Received 1 June 2015
Revised 27 August 2015
Accepted 14 January 2016

Collaborative writing with wikis: an empirical investigation

Helen S. Du
School of Management, Guangdong University of Technology, Guangzhou, China and
Institute of Big Data Strategic Research, Guangdong University of Technology, China
Sam K.W. Chu
Faculty of Education, University of Hong Kong, Hong Kong, Hong Kong
Randolph C.H. Chan
Department of Psychology, The Chinese University of Hong Kong, New Territories, Hong Kong, and
Wei He
Department of Management and Marketing, The Hong Kong Polytechnic University, Kowloon, Hong Kong

Abstract

Purpose – The purpose of this paper is to investigate the process and interaction among group members using wikis to produce collaborative writing (CW) projects, and to compare their collaborative behavior among students at different levels of education.

Design/methodology/approach – The study investigated the participation and collaboration of Hong Kong primary school, secondary school, and university students in the process of developing their wiki-based CW projects. Both qualitative and quantitative data were obtained from analyzing the revision histories and the content of wiki pages.

Findings – Results indicated that the level of education significantly affected student CW actions, and their interaction and coordination behavior to co-construct the work. Also, the frequency of collaborative activities varied noticeably among the primary, secondary, and university students.

Practical implications – The study enriches our understanding of the complex and dynamic process of CW using wikis. It has practical implications on why and how the pedagogy and technology should be implemented differentially for the students at three different levels of education to facilitate collaborative knowledge construction.

Originality/value – Research to date is still lacking an in-depth knowledge about the processes and activities involved when students write collaboratively on wikis. Also, no study has yet compared the collaborative behavior among students at different levels of education. The results of this study contribute to the development of new and appropriate modes of group-based collaborative learning at all levels of the education system for the twenty-first century.

Keywords Wiki, Collaborative behaviour, Collaborative writing, Social media adoption

Paper type Research paper

Introduction

Wikis, as a well-recognized social media tool, have been gaining momentum and popularity in the educational sector ever since they made their debut in the early 1990s. Educators have seen in them a multitude of possibilities for teaching and learning

This work was supported by the National Natural Science Foundation of China fund (No. 71572050) and the Guangdong Graduate Education Innovation Project fund (No. 2016XSLT17).

Online Information Review
Vol. 40 No. 3, 2016
pp. 380-399

1468-4527
DOI 10.1108/OIR-06-2015-0173

across disciplines and levels of education, especially regarding their potential with the rapidly growing wiki applications in collaborative knowledge construction (Caverly and Ward, 2008). One particularly popular use of the wiki is as a tool for collaborative writing (CW), in which two or more authors share responsibility for the creation of a single document (Dillon, 1993). So far, the use of wikis for CW varies widely, ranging from story writing among students in the language classroom (e.g. Castañeda and Cho, 2013) to group report writing in inquiry-based projects (e.g. Biasutti and EL-Deghaidy, 2015), at all levels of education, from primary school pupils to university students. The potential of the wiki as a CW tool has attracted the attention of researchers in recent years. An emergent body of research has been done on wiki-based CW, focussing on its design, implementation, and impact on collaborative knowledge construction (e.g. Hadjerrouit, 2014).

Despite these studies, there is still a dearth of in-depth knowledge about the processes and activities involved in students interacting with and learning from each other when they write collaboratively on wikis. Since CW on wikis is a social act involving a number of people, it is a complex and dynamic process consisting of individual writing actions as well as group dynamics (such as how the work is distributed and coordinated among group members, and how members interact and communicate with each other to co-construct the work). It is important to have a clear understanding of the collaborative activities involving both content input actions and comment actions on wikis in the CW process, in order to guide the effective and efficient design and implementation of collaborative knowledge construction. In addition, no study has yet compared students' collaborative behavior at different levels of the education system. This paper therefore presents an exploratory study of wiki-based CW among primary school students, secondary school students, and university students in Hong Kong. The purpose of the study was to examine the behavior of students in wiki-based CW process at different levels of the education system. Based on data drawn from the students' group report revision and comment history on wikis, the study aimed to evaluate and compare the participation and collaboration of students at each of (and among) the three levels of education, and to understand the collaborative activities (i.e. patterns and frequencies of input/comment actions), and the distribution and coordination of work among group members in co-developing the CW projects on wikis.

Literature review

CW has long been used in a wide range of educational settings (e.g. Speck *et al.*, 1999). Its pedagogical value is rooted in social constructivist theories of learning. Grounded in the work of Vygotsky and Bruner, social constructivism views cognitive development as a socially situated process (Kim, 2001). Individuals build on their knowledge and skills through social interaction with more capable others, who provide them with the assistance they need to go beyond their existing levels of development. Such assistance is now commonly referred to in the literature as "scaffolding," a metaphor introduced by Wood *et al.* (1976). In a classroom context, scaffolding can be provided not only by teachers but also by peers. Research has shown that people engaging in pair or group work are able to support each other in the processes of information seeking (Shah and Marchionini, 2010), information retrieval (Mohammad *et al.*, 2015), knowledge building (Lai and Law, 2006), critical thinking (Sharma and Hannafin, 2005), problem solving (Fawcett and Garton, 2005), and language acquisition (Donato, 1994). Accordingly, learners should be given the opportunity to participate in activities that encourage social interaction and peer-influenced learning.

CW is a typical example of these collaborative activities. It involves multiple learners in the co-production of different aspects of the writing, ranging from content, structure, and language usage. Also, it introduces collaboration between a group of learners from the early stage of planning to the later stage of revising and editing. In the initial stage, CW provides the opportunities for collective brainstorming through interacting and commenting on each other's work, which facilitates idea development and enhances creative writing (Vass *et al.*, 2008). Unlike individual writing, CW affords the learners to review the co-created texts and generate feedback for their peers to improve the organization and mechanics of the writing. The extent and intensity of these collaborative editing process enhances the effectiveness of knowledge building (Swain, 2006). Empirical studies have indicated that the products co-created by CW had higher grammatical and lexical accuracy (Dobao and Blum, 2013) and greater linguistic complexity (Storch, 2005), compared with the individually written products.

Besides collaborative activities, previous studies have also investigated the work distributed and coordinated among the collaborating group members by means of the division of labor in the CW process. Morris and Horvitz (2007) highlighted that the collaborative process enables individuals with different sets of skills to pool their individual resources and contribute their strengths based on the division of labor, thereby fostering effective task accomplishment. According to Lowry *et al.* (2004), there are five different forms of distributing and coordinating work in CW: single-author writing – one group member writes as a representative for the entire group; sequential single writing – each group member is assigned a portion of the document, writes his or her portion and then passes the document onto the next group member; parallel writing – a group divides the writing into separate parts, and all members work on their assigned parts at the same time; reactive writing – group members react to and revise each other's contributions to develop their product; and mixed mode – a combination of two or more of the patterns described above.

