

Learning Analytics for Collaborative Language Learning in Classrooms: From the Holistic Perspective of Learning Analytics, Learning Design and Teacher Inquiry

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(Submitted June 30, 2020; Revised September 5, 2020; Accepted November 12, 2020)

ABSTRACT: Learning analytics (LA) has been increasingly using in teaching and learning. However, in the field of applied linguistics, the use of LA has only begun to touch the surface. There is a need for understanding how LA and learning design (LD) influence each other and provide useful information to language teachers in the context of specific courses or learning environments. In this study, a retrospective analysis was conducted to identify the factors influencing LA for collaborative language learning in classrooms, from a holistic perspective by integrating LA, LD, and teacher inquiry. The findings suggested that (1) LA focused on interactions can inform pedagogical refinement effectively when LD in language learning is premised on social constructivist theories; (2) LA supported teacher inquiry and LD on condition that the teacher holds innovation-oriented beliefs and the participatory culture between teachers and researchers. The study provided insights into the use of LA in collaborative language learning classrooms that focus on collecting and evaluating learners' interaction process beyond gleaning linguistic or behavioral facts. Professional development implications and future research are also addressed.

Keywords: Learning analytics, Learning design, Teacher inquiry, Second language learning, Collaborative language learning

1. Introduction

In recent decades, learning analytics (LA) as a nascent research field has aroused wide interest and attention in educational research and practice (Johnson et al., 2011; Rosé et al., 2016). It is an area of research involving collection, organization, analysis, and reporting of data about learners and their contexts in order to generate information and identify potential issues for prediction and pedagogical decision-making (Bienkowski, Feng, & Means, 2012; Ferguson, 2012; Reimann, 2016). Although the field is still in its infancy, its potential in the educational field has been widely acknowledged, including (1) explaining unexpected learning behaviors; (2) identifying successful learning patterns; (3) detecting misconceptions and misplaced effort; (4) introducing appropriate interventions; and (5) increasing users' awareness of their own actions and progress (Mangaroska & Giannakos, 2019; Papamitsiou & Economides, 2014). The process of using LA involves making sense of the presented information by taking contexts into account and taking actions accordingly (Siemens, 2013; Wise & Vytasek, 2017). Teachers can be engaged in LA by analyzing learning data for the purpose of informing, refining, and designing learning.

In the field of computer-assisted language learning, the evolution of techniques for analyzing big data is gaining attention, and LA has been used to evaluate linguistic data that can provide knowledge about learners' needs and areas of concern (Godwin-Jones, 2017), or analysis of students' behavioral patterns (e.g., Gelan et al., 2018). However, due to little agreement on what logged interaction data may be meaningful for understanding the complex learning process and enlightening language teachers, the use of LA has only begun to touch the surface in the field of applied linguistics (Godwin-Jones, 2017; Link & Li, 2015). Meanwhile, Greeno (1998) and others have argued that any analysis of learning will be incomplete if it does not conceptualize learning as a sociocultural practice. Reimann (2016) also further stated that such an understanding of learning practices is necessary for not only theoretical but also pedagogical purposes. Hence, there is a need for understanding how LA can provide useful information to students, teachers, and designers in the context of specific courses or learning environments. On this basis, a holistic perspective by integrating LA, learning design (LD), and teacher inquiry, is particularly important to investigate the potential of LA in the computer-supported language classroom, where language learning is distributed, and creating and sharing content by learners are enabled by web 2.0.

Therefore, this paper shares a case of computer-supported collaborative Chinese second language (L2) learning in Singapore. McKenney and Mor's (2015) integrated framework of LA, LD, and teacher inquiry is adopted to articulate how they are mutually supportive and how LA could be beneficial to collaborative language learning in classrooms. The study seeks to provide insights into the integration of LA in the computer-supported collaborative language learning classroom that focuses on collecting and evaluating learners' interaction process. Implications for the development of future LA tools and professional development for language teachers are also explored.

2. Literature review

2.1. LA in language learning

Big data have played a significant role in the field of computer-assisted language learning and second language acquisition (Godwin-Jones, 2017). Advances in natural language processing have enabled rich tagging and annotation of corpus data, and there has been growing interest in learner corpora and student-created corpora, collections of written or spoken language by learners, to highlight frequent or common errors in students' lexis or syntax (Godwin-Jones, 2017). With advances in LA, educators' decision-making process is informed with actionable information for supporting students' language learning. Li and colleagues (2018) used LA to examine learners' self-regulated behaviors based on logged data from 2454 freshman university students, and they identified typical learning patterns in an online learning environment which inform educators of pedagogical decision-making. Based on a computer adaptive testing platform, Aristizábal (2018) showed how an American international school in Vietnam had been using data and LA to understand students' learning from different forms of assessment and how they used these findings to improve the reading skill of English as a foreign language students. The study pointed out that it was teachers' pedagogical and epistemological backgrounds that made LA significant and meaningful, which contributed to teachers' reflection on their teaching practices and gaining insights into pedagogical decision-making to improve student English reading.

Some studies have shown the effectiveness of LA in computer-assisted vocabulary learning, and in these studies, language learning was conceptualized as the sociocultural practice where contexts and interaction were emphasized (Ellis, 2008). For example, Mouri et al. (2018) reported a study on evaluating the effectiveness of the learning analytics tool VASCORLL 2.0 in connecting students' vocabulary learning acquired via eBook to that learned from real-life in higher education. VASCORLL 2.0 helped to automatically visualize and analyze all learning logs accumulated in an e-Book system and real-life learning. For instance, if a learner learned and saved a new word using the e-Book, the learner's node and its links with the relevant node of word or learning material in the learning structure would be visualized. The findings indicated that the tool is effective in providing learners' more opportunities in vocabulary learning. In addition, Hsiao, Lan, Kao, and Li (2017) developed a visualization analytic method to understand the impact of various learning strategies on college students' Chinese vocabulary in a virtual world. The research findings show that the visualization analytics method could help teachers visualise students' different learning strategies of vocabulary acquisition.

