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Online Collaboration in a Large University Class Supports Quality Teaching

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Abstract

Quality teaching in large classes is generally challenging to achieve. In large classes, there are fewer possibilities for students to interact with the teacher and with each other; the motivation to study decreases as does the possibility for receiving feedback during the learning process. This can result, among other things, in reduced understanding of the learning material and therefore in lower academic performance. The aim of this study is to investigate whether computer-supported collaborative learning (CSCL) can have a positive impact on aspects of quality teaching such as interaction, motivation and understanding. Two online collaborative activities were designed and implemented in a regularly scheduled course with approximately 200 undergraduate students. This study adopted a mixed method of both qualitative and quantitative analysis: data were collected from surveys, in-depth interviews, forum logs, and exam scores. The results show that CSCL facilitates motivation, interaction and achievement of deep understanding. More particularly, one CSCL activity was found to be a significant contributor to students' academic performance and this confirmed that traditional lecturing blended with CSCL improves the quality of the teaching compared to traditional lecturing only, at least as far as understanding is concerned. Moreover, the study indicates that different types of collaborative activities have different

effects on learning and that the design of collaborative activities is therefore critical to outcomes. In this respect, it also reveals that social loafing, which is usually considered to have only negative effects on collaboration, can instead have a positive impact on learning if the task is appropriately designed.

Introduction

Although quality teaching has gradually become the centre of gravity in the agenda of higher education (High Level Group on the Modernisation of Higher Education, 2013; Authors, 2014), it still presents several challenges in large university classes. The aim of quality teaching is that students reach a deep understanding of the subject content (Entwistle, 2009, Author, 2014) and this requires that they are motivated to learn and they actively engage in focused learning. However, large classes may negatively influence students' motivation as well as their academic performance, resulting in a threat to quality teaching. In fact, in large classes students are often anonymous to both the instructor and to each other. This anonymity may result in diminished personal responsibility for learning, which reduces students' learning motivation (Cooper & Robinson, 2000). Moreover, a number of studies have shown that students in large classes have weaker results than those in small classes in terms of both test scores (Bandiera, 2010; De Paola, Ponzo & Scoppa, 2013) and perceived learning outcomes as assessed by self-report questionnaires (Monks & Schmidt, 2010). Furthermore, traditional lecturing is the dominant method in large university classes (Carbone & Greenberg, 1998; Deslauriers et al., 2011) and this typically reduces students' interaction with both the teacher and their peers.

If it is properly implemented, collaborative learning has the potential to provide important solutions to address these problems. First, it helps to build a learning community for the students, which can reduce feelings of isolation and improve students' motivation to learn (Rovai, 2002). Second, it improves interactions among students through group work, which facilitates active engagement in the learning process (Blumenfeld et al., 2006). Third, it enhances students' understanding of the learning subject by providing new possibilities for student engagement in academic debates (Golbeck & El-Moslimany, 2013). Considering the practical difficulties of realising face-to-face collaborative learning in large classes (time consuming, physical space required, cost of interventions, etc.), Computer-Supported Collaborative Learning (CSCL) could offer an effective strategy. CSCL is a type of collaborative learning that uses a computer: two or more people learn together connected through the internet using software such as social networking tools, and cloud-based or virtual technologies for teamwork (Dillenbourg, 1999; Karadimce & Davcev, 2013; Hamilton, 2007).

However, it is not easy to realise effective collaboration in practice due to issues such as social loafing and process losses. Social loafing describes a phenomenon in which a person exerts less effort to achieve a goal when they work in a group than when they work alone (Latane, Williams & Harkins, 1979; Karau & Williams, 1993). Using the terminology coined by Schnake (1999), social loafers can be distinguished as "free riders" and "suckers". The former includes those group members who do not devote effort to the group task (Kerr & Bruun, 1983; Morris & Hayes, 1997; Joyce, 1999). The latter are active or capable group members who reduce the level of their own effort after they discover free riders in the group (Kerr, 1983; Schnake, 1991). The notion of process losses refers to the fact that at least some members of the group must invest time and cognitive resources to group coordination, instead of using these resources to learn (Steiner, 1972; Hertel, 2011). Both social loafing and process losses may result in inefficiencies for group work.