The emergence of wiki technology has opened up new possibilities for implementing collaborative learning (Carroll *et al.*, 2013; Li *et al.*, 2014). Many online platforms have been developed and implemented to allow multiple learners to co-create and co-edit the web content collectively through a web browser, such as Search-Together (Morris and Horvitz, 2007), ClassSearch (Moraveji *et al.*, 2011), Classroom Wiki (Khandaker and Soh, 2010), MediaWiki (Hadjerrouit, 2011), and Wikispaces (Lee, 2013). These wiki-based CW tools (or wikis in short) provide users with synchronous access, version control, change tracking, and comment functionalities, which are beneficial to the collaborating writers (Noël and Robert, 2004). Easily accessible and functional, a wiki is seen as a viable tool to extend CW beyond the confines of the traditional classroom. It provides a virtual platform for collaborating learners to have immediate access to the latest version of their joint written work and serves as a ubiquitous means of coordinating their writing efforts. At the same time, educators can make use of the same platform to access every version of the students' developing work and offer appropriate support and scaffolding without the constraints of time and space. This makes the study of the wiki's educational potential rather important.

However, research on the educational use of wikis in CW is limited. Most of the existing studies seem to fall into two categories. The first category of research is prescriptive, with a focus on the pedagogical design, implementation and evaluation of wiki-based CW. The second category of research is exploratory, with the general aim of observing and analyzing the interplay between learners and the wiki's CW environment. It constitutes most of the current research, with active contributions

from various fields of education. Our review of this growing body of research has shown an intricate and dynamic picture of wiki-based CW in the classroom. Its findings have offered insights into the use of wikis in CW from three perspectives: students' perceptions, written products, and writing processes. Table I outlines existing prescriptive and exploratory studies on the educational use of wikis.

A sizable amount of research has been conducted to investigate students' perceptions of the use of wikis in CW. Much of the research has shown that students tend to have positive views of CW with wikis (Mirk *et al.*, 2010). They considered wikis as useful tools for facilitating better writing (Elola and Oskoz, 2010), team interaction (Woo *et al.*, 2011), and intragroup collaboration (Chao and Lo, 2009). In comparison, research is less conclusive concerning the effects of wiki-based CW on students' written

	Prescriptive study	Exploratory study
Perception	A CW approach to wiki development based on rapid prototyping was proposed and found to support discussion and information sharing (Hadjerrouit, 2011)	Wiki enhanced organization and the reflective aspect of learning, and facilitated mutual learning (Wang *et al.*, 2013)
	Students showed positive perceptions of the implementation of a wiki-based CW project with a five-stage writing process (Chao and Lo, 2009)	Wiki improved teamwork and supported collaborative learning (Woo *et al.*, 2011)
		Students showed positive attitudes toward collaborative use of a wiki (Mirk *et al.*, 2010)
		Wiki enriched the content and structure of writing (Elola and Oskoz, 2010)
Written product	A V.S.P.O.W CW approach was implemented and found to be conducive to linguistic skills enhancement among the students (Wong *et al.*, 2011)	Students produced longer and more coherent texts during CW on wikis (Mak and Coniam, 2008)
	The implementation of classroom wiki was shown to improve students' attainment of collaborative learning outcomes and facilitate teachers' assessment of students' writing contributions (Khandaker and Soh, 2010)	The texts collaboratively produced on wikis tended to be longer and more accurate than the texts produced by individuals (Liou and Lee, 2011)
		CW with wikis contributed to significantly higher levels of writing quality and user satisfaction with the writing output, compared with writing in MS Word (Shu and Chuang, 2012)
Writing process	Survey grids and ad hoc formulae were developed to evaluate the students' wiki participation and contribution (Trentin, 2009)	Three patterns of wiki interaction were identified among small online writing groups: collectively contributing/mutually supportive, authoritative/responsive, and dominant/withdrawn (Li and Zhu, 2013)
	Hazari *et al.* (2009) explored the pedagogical effectiveness of using wiki in terms of learning/pedagogy, motivation, group interaction, and technology, and provided the best practice of using wiki to develop pedagogically effective CW environments	Only a minority of students made most of the comments contributed and interacted with group members through the comment function (Judd *et al.*, 2010)
	Meishar-Tal and Gorsky (2010) used a refined taxonomy to categorize the actions performed on wikis, and revealed that the students mostly added content to the wikis but rarely deleted the existing content	

Table I.
Educational use of wikis

products. There is still not enough research into the topic to make any significant generalizations. Nevertheless, a few studies have suggested that wikis have the potential to enhance the writing output of collaborating learners in terms of length (Mak and Coniam, 2008; Liou and Lee, 2011), quality (Shu and Chuang, 2012), coherence (Mak and Coniam, 2008), and accuracy (Liou and Lee, 2011). Research on the processes involved in students' CW with wikis is equally limited. Most available studies have been conducted in the fields of first and second language learning, with a common focus on the activities and interactions of learners in relation to different elements and stages of writing (e.g. Hazari *et al.*, 2009; Li and Zhu, 2013). Only recently researchers have started to investigate how students act and interact in the CW environment with wikis (Judd *et al.*, 2010; Meishar-Tal and Gorsky, 2010).

The literature shows that research on wiki-based CW and group learning has been dominated by perception-based studies and empirical research mostly at the university level. Very little work has been done on students' collaborative activities and coordination patterns during the process of CW, especially at the primary and secondary school levels. Moreover, no research has been conducted to compare the use of wikis in CW at all three levels of education. The present cross-education-level comparison study attempted to fill the research gap by examining and comparing how these different levels of student groups engaged in the process of CW on wikis. Using a mixture of qualitative and quantitative data derived from the students' input and comment actions and group dynamics (rather than perceptions) on wikis, the study aimed to gain a genuine understanding of the students' collaborative activities and coordination patterns in co-developing their group projects using wikis at `all three levels of education.

Research method

Research questions

This study examined how Hong Kong primary school, secondary school, and university students participated and collaborated in completing their wiki-based CW projects. Since the CW process involves individual report writing actions as well as group dynamics, the study aimed to answer the following four main questions:

(1) What are the patterns of input action performed by the students at different levels of education?

(2) What are the patterns of comment action performed by the students at different levels of education?

(3) How do these students distribute and coordinate their writing work among group members?

(4) What are the frequencies of these collaborative activities involving input and comment actions, and how have they evolved in the CW process?

Participants and settings

The study involved participants ($n = 68$) from all three levels of the education system in Hong Kong: primary school (five groups, $n = 21$), secondary school (five groups, $n = 25$), and university (four groups, $n = 22$). The participants were randomly divided into either four or five groups depending on their total number. They were required to conduct a group project and write their project reports on wikis. They were instructed to use either PBworks (http://pbworks.com/) or Google Sites (http://sites.google.com/) to produce and co-construct their group projects in English. The CW process was done

during the school lessons and at home, but the students were asked to access wikis individually at all times and to participate asynchronously as much as possible to avoid loss of concurrent updates. The primary school students undertook two-month English writing group projects from May to June 2011. The secondary school students worked on Liberal Studies group projects from November 2010 to April 2011. The university students were engaged in Knowledge Management group projects from January 2011 to April 2011. All of them were guided and assisted by their subject teacher during the course of the projects.