There is also a trend to apply LA to students' collaborative writing. Hu (2017) proposed a LA tool embedded in Wikiglass for automatically recognising, aggregating, and visualising levels of thinking orders in secondary student collaborative writing in inquiry-based learning in order to assist teachers in identifying individual and group work and selecting example sentences as teaching materials. Text categorisation models were constructed and evaluated using machine learning and natural language processing techniques, to make an attempt to identify at-risk individuals and groups, refine assessment rubrics, select example sentences as teaching materials, and facilitate students' self-regulated learning. However, as Yim and Warschauer (2017) stated in their paper about text mining used in web-based L2 collaborative writing, the use of data and text mining for understanding writing processes in language learning contexts was largely underexplored.

In sum, the majority of studies on LA in language learning have been conducted in higher education and concentrated on exploring the role of LA in students' self-regulated learning. In addition to evaluating linguistic data, the potential of LA used in understanding the complex interaction process in sociocultural views of language learning, and its significance of pedagogical implications have been increasingly acknowledged. There is scarce literature reporting how to analysing and visualising interaction data in collaborative language learning in classrooms, though the importance of quantifiable information about collaborative language learning has been highlighted (Yim & Warschauer, 2017).

2.2. Interplay of LA, LD and teacher inquiry

2.2.1. Interplay of LA and LD

The relationship between LA and LD can be traced back to collecting qualitative and quantitative data to inform educators of revision and fine-tuning of the instructional system under development before the terms LA and LD were coined (Persico & Pozzi, 2015). LD is another field associated with technology-enhanced learning. It can be seen as a form of documentation of pedagogical intent that can provide the context to make sense of diverse analytic data (Lockyer, Heathcote, & Dawson, 2013). Today's classrooms are turning to be technology-rich and data-rich environments, where teachers need to make effective use of technology. Yet during the process of integrating technology with teaching in classrooms, teachers may generate a series of "wonderings" or "burning questions" from practice. To keep the pace of the fast development of technological tools and their use in teaching and learning, today's teachers, more than ever before, need to change the traditional classroom teaching mode, and break their isolation to develop more solid, extensive, and dynamic design competence (Conole & Culver, 2010; Persico & Pozzi, 2015). Hence, a collaborative inquiry endeavor by teachers is underscored by research in LD (Laurillard, 2013; Mor & Mogilevsky, 2013; Persico & Pozzi, 2015).

As argued by Lockyer et al. (2013), LD is based on its reusability and adaptivity across educational contexts, in which excellent teaching practice can be captured, interpreted, and readapted. LD could support teachers as designers of a technology-enhanced learning environment and enhance their professional expertise (Voogt et al., 2011). Both research and the practice of LD have evolved with mainly two purposes: to provide models or a framework to promote teaching quality with shared knowledge among educators (Lockyer et al., 2013) and to focus on the integration of technology into teaching and learning for a semantic structure for analytic (Mor et al., 2015). Several studies also have tried to improve the LD experience by utilizing LA and providing a contextual framework to help teachers understand the information that LA provides (Bakharia et al., 2016; Lockyer et al., 2013; Sedrakyan et al., 2018) so as to further facilitate pedagogical actions.

2.2.2. Mediating role of teacher inquiry

The mediating role of teacher inquiry when connecting LA with LD has also been acknowledged (Alhadad & Thompson, 2017). Teacher inquiry can be seen as a set of research practices by which teachers generate questions, collect data, as well as examine their practice and effects on students' learning for enhancing their professional knowledge and improving teaching practice in the classroom (Clarke & Erickson, 2003). Unleashing the potential of teacher inquiry for improving teachers' practice and professional developments supported by LA and LD is significant in technology-rich environments. The inquiry process is characterised as "purposeful observation that involves deliberate planning to anticipate what, when, and how methods are to be observed" (Rich & Hannafin, 2008, p. 1427) and one of the goals of teacher inquiry is to develop educators' ability for critiquing and improving their own teaching. Recently, some research studies have focused on the opportunities provided by technology, such as LA to support holistic and data-informed LD and teacher inquiry. Mor et al. (2015) stated that teacher inquiry should be a method for data-driven teaching reflection for the benefit of student learning, which is aligned with Dawson's opinion (2006) that teacher inquiry could be recognized as the process of helping teachers to learn to become effective technology-users. LA is able to make teacher inquiry and LD more scientific and reliable. However, the "intuitive and tacit practices of LA, LD and teacher inquiry are far from the structured and technology-enhanced vision of these three domains common in the academic literature." (McKenney & Mor, 2015, p. 265).

2.2.3. Investigating LA in language learning from a holistic perspective

To sum up, the fields of LA, LD, and teacher inquiry do not occur in isolation (McKenney & Mor, 2015), but need to be studied synergistically. As stated by Mor et al. (2015), LA could be used to improve LD and support teacher inquiry. LD provides a semantic structure for LA, whereas teacher inquiry could utilize the information provided by LA (McKenney & Mor, 2015), as well as raise reflective questions for LA and LD to follow up. Regarding the integration of LA, LD, and teacher inquiry, some studies have focused on technology development (Haya et al., 2015; McKenney & Mor, 2015; Mouri, Uosaki, & Ogata, 2018), and adopting top-down design principles (Bakharia et al., 2016; Ifenthaler et al., 2018). Other studies have proposed an integrated conceptual framework (McKenney & Mor, 2015; Mor et al., 2015; Persico & Pozzi, 2015) to illustrate the relationships among them. However, studies that have been conducted to investigate the synergetic relationship among them empirically are rarely found, particularly in the context of language learning. The holistic

perspective by them can help to understand LA for collaborative language learning in classrooms more comprehensively and meaningfully.

3. Research questions

From the holistic perspective of LA, LD, and teacher inquiry, this study aims to understand how LA can be beneficial to collaborative language teaching and learning in the classroom environment, taking a case of computer-supported collaborative L2 writing as an example. Cobb et al. (2003) argue that retrospective analysis “provides a trustworthy account of the process whereby a series of events—each of which is local and contingent—can be seen as part of an emergent and potentially reproducible pattern” (p. 12). Retrospective analysis attempts to generate a coherent framework that counts for situated effects, thus making it possible to anticipate outcomes in future designs (Cobb et al., 2003). Therefore, in this paper, the factors influencing LA for language teachers in the computer-supported collaborative learning are systematically identified via retrospective analysis of data collected in the GroupScribble (GS)-supported collaborative L2 learning study. The retrospective analysis is guided by the two research questions below.