With the aim of understanding the impact of CSCL on quality teaching in large classes as far as interaction, motivation and understanding is concerned, this study designed and implemented two online collaborative learning activities in an authentic large class setting.

Thus, the complexity of the real teaching and learning setting was preserved as much as possible rather than simplified due to the experimental objectives (Brown, 1992). This study indicates that specific computer-supported collaborative activities facilitate quality teaching by improving interaction, motivation, understanding as well as the feedback and the learning outcome in a large university class (the feedback facilitates student understanding in the process, while the learning outcome describes the students' understanding in the end of this process) .

Related studies

Quality teaching in large classes

In the literature, a number of factors have been identified that contribute to quality teaching (Ramsden, 2003; Biggs & Tang, 2011). However, some of these elements turn out to be particularly relevant and are cited regularly especially when it comes to improving teaching quality in specific contexts. If we focus on large classes, then learning is certainly jeopardized by factors related to the high number of students and the unfavourable student teacher ratio.

A main consequence of the high number of students in a class is that they have reduced possibilities for teacher-student interaction and student-student interaction (Vygotsky, 1978; Littleton & Light, 1999; Moore, 1989; Garrison, 1999). A second phenomenon that spoils the teaching quality of large classes is reduced student motivation (Cooper & Robinson, 2000; Ryan & Deci, 2000; Nico & Macfarlane-Dick, 2006) which might be due, among other things, to lack of interaction in conjunction with other issues such as students' active engagement may decrease because they fear they will say something foolish in front of so many people（Gleanson, 1986; Geski, 1992). A third factor directly related to the high number of students that puts the quality of teaching in large classes at risk is the lack of feedback from the instructor and from advanced peers (Pask, 1976a; Vygotsky, 1978; Laurillard, 2012). This, together with the lack of motivation and interaction, might also give rise to reduced learning outcomes in terms of both deep understanding and academic performance (Entwistle, 2009). In fact, understanding and academic performance are not necessarily one and the same thing. However, if the evaluation of student achievement is adequately designed and if outcomes reflect how deeply students have understood the subject, then academic performance can be considered to provide a measure of understanding (Entwistle, 2009; Biggs & Collis, 2014).

Collaborative learning for quality teaching in large classes

Existing studies indicate several benefits from using collaborative learning for quality large class teaching in higher education. First of all, collaborative learning supports students' active engagement in the learning process. Leger et al. (2013) conducted a study involving three successive offerings of the same course in different modes: (a) traditional lecturing only (438 students); (b) online lectures recorded in (a) (157 students), students attended an interactive class (approximately 50 students) for small-group work once per week; (c) same as (b) (324 students) but with an increased number of students in the small-groups and reduced resources in terms of teaching assistant support for students and the time commitment of the instructor. This study indicated that students had the highest level of engagement in mode (b) and the lowest in mode (a). This shows that group work is important for quality teaching, but it also highlights that not all forms of group work give rise to the same benefits. In fact, as e.g. Hommes et al. (2014) show, informal or too large learning groups exhibit less active engagement than formal learning groups, and this indicates that the effectiveness of group work depends on how it is organized. Online group activities may be of considerable help in creating effective collaboration. Dougherty et al. (2014) used the social networking site Facebook to facilitate 200 students to become active and collaborative participants in the learning process. Students confirmed that they felt they belonged to the class, and their interaction with peers created social bonds that enhanced learning.