Data collection and coding

Two kinds of student-contributed wiki content were collected and analyzed in the study: students' input in their group projects, and students' comment on their group projects. These two types of data were automatically recorded and made available on their group wikis by means of the built-in functions of PBworks and Google Sites.

The input from individual students was accessed through wiki's revision history function, which allowed direct access to all the previous versions of a wiki page, and detailed every change made to the page. Also, the comment that each student in the group wrote and the replies on each wiki page were all kept and accessible on wikis by the comment function. Three types of input and comment data can be captured on students' wiki projects: the name of the student making each change, the date and time a change was made, and the content of a specific change made. These data were used to analyze the type, amount, and frequency of students' input actions and corresponding comment actions performed in the process of co-developing their group projects using wikis.

Coding of input actions. Based on Meishar-Tal and Gorsky's (2010) action taxonomy, which was derived from Pfeil *et al.*'s (2006) categories of change, the student input actions performed on wikis were classified into eight categories, namely "adding," "moving," and "deleting" actions on a sentence, and editing "grammar," "words," "images," "links," and "format" actions within a sentence. These eight categories were further classified as either high-level or low-level input actions. High-level input actions refer to more advanced editing process which involves both review and revision of the structure and content of the writing, whereas low-level input actions refer to elementary input process which consist of either the addition of the new information (e.g. text, image, link) or formatting changes. A diagram of the modified taxonomy of input actions is illustrated in Figure 1. This modified taxonomy offered a hierarchical and cross-disciplinary model for classifying CW actions on wikis, and was adopted in the study to measure students' input actions in the process of co-developing their group projects using wikis. The data of students' input actions were analyzed to assess how much and how often students had contributed directly to the content of their group project on wikis, as well as their coordination patterns during the CW process.

Coding of comment actions. Comment actions performed by the students were classified using a content analysis coding scheme adapted from the work of Judd *et al.* (2010). As described in Table II, this scheme consisted of two main categories: "Nature" and "Target" of the comment actions, with a total of six sub-categories: namely commenting on the "Content," "Form," and "Work" nature; and commenting to the "Individual," "Group," and "Reply" target. The data of students' comment actions were analyzed to understand the patterns of interaction among group members and the frequency of collaborative activities involving comment actions in the process of co-developing their group projects using wikis.

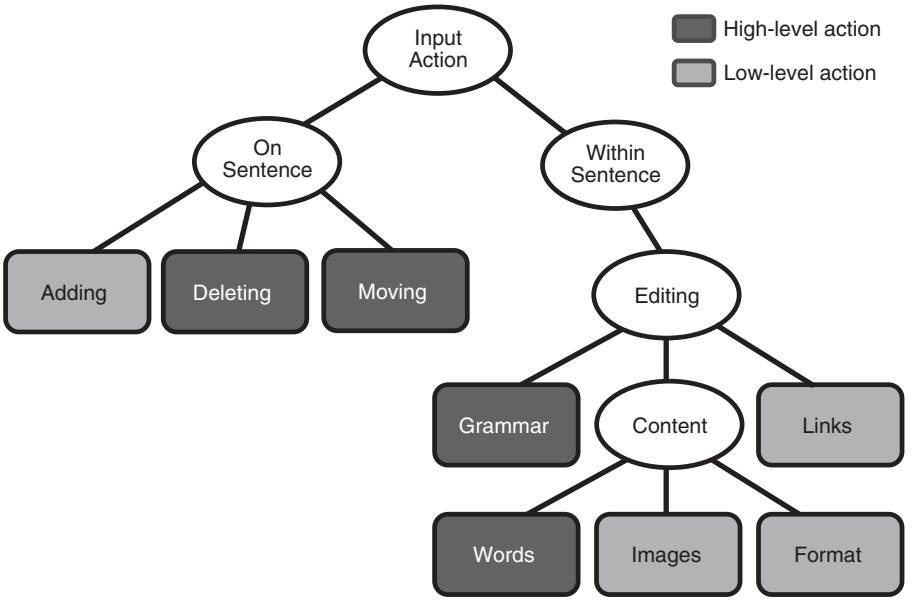


Figure 1.
Categories of input action on wiki

Category	Description
Nature of comment action	
Content	A comment on the selection, organization, and presentation of ideas
Form	A comment on the mechanical aspects of writing, such as grammar, spelling, and format
Work	A comment on the communication and coordination of group work
Target of comment action	
Individual	A comment addressed to an individual group member
Group	A comment addressed to the whole group
Reply	A comment written in response to another comment

Table II.
Categories of comment action on wiki

To ensure the validity and reliability of the study, two coders were hired to code the students' inputs and comments on their wiki-based group projects, based on the abovementioned two coding schemes adapted from prior studies. One coder was responsible for the primary school and university students' data, and the other one coded the secondary school students' data. They each worked independently. To ensure the reliability of their coding, the first coder randomly selected and coded 20 percent of the data for which the second coder was responsible. Inter-rater agreement was 86 percent. Since the coding schemes were quite straightforward, the discrepancies between the earlier and the later coders were largely due to coding mistakes. The two coders were then asked to recode their own responsible data set. After this round of recoding (correction of mistakes), 91 percent inter-rater agreement was reached following the first round of the reliability testing method. The corrected full data set was then used for empirical analysis.

Findings and discussion

Patterns of input action

In general, the university students seemed to write more and write more frequently on their wiki-based group reports than did the secondary and primary school students. On a monthly average, they performed over 15 input actions, while the secondary and primary school students only performed 4.15 and 1.47 input actions, respectively. Following the coding scheme illustrated in Figure 1, the student's input actions on their group wikis were characterized by the addition of sentences and editorial changes, in which "adding" on sentences, and editing "images," "format", and "links" within sentences are low-level input actions, while "moving" and "deleting" on sentences, and editing "words" and "grammar" within sentences are high-level input actions. As shown in Table III, the one-way between-group analysis of variance (ANOVA) tests suggested that there were significant differences in both high-level input actions ($F(2,\ 65) = 31.9,\ p = 0.000$) and low-level input actions ($F(2,\ 65) = 24.26,\ p = 0.000$) between primary school, secondary school, and university students.

