teaching and Teacher Education* 63. 243–253.
- Walqui, Aida & van Lier Leo. 2010. *Scaffolding the academic success of adolescent English language learners*. San Francisco: WestEd.
- Walsh, Jackie A. & Beth D. Sattes. 2015. *Questioning for classroom discussion: Purposeful speaking, engaged listening, deep thinking*. Alexandria: ASCD.
- Wood, David, Jerome S. Bruner & Gail Ross. 1976. The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry* 17(2). 89–100.