- (1) How LA focusing on interactions and LD were mutually beneficial in computer-supported language classrooms?
- (2) What factors influenced and shaped teacher inquiry when connecting LA with LD?

4. The GS study

The case of GS-supported collaborative writing with a learning analytics tool in a Chinese L2 class was deemed appropriate for this retrospective analysis. First, the case synergistically combined the three key elements, LA, LD, and teacher inquiry. Second, the effectiveness of using GS in L2 classrooms to enable productive collaborative learning, and the essential role of teachers during the process had been evidenced (Wen, 2019). Data from the GS intervention were re-coded to understand how its LA tool interacted with the LD and mediated by teacher inquiry.

4.1. Participants and the computer-supported classroom enabled by GS

The case was about a Chinese language teacher under the pseudonym “Mdm Y” who used an online representational tool—GS in her secondary 3 (Grade 9) Chinese writing class in a neighbourhood school. The teacher had more than 10 years of teaching experience. The class was a normal Chinese class with 29 local students (aged between 15 to 16 years). In most secondary schools in Singapore, students are channeled into a higher Chinese or normal Chinese class based on their language proficiency. Compared with the higher Chinese class, the normal Chinese class requires a comparatively lower level of linguistic proficiency and cultural knowledge.

GS is a generic online representational tool for supporting brainstorming and knowledge construction, like Lino or Padlet that has been widely used in today’s classrooms. In a typical GS class, students were assigned to small groups with 3 to 5 members, sitting together and using a personal computer. In this way, students in the same group were able to do both GS-based and face-to-face interactions. The class of students was classified into 7 groups homogeneously to complete pre-writing activities using GS in the classroom environment. They were grouped homogeneously according to their scores of the Chinese language examination at the end of Secondary 2 when it was before intervention. The total score of the examination was 100, and the average score of the class was 57.03 ($SD = 9.13$). As students’ language proficiency might influence their reactions to different pedagogical approaches (Wen, 2019), we sought to purposefully investigate a high-ability group and a low-ability group to maximize the variation of interaction patterns. Based on that, a group with lower language proficiency (Group 1) and a group with higher language proficiency (Group 6) were randomly selected as our target groups. They were Group 1 ($Mean = 51.14$, $SD = 3.07$) and Group 6 ($Mean = 62.47$, $SD = 3.88$).

As shown in Figure 1, the GS user interface presents each user with a two-paned window. Its lower pane is made up of the user’s private board, whereas the upper pane is the public board. The private board is provided with virtual pads of fresh scribble sheets on which the user can draw or type. Students can share the scribbles sheets by dragging them from the private space to the public space. The most essential feature of the GS is the combination of the private board, where students can work individually, and group boards, where students can post the work, view others’ work and take items back to the private board for further elaboration. A student can

select any group board by clicking on the board number at the top right corner, and browse all other groups' postings on the public space. Hence, the tool may make intra- and inter-group interactions more convenient. In this way, students have an opportunity to exchange their ideas and provide comments for one another without physical movement in classroom environments.

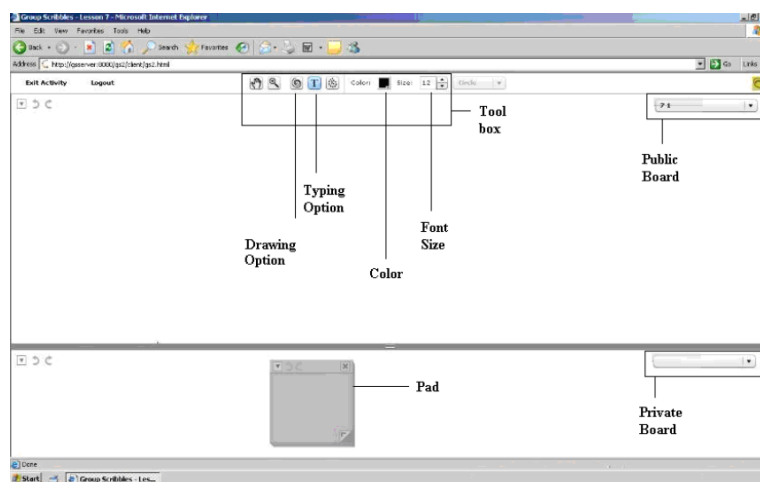


Figure 1. The user interface of GS with a two-paned window

After technical training for both the teacher and all the students, we also conducted a series of professional development sessions for the teacher to ensure that she had a good understanding of GS-based language learning design. In the professional development session, the rapid collaborative knowledge improvement (RCKI) concept and its related design principles (e.g., spontaneous participation, multimodal expression, or idea diversity) were introduced. RCKI focuses on democratic knowledge sharing and continuous individual and group knowledge enhancement (Wen, Looi & Chen, 2011; Wen, 2019). It is proposed to address the constraints faced by classroom teachers when they are designing and implementing knowledge construction and improvement practices within the short duration of a classroom lesson.

4.2. GS-based collaborative writing activity design

Collaborative L2 writing is a recursive, bottom-up process that requires participants to collaboratively contribute words/phrases or ideas, and eventually compose their compositions in individuals or groups (Oxford, 1997). Although brainstorming as the fundamental pre-writing activity has been emphasized in various models of the writing process, there is a paradox between L2 writers' ideas expressions and their limited target language proficiency. Some studies (Scott, 1996; Stapa & Majid, 2009) have shown that, for L2 writers, the low proficiency of the target language often requires them to focus primarily on vocabulary and grammar, and hence hampers idea generation and expression. Nonetheless, there are also studies (e.g., Wong et al., 2009) suggesting that the collaborative writing process should start with contributing vocabulary. In practical collaborative L2 writing activities, teachers usually encourage students to write down their ideas or vocabulary as much as possible.

Therefore, both "idea first" and "vocabulary first" strategies were used in designing GS-based collaborative writing activities. In the "idea first" activity, students were encouraged to contribute ideas relevant to the topic using whichever representational forms they are comfortable with and competent in. For example, they could share their ideas in English or drawing pictures. In the "vocabulary first" activity, students were encouraged to contribute Chinese words, phrases, or idioms they could think about with the given topic (more details can be found in the section of results).