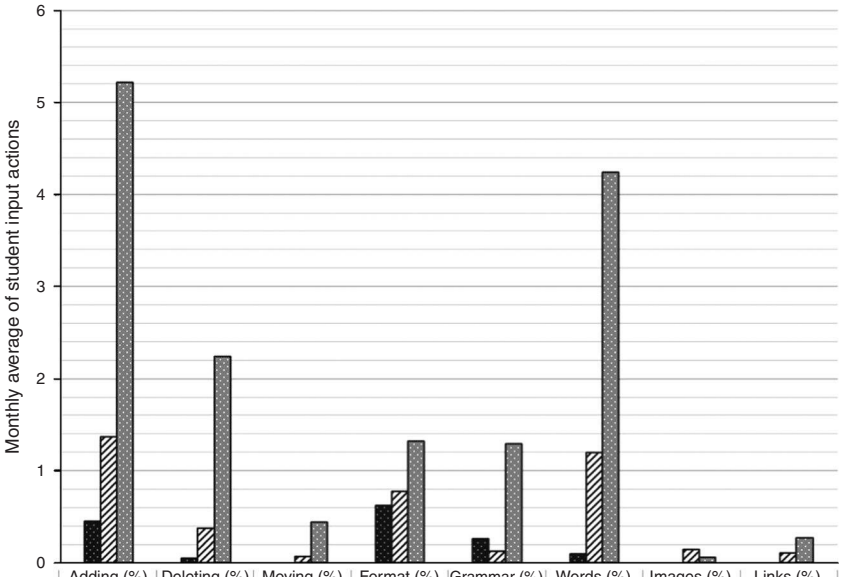
In addition, the within-group two-sample *t*-tests shown in Table III suggest that both primary school students ($t = -2.78,\ p = 0.012$) and secondary school students ($t = -2.97,\ p = 0.007$) performed significantly more low-level actions than high-level actions, but no significant difference was observed for the university students. The detailed distribution of the eight categories of student input actions illustrated in Figure 2 is consistent with the above findings. In particular, the two most frequently performed input actions by primary school students were both low-level actions, such as editing "format" within sentences and "adding" on sentences, which constituted over 72 percent of the total number of CW actions performed. However, more than half of the university students (55 percent) performed high-level actions like "moving" and "deleting" on sentences, and editing "words" and "grammar" within sentences. Secondary school students seemed to stay in the middle, with 42 percent of them made high-level actions. These findings suggest that level of education has a significant impact on students' collaborative input actions, with students at the higher level of education more likely to focus on high-level input actions.

In addition to the above significantly different high-level and low-level input actions found among the students at the different education levels, we also observed some general activity tendencies in the study. First, students at all three levels of education tended to add rather than delete text in the process of CW on wikis. The same tendency was noted by Meishar-Tal and Gorsky (2010) in their respective studies of university students. Second, when writing the wiki-based group reports, both secondary and university students were inclined to focus their content editing efforts on words rather

Input action	Mean (SD)[a] Primary school ($n = 21$)	Secondary school ($n = 25$)	University ($n = 22$)	ANOVA (between group)
High level	0.40 (0.83)	1.76 (2.06)	8.22 (5.63)	31.90 ***
Low level	1.07 (1.45)	2.39 (2.02)	6.86 (4.36)	24.26 ***
t-test (within group)	−2.78 *	−2.97 **	1.71	

Notes: [a]Monthly mean value was used here because of the varying time taken by the primary, secondary, and university students to complete their group projects; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$

Table III. Comparison of student input actions



	Adding (%)	Deleting (%)	Moving (%)	Format (%)	Grammar (%)	Words (%)	Images (%)	Links (%)
Primary	30.56	3.23	0.00	42.10	17.66	6.45	0.00	0.00
Secondary	32.91	8.99	1.61	18.78	3.05	28.73	3.37	2.57
University	34.59	14.85	2.94	8.74	8.59	28.11	0.38	1.81

Figure 2.
Student input actions by category

than format, while the opposite was the case for the primary school students. Third, both secondary and university (but not primary) students seldom edited their group wikis for grammatical errors. The relative absence of grammatical corrections corroborates a similar finding by Mak and Coniam (2008) among secondary school students.

One potential factor influencing our results may lie in the nature of the wiki-based CW task the students were assigned to perform in the study. For the secondary school and university students, the group reports they wrote on wikis were the end products of their liberal studies or knowledge management projects, which accounted for part of their subjects' final grades. In such a context, report writing was not viewed as a language task but as part of a subject-based research project. Accordingly, the secondary school and university students gave priority to the content over the form as they collaborated on their written reports. They focussed their efforts on adding and editing text but paid little attention to the mechanics of writing, as demonstrated in their activity tendencies. In the case of the primary school students, however, the wiki-based CW project was an English assignment and would not count toward their final grades. Therefore, the students had less incentive to focus on content. Also, the fact that it was an English assignment probably explains why the primary school students engaged more in grammatical actions compared with the secondary school and university students in the study.

Patterns of comment action

There was evidence that the group members had interacted and communicated through the wiki comment facility in the process of their project report writing. In the study,

a different pattern of comment actions among the group members was observed at the three levels of education. As a result, the type and amount of wiki comments made by members to complete their group projects and the distribution of these comment actions were analyzed. Following the classification defined in Table II, the students' comment actions on wikis were classified as commenting on the "Content," "Form," and "Work," and commenting to the "Individual," "Group," and "Reply," of which the first three types were the "Nature" of comment actions and the latter three were the "Target" of comment actions. As shown in Table IV, the between-group ANOVA tests suggested that the comment actions made by the primary school, secondary school, and university students on their group work was significantly different, particularly with respect to comments relating to form ($F(2, 65) = 3.4$, $p = 0.04$) and work ($F(2, 65) = 3.44$, $p = 0.038$), as well as to group ($F(2, 65) = 3.22$, $p = 0.046$) and reply ($F(2, 65) = 4.28$, $p = 0.02$). In addition, the within-group ANOVA tests suggested that the primary school students focussed their comment actions significantly more on the wiki content and form than on their group work ($F(2, 19) = 11.69$, $p = 0.000$), while both secondary school ($F(2, 23) = 5.8$, $p = 0.009$) and university ($F(2, 20) = 8.25$, $p = 0.002$) students focussed their comment actions significantly more on the wiki content than on form and their group work. Also, among the primary school students there were significant differences between the number of comments targeting at the individual, group, and reply ($F(2, 19) = 5.37$, $p = 0.014$), while for both secondary school and university students there were no significant differences concerning the target of their comments.

Since the time taken by the students at different levels of education to complete their wiki-based group projects varied, we analyzed the detailed distribution of the group comment actions using a monthly average. The five groups of primary school students posted a total of 39 comments, with an average of 7.8 comments per group, of which content and form constituted over 60 percent. The five groups of secondary school students posted a total of 178 comments, with an average of 35.6 comments per group, of which 31.2 percent concerned content and 26.7 percent were targeted at the group. Similar to the secondary school students, the four groups of university students posted a total of

Comment action	Mean (SD)[a] Primary school ($n = 21$)	Secondary school ($n = 25$)	University ($n = 22$)	ANOVA (between group)
Nature of comment action				
Content	0.48 (0.56)	0.74 (0.78)	0.97 (1.15)	1.72
Form	0.43 (0.62)	0.17 (0.46)	0.08 (0.19)	3.40*
Work	0.00 (0.00)	0.27 (0.49)	0.18 (0.34)	3.44*
ANOVA (within group)	11.69***	5.80**	8.25**	
Target of comment action				
Individual	0.43 (0.46)	0.32 (0.59)	0.31 (0.41)	0.40
Group	0.10 (0.20)	0.63 (0.86)	0.66 (1.11)	3.22*
Reply	0.05 (0.22)	0.23 (0.37)	0.40 (0.53)	4.28*
ANOVA (within group)	5.37*	2.59	1.89	