Secondly, collaborative learning supports better academic performance. Several studies have shown a significant improvement in students' exam scores when students were involved in collaborative activities (McInerney & Fink, 2003; Yamarik, 2007; Kelly, Baxter & Anderson, 2010). McInernery & Fink's (2003) three-year study shows that – after a group project was introduced for the second and third years – the average student score was higher than in the first year. Yamarik (2007) conducted a two-year study, and divided students into two groups designing traditional lecturing for one and collaborative learning for the other group. In total, 116 students were involved. The results showed a statistically significant improvement (3-4%) on students' exam scores in the collaborative learning group. Kelly et al. (2010) designed online collaborative activities for an undergraduate class with 416 students in the academic year 2006-2007. They compared their exam scores with students in the academic year 2005-2006 and again showed statistically significant improvements in exam scores for students who had engaged in collaborative learning.

Although the studies mentioned above provide evidence that collaborative learning can lead to better academic performance, the results cannot be said to demonstrate that improvements in academic performance result from collaborative learning, since there are some issues that challenge the validity of the reported measurements. One of the main problems concerns the fact that most studies neglect to consider general intelligence as a significant factor in academic performance (McInerney & Fink, 2003; Yamarik, 2007; Kelly et al., 2010), in spite of the fact that general intelligence certainly plays a major role in the results achieved by students (Furnham & Chamorro-Premuzic, 2004; Chamorro-Premuzic & Furnham, 2008).

Moreover, there are methodological weaknesses in a number of studies on collaborative learning. In some studies, it was not demonstrated that adding group work resulted in an improvement in individual performance since the researchers only compared the mean of all the students' exam scores in the two conditions (McInernery & Fink, 2003). For studies using a two-group design (collaborative learning versus traditional learning), results might be biased by the lecturers' personal preference for the more favourite teaching approach rather than the effectiveness of the teaching approach itself (Yamarik, 2007). Further, according to the Hawthorne effect (Adair, 1984)[1], this type of experimental design might fail to indicate the effectiveness of the teaching approach per se, since students were aware that they were divided into two groups for an experiment, and this might have motivated them to become more active and engaged in the learning activities.

CSCL for quality teaching in large classes

In the case of CSCL, the situation is even more controversial. In fact, the impact of CSCL on quality teaching is still unclear since it has been shown that it has both positive (Yamarik, 2007; Kelly et al., 2010; Leger et al., 2013; Hommes et al., 2014; Dougherty & Andercheck, 2014) and negative effects (Capdeferro & Romero, 2012). In particular, there is some evidence which indicates that CSCL might not have any positive effects on the learning process. Alexander (2006), for example, investigated the use of virtual teams in a large class setting, showing that very few students were interested in collaborating online with their peers and that most of them were unsatisfied with the learning process in virtual teams.

Thus, more evidence is required to better understand the role of CSCL in large class teaching. In addition, studies maintaining that CSCL improves the quality of teaching compared to traditional lecturing methods are far from being definitive due to biases in the design of comparisons (Yamarik, 2007; Kelly et al., 2010). Furthermore, few studies explore the effect of CSCL on quality teaching in terms of the forms of collaboration employed (Nicol & Boyle, 2003).

In our study, we consider all the issues mentioned above and try to determine whether CSCL can indeed help to achieve quality teaching in large classes after taking into account the

1The Hawthorne effect indicates individuals might modify or improve an aspect of their behavior in response to their awareness of being observed or studied.

general intelligence factor, and the methodological issues of previous studies as well as the open questions concerning the positive and negative effects of collaborative learning and especially of differently designed forms of collaboration. More specifically, the questions we address in this study are: (Q1) Does CSCL help to achieve quality teaching in large classes? (Q2) Does traditional lecturing blended with CSCL result in a higher quality of teaching compared to only traditional lecturing in large classes? (Q3) Do different forms of CSCL have different effects on quality teaching in large classes?

Method

Study design

We conducted a survey, in-depth interviews, and collected forum logs as well as several relevant student scores. A mixed method approach was adopted, using both qualitative and quantitative analyses to interpret these data (Table 1). This enabled us to investigate each issue using different methodological approaches in order to provide a comparably complete picture (Creswell, 2013).