The "idea first" activity was designed for Lesson 1 and Lesson 2 with the writing topic "why do Singaporeans feel discontented?" In Lesson 1, students were required to start writing by brainstorming ideas on the GS platform. After that, in Lesson 2, students continued to organize the ideas they shared and select a few good ones to further refine and expand to paragraphs via GS. Taking the screenshot of group 1 in Lesson 1 as an example (Figure 2), after brainstorming in term of the given topic, the group of students classified their ideas into three main categories, "claims," "reasons" and "suggestions/solutions" in term of the four elements provided by the teacher. One week later, the same group in Lesson 2, further refined and improved their group artifacts. As

shown in Figure 3, three main reasons proposed in the prior lesson were selected and further elaborated and their corresponding solutions were provided and improved.

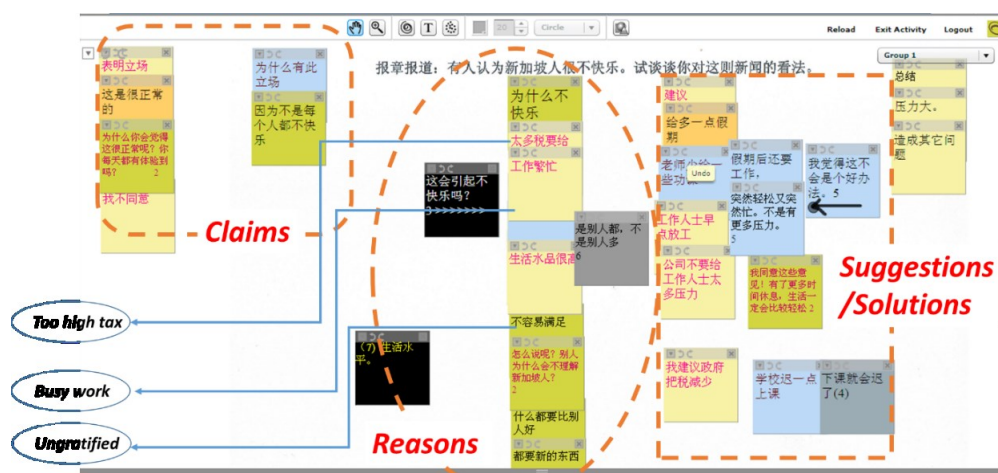


Figure 2. GS screenshot from Group 1 at the end of Lesson 1

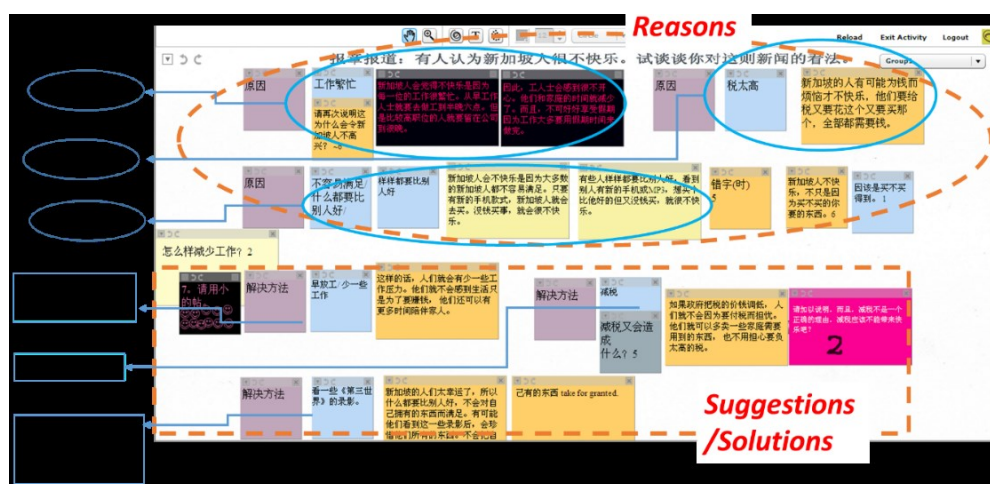


Figure 3. GS screenshot from Group 1 at the end of Lesson 2

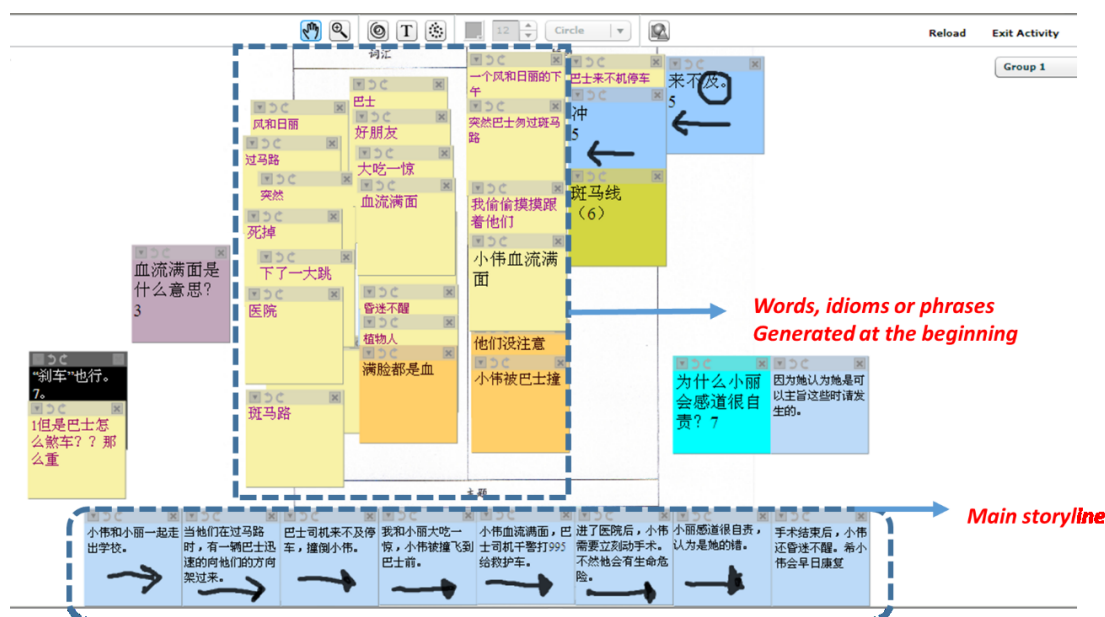


Figure 4. GS screenshot from Group 1 at the end of Lesson 3

The “vocabulary first” activity was designed for Lesson 3 and Lesson 4, in which the task was to make a story based on the given scenario that “when you see your classmates whispering at the school gate, what will you think of?” In Lesson 3, students were asked to start writing by generating vocabulary related to the new topic (Figure 4). In Lesson 4, they were asked to generate main paragraphs with the words/phrases collected in Lesson 3. In the “words/phrases” activity, students were encouraged to contribute suitable Chinese words, phrases, or idioms that could be adopted directly in the final writing. In the process of interacting with others, students could enlarge their vocabulary and equip themselves with better understandings of the collected vocabulary.