Notes: [a]Monthly mean value was used here because of the varying time taken by the primary, secondary, and university students to complete their group projects; *$p < 0.05$; **$p < 0.01$; *** $p < 0.001$

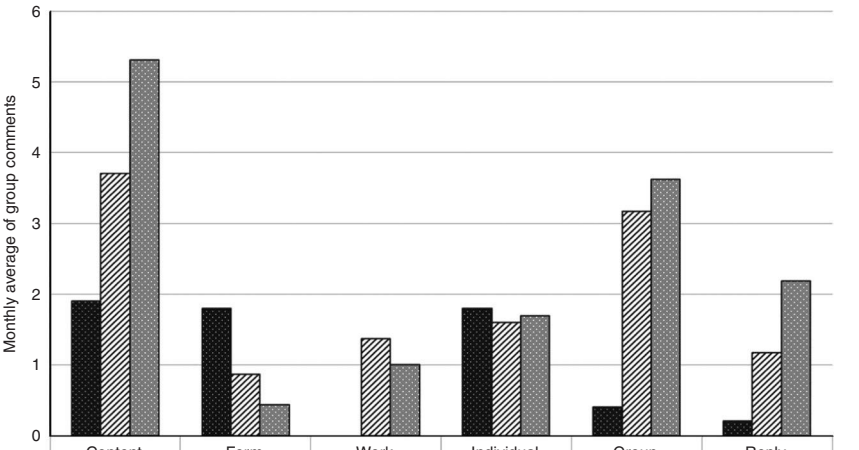
Table IV. Comparison of student comment actions

111 comments, with an average of 27.8 comments per group, of which 37.3 percent concerned content and 25.4 percent were targeted at the group. As illustrated in Figure 3, both secondary school and university students much preferred to focus their comment actions on content over form and work. The primary school students, however, focussed their comment actions largely on content and form, but not at all on work. In terms of the target of comments, the primary school students mainly addressed their comments to an individual group member, while both secondary school and university students' comments were mostly addressed to the whole group. The predominance of students' commenting on "Content" and targeting at "Group" (except at the primary school level) was an indication that students engaged in effective online communication to exchange ideas among group members. The result further suggests that level of education seemed to have affected not only the degree of interaction but also the effectiveness of collaboration.

It is important to note that the students' comment actions do not provide a complete picture of their collaboration in the wiki-based report writing process. As they collaborated on their group reports, they used more than the comment facility on wikis to interact and communicate with their group members. These comments on the group wikis indicated that the students made use of telephones and e-mails to support their CW on wikis. Each group was also given classroom time to work on their report and meet face to face regularly in school. The collaborative activities that the students engaged in through those combined means of interaction and communication were not included in the present analysis. Thus, the patterns of comment actions reported in this study should be treated with great caution. However, the results of this study are an indication of the extent to which the students interacted and collaborated with each other through the commenting facility on wikis.

Work distribution and coordination

During the CW process, group members divide their writing tasks into smaller parts, allowing individual members to pool their resources and contribute their strengths



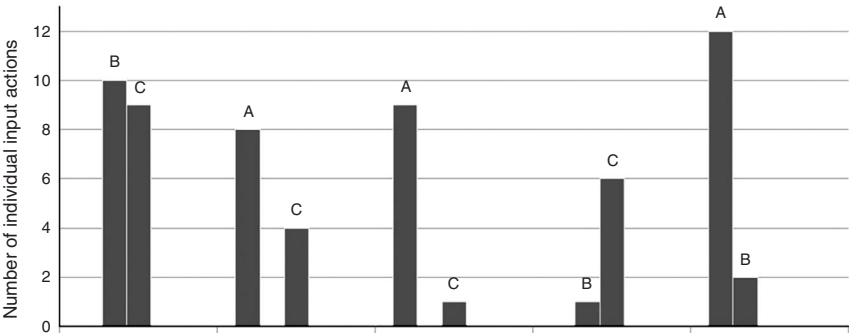
	Nature of comment action (%)			Target of comment action (%)		
	Content	Form	Work	Individual	Group	Reply
Primary	31.15	29.51	0.00	29.51	6.56	3.28
Secondary	31.18	7.30	11.52	13.48	26.69	9.83
University	37.28	3.07	7.02	11.84	25.44	15.35

Figure 3.
Group comment actions by category

based on the division of labor. Hence, the coordination among the collaborating group members of the CW projects in our study was indicated by: the distribution of input actions among group members, and the proportion of input actions performed on individual sections of the project reports by group members. The results of our study suggest that the writing of the wiki-based group reports was not evenly distributed among the students in each group, with the greatest disparity among the group members at the primary school level, less so at the secondary school level, and the least at the university level. Primary school students were observed to have coordinated less among group members than secondary school students, and even less so than university students.

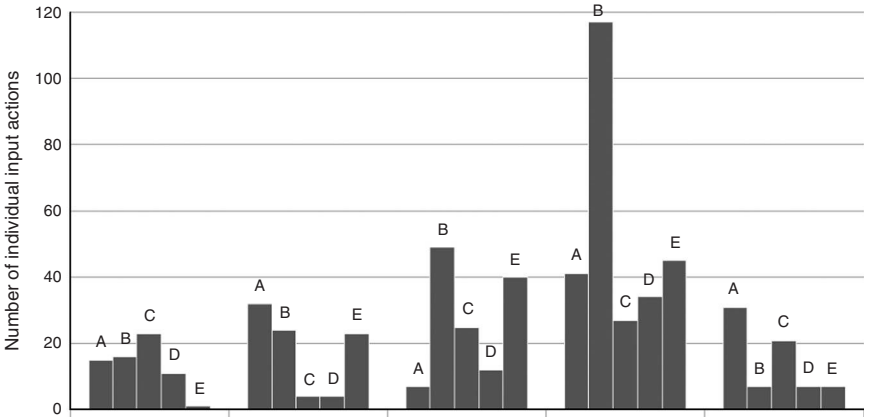
As illustrated in Figure 4, all five primary school student projects were completed by two members in the group, involving only half or even less than half of the group members. The other three members made no contribution to the group report. Over 83 percent of the input actions in three of the five groups were performed by only one student in the group. In the other two groups, student A of Group 2 contributed twice as much input as student C of the same group, while student B of Group 1 performed three times more input actions concerning adding and deleting sentences than student C of the same group, whose primary action (81 percent) was editing within sentences (see the cross-tab of Figure 4). In addition, the study found that 89.2-100 percent of the project report was written by a single author in the primary school student groups.