Table 1 A summary of data collection and analysis

Data	Analysis method	Targeted aspects
Survey (items cf. the supplemental materials)	Descriptive statistics	The impact of CSCL on interaction, motivation, feedback provision (Q1, Q3)
Survey (open space), in-depth interview	Thematic analysis	
Forum logs	Descriptive statistics	
Data from the Faculty (i.e. university entrance scores, final exam scores in PhilSci, the evaluation of GW)	Inferential statistics: a mixed regression model	The impact of CSCL on learning outcomes (Q2, Q3)

Context

This study was conducted in a mandatory undergraduate course - Philosophy of Science (PhilSci) at an Italian public university. PhilSci is scheduled in the 2nd year of undergraduate study, and the number of students is approximately 200. Before the implementation of CSCL in PhilSci, students were only taught by one instructor (without any teaching assistants) using traditional lecturing with optional attendance. Students were divided into three rooms due to the large enrolment numbers. The instructor was in the largest room (80 seats), and the other two rooms were connected to the instructor's room by live streaming. This situation made it difficult for the instructor to interact with students and this turned out to be problematic because the subject was perceived as particularly difficult by the students. In fact, a number of students tried to pass the final exam several times and some even registered in the course for two or three consecutive years.

We designed two different CSCL activities, a formal and an informal collaboration, and implemented them in PhilSci. Our aim was, first of all, to consider whether these interventions actually improved opportunities for interaction during the teaching and learning process, increased student motivation and provided feedback during the learning process. Moreover, our intent was to assess whether these activities would help students understand this "difficult subject" better. Finally, considering that these activities were structurally different, our goal was also to establish whether different forms of collaboration have different effects on quality teaching.

Participants

All the participants were students registered in PhilSci. 220 students participated in the online learning community for questions and answers (QA) while 52 students participated in the group work on collaborative writing with blind peer assessment (GW). Both QA and GW were optional activities, thus, two incentives were designed to encourage participation. For QA, students who posted at least five good questions or three good answers on the online forum got one bonus point towards the final exam mark (the full mark was 30 points[2]). A question was considered good if it was pertinent and relevant with respect to the subject matter at issue (it had to be clear that the general framework of the subject had been correctly understood; the question had to be significant and interesting: mere clarification-seeking questions in which the student asked about issues that had already been discussed by the teacher or explained in the study materials were not considered good). The quality of the answers was determined on the basis of analogous criteria: pertinence and relevance with respect to the question, correct understanding of the framework, clarity and completeness of the information provided.

Students were motivated to participate in GW by the offer of a bonus: they could replace one of the questions in the final exam (approx. 6 written questions in total, all open and requiring a structured and elaborated answer) with a different question of their own choice concerning any topic covered during the course. We designed the bonus in this way to make sure that the evaluation of the final exam was based on individual performance only. As a matter of fact, we were aware that GW had the potential to encourage social loafing; thus, the evaluation of GW did not contribute directly to the final exam score as this might have biased the precision with which individuals were assessed.

Due to the two incentives, during the year when we conducted this study, the majority of students registered in PhilSci participated in at least one CSCL activity. To make the number of observations between students who participated in CSCL activities ('experiment group') and those who did not ('control group') statistically comparable in the mixed regression model, we also included students registered in PhilSci one year before the study was conducted. However, since students can register in PhilSci for two or three consecutive years, this meant that students who had registered in PhilSci one year before this study may have

2The instructor considered it more difficult and time consuming to provide a good (fully elaborated) answer than to think of a good (i.e. nontrivial) question. For this reason, the number of questions/answers required for the bonus was unequal.

registered again in PhilSci and participated in CSCL activities. Therefore, we had strict criteria for students selected in the mixed regression analysis. Students in the experiment group had to have registered in PhilSci for the first time in the year the study was conducted and have participated in at least one CSCL activity. Students in the control group either had to have registered in PhilSci for the first time in the year the study was conducted and never have participated in the CSCL activity or they had to have registered in PhilSci one year before the study was conducted and have taken exams within that year. In this way, we avoided a bias due to the different PhilSci registration times.