4.3. LA module for GS

An analytical module for GS was designed for teachers and researchers to capture and analyse students’ GS-based actions, such as posting, editing, or visiting others’ postings. It could be used both during and after class. With the analytical tool, the actions of each student could be captured and recorded automatically by the data logging mechanism. A large amount of logged data was converted to indicators and visualized to show whether students actively engaged in the learning activity. Underlying the pedagogical concept of RCKI, seven types of action were included in the analytical tool (see Table 1). For instance, the number of “post to board” can indicate whether students participate in idea sharing actively. Whether they have awareness of improving their own ideas (through the number of “edit own post on board”) or modifying answers for others (through the number of “edit another post on board”) can be reflected as well. The unit of analysis can be an individual student or a group of students.

Table 1. Action indicators based on the logged data.

No.	Action	Description
1	Post to board	Create a scribble note and post (move) to the public board
2	Edit own post on board	Edit the content of the scribble note that is posted on the public board. The scribble note is posted by the same user.
3	Edit another post on board	Edit the content of the scribble note that is posted on the public board. The scribble note is posted by a different user.
4	Repost own post to board	Move the scribble note that is posted on the public board to the private board, and then put it back on the public board. The scribble note is posted by the same user.
5	Repost another post to board	Move the scribble note that is posted on the public board to the private board, and then put it back on the public board. The scribble note is posted by different users.
6	Delete own post from board	Delete the scribble note from the public board. The scribble note is posted by the same user.
7	Delete another post from board	Delete the scribble note from the public board. The scribble note is posted by a different user.

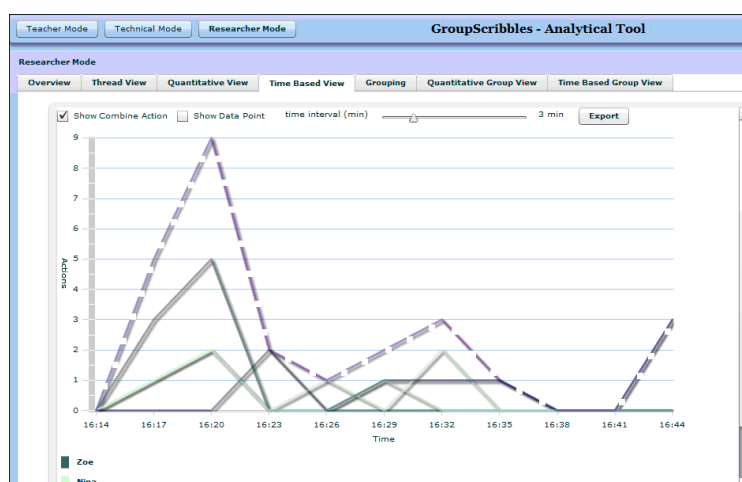


Figure 5. Time-based actions of a group of students

Figure 5 is a screenshot of the analytic tool’s interface. It displays time-based actions of a group of students, via “Time Based View.” In the graph, the X-axis refers to time and the Y-axis refers to the number of actions. The solid lines in different colors represent different student actions and the dashed line reflects the time-based actions of the whole group. It can be read from the graph that the GS-based activity started from 16:14 and lasted

for 30 minutes until 16:44. After the point of 16:23, the number of group actions dropped to a low level. The group actively participated in the first 9 minutes of the activity.

4.4. Data sources

In order to reduce the risk of bias and enhance the trustworthiness of our findings, we re-coded the existing data from multiple sources and collection methods (Lincoln & Guba, 1985). More specifically, there were five types of data: (1) lesson plans; (2) field notes from each post-lesson discussion; (3) teacher's interviews; (4) screenshots of LA findings; (5) screenshots of student-generated artefacts. We then triangulated these multiple sources of data.

- (1) **Lesson plans:** Before every GS lesson, Mdm Y designed a lesson plan and shared it with the research team, based on the RCKI concept and its related design principles. The research team provided feedback and suggestions to her before each lesson. A total of 8 lesson plans about GS-based collaborative writing were co-design.
- (2) **Field notes from each post-lesson discussion:** We immediately conducted a post-lesson discussion with Mdm Y after each GS lesson. The purpose was to encourage the teacher to reflect on her lesson design and enactment. During the process, we shared class observation notes and LA results drawn from the analytical tool with her. The first author of the research team led these discussions, and all members of the research team (usually 2-3 researchers) kept written field notes of the discussion.
- (3) **Teacher interviews:** We had two formal interviews with the teacher before and after our collaborative respectively. Both interviews were semi-structured and conducted by the first author and lasted about 50 mins. There were some of the same questions in the pre-and post-interview, in order to track the teacher's belief, her understandings of pedagogical design, and the use of LA. The interviews were audio-recorded and verbatim transcribed.
- (4) **Screenshots of LA visualization:** The analytical module for GS was developed and used after the first semester of the intervention, so it was used to analyze the four GS lessons in the second semester. Some representative screenshots of LA findings of the four lessons were saved and shared with the teacher.
- (5) **Screenshots of student-generated artefacts:** After every GS lesson, the research team helped Mdm Y to do a screenshot of each group's artifact. Then, Mdm Y printed out these screenshots and shared them with students as supporting materials for subsequent individual writing. In this paper, we did not investigate the process and effect of the learning activities via these student-generated artefacts, because that was not the focus of this paper. We mainly used these screenshots to explain the activity designs and to support the findings drawn from the LA tool.