For the secondary school students, all members in each group contributed their input in the wiki projects, with student E in Group 1 the least active contributor, making only one input (less than 2 percent of the group input), and student B in Group 4 the most active contributor, making 117 input actions (over 44 percent of the group work). As noted in Figure 5, two or three group members tended to contribute more



	Group 1					Group 2				Group 3				Group 4				Group 5			
Student	A	B	C	D	E	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
Adding	0	4	2	0	0	1	0	1	0	3	0	1	0	0	0	4	0	2	1	0	0
Deleting	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moving	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Format	0	4	3	0	0	3	0	3	0	4	0	0	0	0	1	1	0	6	1	0	0
Grammar	0	0	4	0	0	2	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0
Words	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Images	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Links	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4.
Primary school students' individual input actions

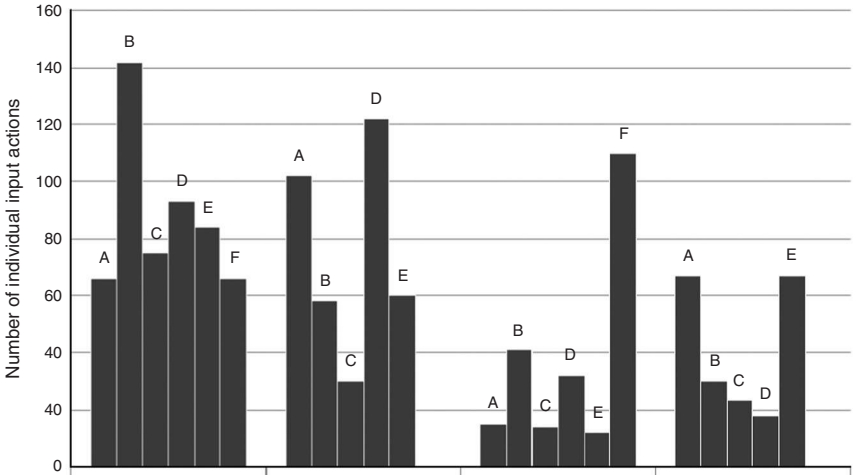


	Group 1	Group 2	Group 3	Group 4	Group 5
Student A	15	32	7	41	31
Student B	16	24	49	117	7
Student C	23	4	25	27	21
Student D	11	4	12	34	7
Student E	1	23	40	45	7

Figure 5.
Secondary school students' individual input actions

than 70 percent of the input actions on each wiki project. A similar disproportion was also evident in the number of actions each student performed on individual sections of the group report. In three of the five groups, at least 75 percent of the report sections were the work of not more than three members. In the other two groups, this percentage was as much as 42 percent. In addition, the detailed number of student input actions on each report section suggested that each section was written by one or more members of the group. Members divided and coordinated the report writing task within the group, with each member focussing more or less on different sections of the report. Also, the group leaders were found to be the key contributors among group members, except for Group 3. Their contributions were relatively large, both in terms of the number of actions they performed and the number of report sections they worked on.

It is noticeable in Figure 6 that the uneven distribution of input actions among the group members at the university level was less than that among the primary and secondary school student groups. Members in each of the university groups all contributed their input in the wiki projects. The lowest number of input actions was that of student E of Group 3, which constituted 5.36 percent (12 actions) of the group work, while the most active person, student B of Group 1, contributed 142 input actions, constituting 27 percent of the group work. Except for Group 3, in which student E alone performed 110 input actions (49 percent of the group work), the work distribution in the other three groups was more equally spread among the group members. The detailed work distribution of the students for each report section also suggested more equal division of labor among group members at the university level than that among the secondary school group members. As a result, over 65 percent of the report sections involved contributions from three or more members in the university student groups. This finding suggests that members need to coordinate their work more effectively in order to complete a group project. For instance, as a given member writes a section, others in the group may review the section and create new sections in response.



	Group 1	Group 2	Group 3	Group 4
Student A	66	102	15	67
Student B	142	58	41	30
Student C	75	30	14	23
Student D	93	122	32	18
Student E	84	60	12	67
Student F	66		110	

Figure 6.
University students' individual input actions

The results of our study suggest that student groups at the different level of education demonstrated different patterns of coordination. The "single-author writing" pattern characterized as a large proportion of the wiki report written by only one group member were typically seen in the primary school student group projects, as this type of coordination involves the minimum activities of planning, drafting, and revising, and usually occurs when the writing task is simple. The secondary school students appeared to have the "parallel writing" characteristic in coordinating and co-constructing their group work. Almost all the groups divided up the writing of their reports, with one or more students responsible for an individual section of the report. The writing actions of the university student groups were more evenly distributed, showing a more even division of labor than that of the secondary and primary school student groups. The university students in our study tended to have a combination of the "parallel writing" and "reactive writing" characteristic. Even without an assigned group leader, some students seemed to take up more than one role within the group, serving in parallel as writers, editors, and reviewers during the report writing process. Compared to the primary school and secondary school students, the university school students also reacted and responded more to each other's comments during the project development process (see also Table IV and Figure 3).

Frequency of collaborative activities

Collaborative activities on wikis refer to both input actions and comment actions. The frequency of these collaborative activities varied across the three educational levels, with the primary school students having the lowest level of collaborative activities and the university students having the highest level of collaborative activities. As shown

in Table V, the majority of the primary (53.4 percent) and secondary (52.0 percent) school students performed input actions less than once a month. On the other hand, the majority of the university students performed input actions (86.4 percent) and made comments (40.9 percent) twice or more than twice a month, which indicated that their participation frequency was much higher than that of the primary and secondary school student groups. The, generally, low frequency of collaborative activities each month at all three educational levels in our study indicates that, although the wiki is said to be an effective CW tool, its actual use by students may not be as satisfactory as it is designed for. This raises questions over the usability and utilization issue of the tool and requires further investigation in future research.

As shown in Figure 7, significant variation was observed in the temporal distribution of wiki input action among the students at different levels of education. Because of the differences in the time taken by the primary, secondary ,and university students to complete their group projects, we used three stages to represent the period of the project: the early stage represents the first one-third of the project period, the middle stage represents the second one-third of the project period, and the later stage represents the last one-third of the project period. As a result, about 44 percent of the primary school students performed their input actions in the early stage whereas the vast majority of the input actions among secondary (79.8 percent) and university (50.8 percent) students occurred in the later stage.

The above frequency of the students' collaborative activities seemed to be indicative of their practical application of wikis during the project development period. The group

%	Less than once a month	Once a month	Twice or more than twice a month
Input action			
Primary	52.4	23.8	23.8
Secondary	52.0	24.0	24.0
University	0	13.6	86.4
Comment action			
Primary	52.4	38.1	9.5
Secondary	12.0	40.0	48.0
University	31.8	27.3	40.9

Table V.
Monthly frequency of collaborative activities

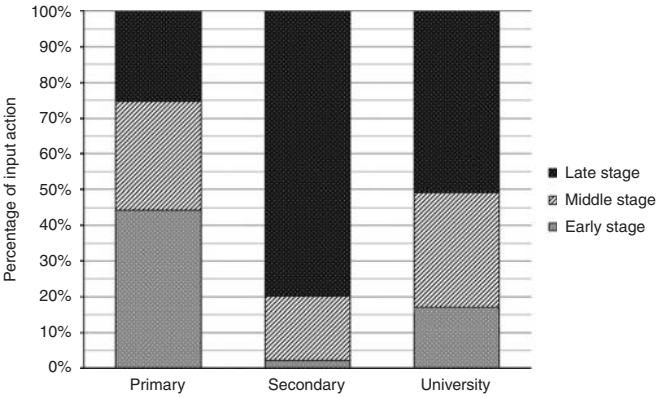


Figure 7.
Percentage of student input action by project stage

wikis were designed as collaborative tools for writing and communicating online, with the purpose of facilitating participation and interaction in the process of CW. In practice, the students in this study utilized their group wikis as a common work platform, where they displayed their work-in-progress or completed work for group members to read, modify, and comment on. Most of them were inclined to contribute the majority of their input actions within a short period of time. Both the secondary school and the university student groups participated more frequently in the last month before the project deadline, while the primary school student groups performed more input actions in the relatively early stage of the project period. This reflects that the university and secondary school students used wikis more as a means of presenting their finished products than as a working tool during the report writing process. The high participation rate for university and secondary school students before the deadline may also be explained by the fact that these students tended to procrastinate (see Steel, 2007 for a review) with regard to their work. A follow-up study may clarify the reasons behind the procrastination of these students, which can be a focus point of our future research.