Procedure

In an attempt to improve the teaching quality of this large class and the learning achievements of the students, we collaborated with the instructor of PhilSci to design two CSCL activities. One activity was an online learning community for questions and answers (QA), and it was designed as an informal collaboration among students. The other activity was group work on collaborative writing with blind peer assessment (GW), and it was designed as a formal collaboration among students. QA was open access to all the students enrolled in PhilSci, and students were given the opportunity to ask questions on the topics discussed during class or on the learning materials. This approach aimed to improve students' engagement outside the classroom and to motivate students to achieve a deeper understanding of the learning material as well as to think critically about the learning subjects. Students had about a week to answer the questions posed by their peers. After this, the instructor commented on both the questions and the various answers posted directly to the forum, specifying which questions were particularly interesting and why, as well as which answers were correct/incorrect/particularly interesting and why.

In the second activity, the GW, the instructor assigned each group a paper written by a philosopher (e.g. Duhem, Poincaré, Carnap, Hanson, Kuhn, Popper, Lakatos, Feyerabend) which dealt with issues like: "What is scientific progress?"; "Can we consider 'science' to be a privileged form of knowledge?"; "How can we distinguish scientific from non-scientific theories?"; "How can a theory be proven empirically?", etc. (for details cf. the Supplementary Materials). In GW, each group wrote a report in which the students were asked to explain and to defend the argument of the author. This was sent to the instructor who assigned it to another group working on related topics addressed by different authors for a blind peer assessment. Finally, the instructor evaluated both the reports and the students' blind peer assessment based on an evaluation guideline (cf. Supplementary Materials), which had also been sent to students for reference in their blind assessment of their peers' reports.

The two activities were implemented in Moodle, an open-source learning environment adopted by our university. Fig.1 is a screenshot of the online learning space of PhilSci in Moodle. The two red rectangles highlight the forums that targeted the two CSCL activities: "Domande sul corso" (QA) and "Lavori di gruppi" (GW). Unlike QA which was designed as an informal collaboration open to all the students enrolled in the course, GW required students to register in the online forum (in the space called "Iscrizione al lavoro di gruppo"): here they could indicate their preferences in terms of group members and the topic/philosopher they would like to work on. We used self-selection group formation rather than random group formation because students might be more willing to work with their friends or acquaintances than to work with strangers and this might result in more effective collaboration. Moreover, working with people you are familiar with might reduce the potential for social loafing. To ensure effective collaboration and flexibility in group formation, we allowed students to form groups of 2-4 members. Table 2 presents a summary of students' participation in the two CSCL activities.

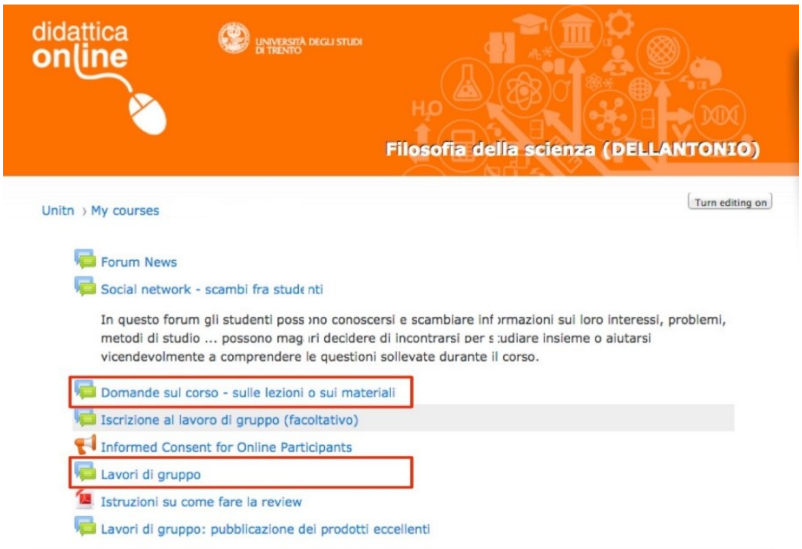

Fig.1 PhilSci in Moodle (screenshot of part of the screen)