4.5. Data analysis

For the present study, summarized data from the original set were re-revisited in light of the framework of LA, LD, and teacher inquiry. Narrative analysis was used to interpret the connection between LD and LA, in terms of lesson plans, field notes, screenshots of LA visualizations and student-generated artifacts in a storied form (Webster, & Mertova, 2007). In order to identify the factors that influence and shape teacher inquiry when connecting LA and LD, thematic analysis was adopted to identify and analyze patterns of meaning from field notes and teacher interviews (Clarke & Braun, 2017). The first author identified the recurring themes in the data set that reflect the teacher's beliefs, her understanding of pedagogical design, and the use of LA. The second author helped to check and add inputs for revisions. Data sources and analytic approaches are presented in Table 2.

Table 2. Data sources and analytical approaches

Data source	Analytic approach	Q1	Q2
(1) Lesson plans	Narrative analysis	x	x
(2) Field notes	Thematic analysis	x	x
(3) Teacher interviews	Thematic analysis		x
(4) Screenshots of LA visualization	Narrative analysis	x	
(5) Screenshots of student-generated artifacts	Narrative analysis	x	

5. Results

5.1. LD can guide the design and interpretation of LA on interaction, which in turn inform pedagogical decision-making

Drawn from the GS analytical tool, Figures 6 and 7 represented student's participation at the class level in Lesson 1 ("ideas first" activity) and Lesson 3 ("vocabulary first" activity) respectively. The horizontal axis of the figure represents the time of the class period with an interval of 6 minutes. The vertical axis is the aggregate count of all students' GS-based actions including posting, editing, reposting as well as deleting. Some logged data such as creating a scribble pad without content, undoing or moving were excluded. In terms of the total number of GS-based actions, there was an obvious difference between the "idea first" lesson ($N = 10,030$) and the "vocabulary first" lesson ($N = 9,851$). According to the RCKI principles, at the beginning stage of the GS-based activity, students should be encouraged to post their ideas the more the better. The analytics visualization indicated that students were more actively engaged in the "ideas first" activity than in the "words first" activity in the first 6 minutes of "brainstorming."

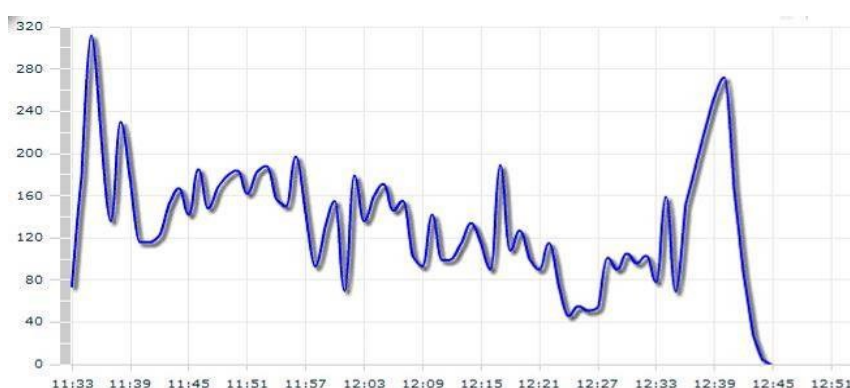


Figure 6. GS-based actions in the "ideas first" activity in Lesson 1 at the class level

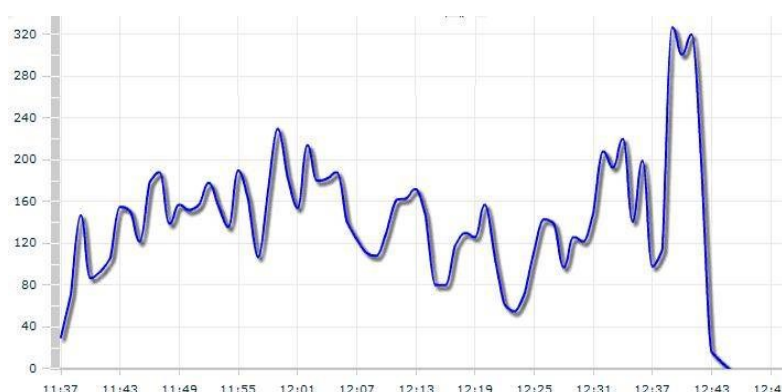


Figure 7. GS-based actions in the "vocabulary first" activity in Lesson 3 at the class level

The GS analytical tool could help teachers to visualize students' participation at the group and individual level as well. Here we showed the findings at the group level to interpret them based on the pedagogical designs. Figure 8 compares the participation levels of the two target groups (Group 1 and Group 6) in the "ideas first" and "vocabulary first" activities. As shown by the LA results, different pedagogical approaches of "ideas first" and "vocabulary first" had an impact on the participation level of groups with different language proficiency. Group 1 with lower language proficiency (an average of 20 actions per 6 minutes) was even more actively engaged in the "ideas first" activity than Group 6 with higher language proficiency (an average of 17 actions per 6 minutes). Nevertheless, the difference in participation between the two groups was not prominent in the "Vocabulary first" activity (both averaged 18 actions per 6 minutes).

In addition, no matter in Lesson 1 or Lesson 3, a massive jump of actions could be observed in Group 1, but it was not obvious in Group 6. The two peaks occurred at the time that the teacher asked the students to further refine their own postings, after visiting other groups' artifacts and providing comments for others. The LA findings illustrated that compared with Group 6, Group 1 with lower language proficiency revised their work more intensively. Yet it was indeed uncommon that nearly 100 actions occurred in such a short time in a group.

This might also have something to do with the group's habit of using GS. They might drag all the postings back to the private board and then repost them to the public board for re-organization. Nevertheless, it was a good sign that the group was working actively as a group to improve their group's artifacts. In this sense, it might be further interpreted that further scaffoldings at the social plane should be provided to the students in the high ability group, to encourage them to participate in the collaborative knowledge improvement more actively and improve their knowledge consistently. On the other hand, further scaffoldings at the cognitive plane were more essential to the students in the low ability group to make sure their more sustained knowledge improvement.