Conclusion

This study examined the participation and collaboration of Hong Kong primary school, secondary school, and university students in the process of developing their wiki-based CW projects. There were four main findings. First, the level of education had a significant impact on the patterns of input actions, with students at the higher level of education tending to write more and more frequently, and more likely to focus on high-level input actions. Second, through an analysis of the comment actions performed on wikis, the level of education seems to have been related not only to the degree of interaction but also to its effectiveness during the CW process. Third, the collaborating students did not generally distribute the writing tasks on the wikis evenly among group members, with the greatest disparity at the primary school level, less disparity at the secondary school level, and the smallest disparity at the university level. Consequently, students at different levels of the education system tended to have different patterns of distributing and coordinating their work among group members, with primary school students essentially showing a "single-author writing" pattern, secondary school students mainly having a "parallel writing" pattern, and university students primarily having a "mixed mode" pattern. Fourth, the application of a wiki as a CW tool did not necessarily guarantee a high frequency of collaborative activities (i.e. high usage) by students in the CW process. In general, students seemed to participate and contribute most of their work in a short period of time, either toward the end (mostly for university and secondary school students) or at the beginning (mostly for primary school students) of the project development period.

The study has its limitations. First of all, the sample size and the number of groups within each education level were small, which may affect the reliability and validity of the group comparison results. Also, the results of the study may not be generalizable to the entire population. Cultural homogeneity of the sample is another issue in that the participants were all students in Hong Kong. Therefore, caution is needed in applying the results of this study to students in other different cultures. In future research, a culturally comparable sample may be used to compare and identify potential cultural influences in the CW process.

Despite the limitations, the cross-education-level comparison of our study offers insights into the ways in which primary, secondary, and university students make use of wikis for CW. It has theoretical, methodological as well as practical implications for

both educators and researchers in the design, implementation, and use of wiki-based CW for all levels of education. From a theoretical perspective, the study explored and compared the collaborative behavior of student at all three levels of the education system in the wiki-based CW environment, showcasing the potentials and possible pitfalls of wikis for group-based collaborative learning. The study offers insights into the individual students' writing actions and group dynamics, two very important and complex CW components, during the course of producing the collaborative work. Methodologically speaking, the two content coding schemes introduced and used in the study provide a theoretically driven and empirically tested content analysis framework, which can be easily applied to other similar studies in the future. Lastly, the study has important practical implications on why and how the pedagogy and technology should be implemented differentially for the students at three different levels of education. Since primary school students had relatively less sophisticated writing and collaboration skills, as indicated by the low amount of input actions and unequal work distribution, teachers should provide more scaffolding support through active feedback of student work and frequent interaction with students on wikis. As students' skills of writing and collaboration increase with their education, teachers' level of online scaffolding and involvement may be mitigated at the secondary and university levels. Also, given that the primary school students were associated with the least frequent input actions and the greatest disparity in work distribution, the wikis designed for primary school students should involve a notification system to remind the users for update and input. The notification messages should contain a brief report of project progress and inform the users about the relative contribution of each group members, so as to motivate them to take active responsibility and have greater involvement in the CW process.

References

Biasutti, M. and EL-Deghaidy, H. (2015), "Interdisciplinary project based learning: an online wiki experience in teacher education", *Technology, Pedagogy and Education*, Vol. 24 No. 3, pp. 339-355, available at: http://dx.doi.org/10.1080/1475939X.2014.899510 (accessed April 7, 2014).

Carroll, J.-A., Diaz, A., Meiklejohn, J., Newcomb, M. and Adkins, B. (2013), "Collaboration and competition on a wiki: the praxis of online social learning to improve academic writing and research in under-graduate students", *Australasian Journal of Educational Technology*, Vol. 29 No. 4, pp. 513-525.

Castañeda, D.A. and Cho, M.-H. (2013), "The role of wiki writing in learning Spanish grammar", *Computer Assisted Language Learning*, Vol. 26 No. 4, pp. 334-349.

Caverly, D.C. and Ward, A. (2008), "Techtalk: wikis and collaborative knowledge construction", *Journal of Developmental Education*, Vol. 32 No. 2, pp. 36-37.

Chao, Y.C.J. and Lo, H.C. (2009), "Students' perceptions of wiki-based collaborative writing for learners of English as a foreign language", *Interactive Learning Environments*, Vol. 19 No. 4, pp. 1-17.

Dillon, A. (1993), *How Collaborative is Collaborative Writing? An Analysis of the Production of Two Technical Reports*, Springer-Verlag, London, pp. 69-86.

Dobao, A.F. and Blum, A. (2013), "Collaborative writing in pairs and small groups: learners' attitudes and perceptions", *System*, Vol. 41 No. 2, pp. 365-378.

Donato, R. (1994), "Collective scaffolding in second language learning", in Lantolf, J.P. and Appel, G. (Eds), *Vygotskian Approaches to Second Language Research*, Ablex, Norwood, NJ, pp. 33-56.

Elola, I. and Oskoz, A. (2010), "Collaborative writing: fostering foreign language and writing conventions development", *Language Learning & Technology*, Vol. 14 No. 3, pp. 51-71.

Fawcett, L.M. and Garton, A.F. (2005), "The effect of peer collaboration on children's problem-solving ability", *British Journal of Educational Psychology*, Vol. 75 No. 2, pp. 157-169.

Hadjerrouit, S. (2011), "A collaborative writing approach to wikis: design, implementation, and evaluation", *Issues in Informing Science and Information Technology*, Vol. 8, pp. 431-449.

Hadjerrouit, S. (2014), "Wiki as a collaborative writing tool in teacher education: evaluation and suggestions for effective use", *Computers in Human Behavior*, Vol. 32 No. 3, pp. 301-312.

Hazari, S., North, A. and Moreland, D. (2009), "Investigating pedagogical value of wiki technology", *Journal of Information Systems Education*, Vol. 20 No. 2, pp. 187-198.

Judd, T., Kennedy, G. and Cropper, S. (2010), "Using wikis for collaborative learning: assessing collaboration through contribution", *Australasian Journal of Educational Technology*, Vol. 26 No. 3, pp. 341-354.