Table 2 A summary of students' participation in the CSCL activities

	QA	GW
Type of forum	Open forum: Every student can access and participate in the forum	Private forum: Every group has a separate space in the forum that can only be accessed by members of the group
Participation	220 students[3]	52 students: 20 groups 6 groups: 4 members 4 groups: 3 members 8 groups: 2 members Note: 2 groups gave up after trying
Number of posts	58 posts including 13 topics and 45 replies	91 posts including 39 topics and 52 replies
Contributors	13 students: 35 posts The instructor: 25 posts	31 students: 49 posts The instructor: 42 posts
Type of posts	Academic-oriented (discussing unclear points, arguing, explaining, etc.)	Administrative-oriented (uploading group reports, assigning reports for peer blind review, etc.)

Data collection instruments

The survey was web-based and was designed for all the students registered in PhilSci (Fig.2). The questions in the survey aimed at assessing whether the CSCL activities were helpful in

3Students were counted as participants in QA if they viewed the QA forum at least once.

terms of all the factors mentioned above. Moreover, our intent was also to assess whether these activities resulted in any of the typical negative effects reported in the literature – mainly social loafing and process losses – and, if so, how strong such effects would be, i.e. whether they would overwhelm or reduce any of the positive effects of these activities. In addition, we also considered two other learning dimensions that have been linked to collaborative learning in the literature, i.e. critical thinking and personalized learning (Panitz, 1999). At the end of the survey, an open space was provided for students to share their learning experiences. Table 3 summarizes what each question aimed at assessing. We also conducted in-depth interviews after the survey, with the main questions in the interview based on a thematic analysis of responses in the open space in the survey.