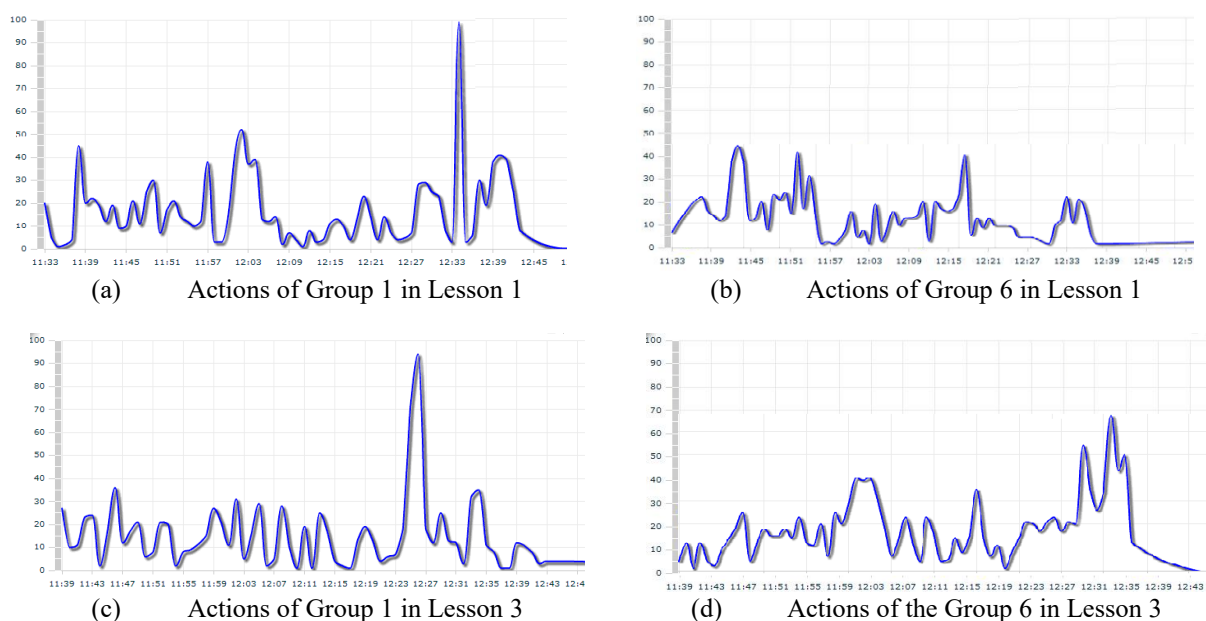


Figure 8. GS-based actions in the “ideas first” (a and b) and “vocabulary first” activities (c and d) at the group level

The lower-ability students typically had very low motivation to participate in Chinese writing. After the researchers shared with Mdm Y the LA results, she said “Initially, I did not expect the lower ability group would complete the task well.” Moreover, to the surprise of the teacher and the researchers, the GS-based group artifacts generated by the lower-ability group were even better than those generated by the higher-ability group in the “idea first” activity, in terms of the richness of and logic of ideas (Group 1’s final artifact was shown in Figure 4, and Group 6’s artifact was shown in Figure 9). Mdm Y said with the feedback, she would be more confident in providing students more time to reflect, involve, and revise their artefacts.



Figure 9. GS screenshot from Group 6 at the end of Lesson 2

The case demonstrated the synergistic relationship between LD on interactions and LA. Although the GS LA module was far from an ideal analytic tool, its findings concentrating on students’ social participation at multiple

levels (class and group levels) could help teachers to monitor students' learning process and make pedagogical decisions. For instance, what length of time should provide for students' online brainstorming; more supports should be provided to the lower ability group at the stage of refined their group artifacts; as well as the "idea first" approach was more appropriate to L2 learners than the "vocabulary-first" approach in collaborative writing.

5.2. Factors influenced and shaped teacher inquiry when connecting LA with LD

5.2.1. Teacher beliefs about and capacity for pedagogical innovation

The interview data demonstrated that Mdm Y held the belief of adopting an innovative approach in her Chinese language teaching. She had motivation and aspiration to change the traditional teaching approach, and she was open to new teaching approaches. As she shared with the research team, even though sometimes the outcomes of innovative approaches were not very positive, she still believed that the diversity of teaching approach helped to improve students' language learning interests. Yet she also mentioned that she was conservative on using technology before the GS lesson. As an experienced teacher, it was not difficult for her to design the first GS lesson. After our first professional development session, she showed confidence in the activity design and shared her lesson plan with us in a short time. The first lesson in the first semester was about describing people and personal qualities, focusing more on vocabulary. However, soon after, she began to realize that in this kind of design, students were difficult to be involved in consistent deep interactions after sharing vocabulary. That was why the pedagogical question was proposed, and the comparison between the approaches of "idea first" and "vocabulary first" were conducted.

When Mdm Y was asked what the biggest challenge she faced in designing GS lessons in the post-interview. She said "the biggest challenge is to be able to reflect the principles of using GS. That is the first point. The other point is how I select a proper topic... I need time to... slowly, I mean, to just come up with the right design for the lesson plan." It demonstrated that the teacher gradually had a better understanding of the design principles of rapid collaborative knowledge improvement, and she began to realize that there was a big difference between the learning activity design emphasized collaborative knowledge construction and the learning activity design mainly concentrated on the transmission of content knowledge. The teacher was eager to learn as she was keen on making pedagogical innovations.

5.2.2. Participatory culture between teachers and researchers

Mdm Y attributed the success of her lesson designs to the collaboration with the research team. She said in the post-interview "I spent a lot of time thinking about what if they (students) were not collaborating. So it is important that I work with you (the first author). Basically, you are half the brains behind this. In the course of (planning) lessons. We are indeed collaborating on this."

Meanwhile, although Mdm Y felt the LA findings we shared with her in post-lesson discussions were interesting and helped her to be more confident to make pedagogical decisions, she also mentioned that she did not have much time to check LA results in the class. It was not easy for her to interpret the results and she was overwhelmed by answering students' answers and observing their posting on GS boards. According to her feedback, it was more straightforward for her to monitor students' learning via viewing students' artifacts shared in the public boards. However, she also mentioned that the LA tool helped to provide her with a holistic picture of student participation. Without the LA tool, it was hard to capture these pieces of information as students were keeping on posting on the GS board during the activities. With the researchers' elicitation and facilitation in how to interpret the LA results based on rapid collaborative knowledge improvement design principles during the post-lesson discussions, the teacher was able to understand how to take advantage of LA on interactions to monitor learning processes and even predict collaborative learning effectiveness.