Khandaker, N. and Soh, L.K. (2010), "ClassroomWiki: a collaborative wiki for instructional use with multiagent group formation", *IEEE Transactions on Learning Technologies*, Vol. 3 No. 3, pp. 190-202.

Kim, B. (2001), "Social constructivism", in Orey, M. (Ed.), *Emerging Perspectives on Learning, Teaching, and Technology*, Jacobs Foundation, Zurich, pp. 300-312, available at: http://projects.coe.uga.edu/epltt/ (accessed June 4, 2011) .

Lai, M. and Law, N. (2006), "Peer scaffolding of knowledge building through collaborative groups with differential learning experiences", *Journal of Educational Computing Research*, Vol. 35 No. 2, pp. 123-144.

Lee, L. (2013), "Exploring wiki-mediated collaborative writing: a case study in an elementary Spanish course", *CALICO Journal*, Vol. 27 No. 2, pp. 260-276.

Li, M. and Zhu, W. (2013), "Patterns of computer-mediated interaction in small writing groups using wikis", *Computer Assisted Language Learning*, Vol. 26 No. 1, pp. 61-82.

Li, X., Chu, S.K.W. and Ki, W.W. (2014), "The effects of a wiki-based collaborative process writing pedagogy on writing ability and writing attitudes among upper primary school students in Mainland China", *Computers and Education*, Vol. 77, pp. 151-169.

Liou, H.C. and Lee, S.L. (2011), "How wiki-based writing influences college students' collaborative and individual composing products, processes, and learners' perceptions", *International Journal of Computer-Assisted Language Learning and Teaching*, Vol. 1 No. 1, pp. 45-61.

Lowry, P.B., Curtis, A. and Lowry, M.R. (2004), "Building a taxonomy and nomenclature of collaborative writing to improve interdisciplinary research and practice", *Journal of Business Communication*, Vol. 41 No. 1, pp. 66-99.

Mak, B. and Coniam, D. (2008), "Using wikis to enhance and develop writing skills among secondary school students in Hong Kong", *System*, Vol. 36 No. 3, pp. 437-455.

Meishar-Tal, H. and Gorsky, P. (2010), "Wikis: what students do and do not do when writing collaboratively", *Open Learning*, Vol. 25 No. 1, pp. 25-35.

Mirk, S., Burkiewicz, J. and Komperda, K. (2010), "Student perception of a wiki in a pharmacy elective course", *Currents in Pharmacy Teaching and Learning*, Vol. 2 No. 2, pp. 72-78.

Mohammad Arif, A.S., Du, J.T. and Lee, I. (2015), "Understanding tourists' collaborative information retrieval behavior to inform design", *Journal of the Association for Information Science and Technology*. doi: 10.1002/asi.23319.

Moraveji, N., Morris, M.R., Morris, D., Czerwinski, M. and Riche, N. (2011), "ClassSearch: facilitating the development of web search skills through social learning", in Tan, D., Fitzpatrick, G., Gutwin, C., Bo, B. and Kellogg, W.D. (Eds), *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, New York, NY, May, pp. 1797-1806.

Morris, M.R. and Horvitz, E. (2007), "SearchTogether: an interface for collaborative web search", in Shen, C., Jacob, R. and Balakrishnan, R. (Eds), *Proceedings of the 20th Annual ACM Symposium on User Interface Software and Technology*, ACM, October, pp. 3-12.

Noël, S. and Robert, J.M. (2004), "Empirical study on collaborative writing: what do co-authors do, use, and like?", *Computer Supported Cooperative Work*, Vol. 13 No. 1, pp. 63-89.

Pfeil, U., Zaphiris, P. and Ang, C.S. (2006), "Cultural differences in collaborative authoring of Wikipedia", *Journal of Computer Mediated Communication*, Vol. 12 No. 1, pp. 88-113, available at: http://jcmc.indiana.edu/vol12/issue1/pfeil.html (accessed April 7, 2014).

Shah, C. and Marchionini, G. (2010), "Awareness in collaborative information seeking", *Journal of the American Society for Information Science and Technology*, Vol. 61 No. 10, pp. 1970-1986.

Sharma, P. and Hannafin, M. (2005), "Learner perceptions of scaffolding in supporting critical thinking", *Journal of Computing in Higher Education*, Vol. 17 No. 1, pp. 17-42.

Shu, W. and Chuang, Y.H. (2012), "Wikis as an effective group writing tool: a study in Taiwan", *Online Information Review*, Vol. 36 No. 1, pp. 89-103.

Speck, B.W., Johnson, T.R., Dice, C.P. and Heaton, L.B. (1999), *Collaborative Writing: An Annotated Bibliography*, Greenwood Press, Westport, CT.

Steel, P. (2007), "The nature of procrastination: a meta-analytic and theoretical review of a quintessential self-regulatory failure", *Psychological Bulletin*, Vol. 133 No. 1, pp. 65-94.

Storch, N. (2005), "Collaborative writing: product, process, and students' reflections", *Journal of Second Language Writing*, Vol. 14 No. 3, pp. 153-173.

Swain, M. (2006), "Languaging, agency and collaboration in advanced language proficiency", in Byrnes, H. (Ed.), *Advanced Language Learning: The Contribution of Halliday and Vygotsky*, Continuum, New York, NY, pp. 95-108.

Trentin, G. (2009), "Using a wiki to evaluate individual contribution to a collaborative learning project", *Journal of Computer Assisted Learning*, Vol. 25 No. 1, pp. 43-55.

Vass, E., Littleton, K., Miell, D. and Jones, A. (2008), "The discourse of collaborative creative writing: peer collaboration as a context for mutual inspiration", *Thinking Skills and Creativity*, Vol. 3 No. 3, pp. 192-202.

Wang, J., Zou, B., Wang, D. and Xing, M. (2013), "Students' perception of a wiki platform and the impact of wiki engagement on intercultural communication", *System*, Vol. 41 No. 2, pp. 245-256.

Wong, L.H., Chen, W., Chai, C.S., Chin, C.K. and Gao, P. (2011), "A blended collaborative writing approach for Chinese L2 primary school students", *Australasian Journal of Educational Technology*, Vol. 27 No. 7, pp. 1208-1226.

Woo, M., Chu, S., Ho, A. and Li, X. (2011), "Using a wiki to scaffold primary-school students' collaborative writing", *Educational Technology & Society*, Vol. 14 No. 1, pp. 43-54.

Wood, D., Bruner, J.S. and Ross, G. (1976), "The role of tutoring in problem solving", *Journal of Child Psychology and Psychiatry*, Vol. 17 No. 2, pp. 89-100.

Further reading

Sharples, M., Goodlet, J., Beck, E., Wood, C., Plowman, L. and Evans, W. (1993), "Research issues in the study of computer supported collaborative writing", in Sharples, M. (Ed.), *Computer Supported Collaborative Writing*, Springer-Verlag, London, pp. 9-28.

Corresponding author
Helen S. Du can be contacted at: hsdu@gdut.edu.cn