6. Discussion

6.1. LA on interactions and LD were mutually beneficial in language learning

The GS-based study showed that LA on cognitive interactions could make group participation at multiple levels in the collaborative learning process visualized. The results of LA informed LD regarding the pedagogical

strategy (“idea first” strategy in this case) that could better be used for collaborative language learning. In the classroom environment, informed by LD, LA on interactions at the group level might be more effectively help teachers monitor learning processes and make pedagogical decisions.

The majority of existing studies on LA in LD has focused on distilling common linguistic mistakes that students have made (Godwin-Jones, 2017), identifying student behavioral patterns (Gelan et al., 2018), examining student self-regulated learning (e.g., Li et al., 2018), or investigating LA’s impact on student academic performance (e.g., Mouri et al., 2018), especially in higher education. Although Hu’s (2017) study adopted LA in enhancing learners’ collaborative writing, it focused on assessment and identifying at-risk students instead of analyzing social interactions at multiple levels. This present study was unique in that it demonstrated how LA on interactions and LD were mutually beneficial in language learning in classrooms.

In addition, it is also noted that in this study, the synergy between LA and LD lies in the visualization of interactions in the social constructivist theory-led design of collaborative learning activities, which has rarely been found in current LA studies on collaborative writing LD. The example of LA on interaction at the pre-writing stage underpinned by rapid collaborative knowledge improvement design principles shows that LA can better inform pedagogical decision-making when collaborative writing LD is grounded with sound theories. According to Yim and Warschauer (2017), this is the research area that still needs to be further explored.

6.2. Teacher inquiry mediating the connection between LA and LD

The GS-based case study provided an example to explain how LA supported teacher inquiry to make evidence-based pedagogical decisions. The L2 teacher defined a burning question (“Idea first” or “vocabulary first,” which approach is more effective in GS-based collaborative L2 writing) that emerged from her practice of using a GS for improving students’ collaborative writing. Indeed, the findings towards the first research question of this study suggested that the LA results were instrumental in making pedagogical decisions. Yet the teacher played a mediating role, and the process of teacher inquiry depended on factors regarding teacher beliefs, a collaboration between researchers and the teacher, and the usefulness of the visualization results.

As the teacher held beliefs of adopting the innovative pedagogy in her teaching, she was keen on collaborating with the researchers and being involved in LD. However, she encountered some difficulties in designing and enacting GS-based activities underlying the rapid collaborative knowledge improvement, and her self-use and interpretation of LA results were quite limited. There might be two possible reasons. One was that this technology-enhanced collaborative writing approach was still new to the teacher. Even with the collaboration between the research team, the teacher still needed time to internalize her understanding of learning activity designs. The cognitive load on the teacher is high during enactment of the computer-supported collaborative learning activities (Prieto et al., 2014). The other reason was because of the frustration in understanding the visualized LA results. Asynchronous analytics interpreted together with the research team, helped the teacher to compare group performances, and make a pedagogical decision. LA, both in asynchronous and synchronous forms can provide opportunities for insights into the language learning process (Reinders, 2018). Ideally, in this case, the teacher would be able to use synchronous analytics to provide more targeted supports to groups in the classroom environment. LA tool introduced in the study still has room for improvement both in functionality and visualization. Future research on teacher inquiry and LA needs to be conducted based on more powerful and user-friendly LA systems and pay attention to both synchronous and asynchronous forms of LA.

Despite the recognition that teachers should be equipped with data for teacher inquiry, there is a dearth of research on how to improve the capacity of teachers to use data (Mandinach & Jimerson, 2016). Existing studies focus on investigating teachers’ beliefs about data use (e.g., Datnow & Hubbard, 2016; Reeves & Chiang, 2019). The findings of this study suggest that teachers’ beliefs about the innovative pedagogical approach may affect their beliefs about data use. On the other hand, existing studies show that innovation-oriented teacher beliefs and participatory culture can influence teacher inquiry and LD (e.g., Song & Looi, 2012). This study demonstrates that the participatory culture between teachers and researchers should be highlighted across the processes of LD, transforming data into information, and transforming information into a decision.

6.3. Limitation of this study

There is no denying that this study has some limitations. First, as we discussed, the LA tool introduced in the study is far from satisfactory in visualizing interactions for RCKI. The retrospective analysis of the study aimed

to provide some insights into the design of LA tool to enable a fine-grained analysis of the collaborative writing process based on social constructivist theories. Secondly, investigating the interplay of LA, LD, and teacher inquiry should be a longitudinal and cyclic process. The case shared in this paper did not go further to collect the data from redesigning and implementing refined learning activities. Further research needs to focus on empirical studies to examine the synergistic relationships among LA, LD, and teacher inquiry longitudinally and at a larger scale to enhance L2 classroom teaching and learning.

7. Conclusion and implications

This study investigated the use of LA in language learning classrooms via exploring the synergistic relationships among LA, LD, and teacher inquiry in a case of collaborative L2 writing. The findings show that (1) LA focused on interactions could inform pedagogical refinement effectively when LD in language learning was premised on social constructivist theories; and (2) LA supported teacher inquiry and LD on condition that the teacher held innovation-oriented beliefs and was keen on collaboration with researchers and professional development.

The implications of this study are twofold. Firstly, as LA is concerned with how to provide teachers with relevant, understandable, and actionable information (Rodríguez-Triana et al., 2018), the study suggests that the indicators and visualization of LA may need to be more straightforward to reflect the collaborative writing process underpinned by sound theories, which, in turn, can inform teacher inquiry and LD. Secondly, teachers' beliefs about the innovative pedagogical approach and teacher-researcher collaboration are critical for teacher inquiry in innovative language LD and practices, which can help the teacher make sense of LA for pedagogical refinement to improve interactions in collaborative language learning. Teachers' professional development on innovative pedagogies should take precedence over their professional development of data literacy.

Acknowledgement

This study is funded by Education Research Funding Programme, National Institute of Education (NIE), Nanyang Technological University, Singapore, with project no. OER 02/20 WY. The data for retrospective analysis is based on the work supported by the National Research Foundation (Singapore) under Grant NRF2007-IDM003-MOE-001. We are grateful to all the researchers, teachers, and students participated in the project.

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