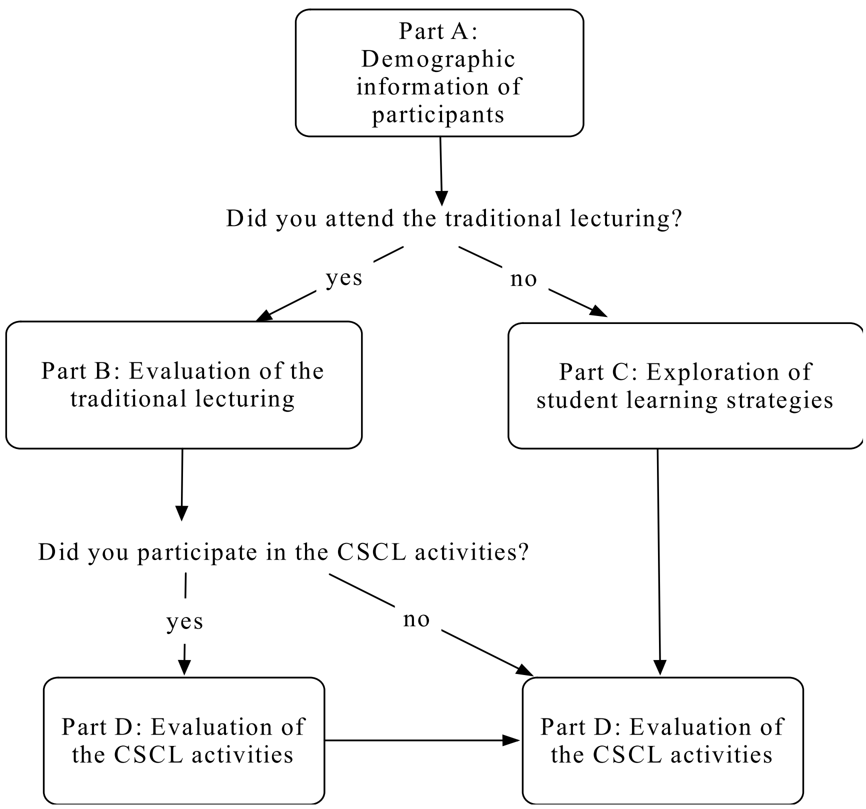

Fig.2 The structure of the survey

Table 3 Part D: Evaluations of CSCL activities

Questions in the survey	Elements we considered
It provides a place to interact with the teacher beyond	Interaction (the instructor)

the classroom	
It provides a place to interact with peers beyond the classroom	Interaction (peers)
It provides extra valuable materials (e.g. questions, answers, papers) to improve my understanding of the subject content	Interaction (subject content)
I get helpful feedback from peers	Understanding (feedback)
I get helpful feedback from the teacher	Understanding(feedback)
It helps to improve my skill in formulating my ideas and discussing with others	General skills for interaction
It helps me to think critically	Benefits of collaborative learning
It motivates me to learn actively	Motivation
I am able to learn according to my interests	Benefits of collaborative learning
It helps me understand key concepts in the course	Understanding (learning outcome)
It helps me build links among concepts in the course	Understanding (learning outcome)
I waste time explaining things to others	Process losses
*[4]Some members in my group do not contribute to the group work	Social loafing
*We invest a lot of time coordinating group administration instead of co-creating the group product	Process losses
*I learn more effectively on my own than in the group	Learning effectiveness: individual learning versus group learning

We collected two kinds of data concerning students' scores, i.e. individual student exam scores in PhilSci (*score*) and each student's entrance exam scores (*entrance*). This last score is used by our department to determine a student's admission to the university since the number of places is limited. The entrance exam does not primarily assess the knowledge that applicants have before starting university, but rather their general capacities to reason and to understand. In fact, it includes mostly logical, mathematical and reading comprehension questions. For this reason, we decided to use this score as a measure of the general intelligence of students. Students' general intelligence is certainly a significant contributor to students' academic performance (Furnham & Chamorro-Premuzic, 2004; Chamorro-Premuzic & Furnham, 2008), however, this factor was not controlled in earlier studies (McInerney & Fink, 2003; Yamarik, 2007; Kelly et al., 2010). In spite of its relevance, the

4 Questions with * were only applied to GW activity.

general intelligence factor is extremely difficult to determine. The entrance exam score we use certainly does not capture all the aspects of what is called ‘general intelligence’, however, it is a good numerical indicator of certain capacities that are essential for the learning process such as reasoning and understanding a text. We estimated the following mixed linear regression equation:

$$score \quad entrance + gender + QA + GW + bonuseffect + examtime + (1|studID)$$

Score is the students’ exam score in PhilSci, and it was the dependent variable. In addition, there were seven independent variables in total, including six observed variables and one latent variable (Table 4). *Gender* was considered since previous studies indicated that this might have relevance for students’ academic performance (Wilberg & Lynn, 1999; Hyde, Shibley & King, 2001; Pomerantz, Altermatt & Saxon, 2002). *QA, GW, bonuseffect,* and *examrepeats* were independent variables designed to model the authentic complex learning situation as closely as possible. QA and GW indicate the two collaborative activities described above. *Bonuseffect* describes the possible influence of the bonus (cf. above) that students obtained by participating in the collaborative activities. Finally, *examrepeats* keeps track of how many times a student took the exam. This was important because there were five exam sessions available at different times throughout the year and students who did not pass or who were not satisfied with their mark in one session could retake the exam at a later date. *StudID* identifies the individual students, and *1|StudID* is used as the random effect in this model, where repeated measurements (i.e. *score*) are made on the same statistical units (i.e. *individual student*).

Table 4 The construction of a mixed linear regression model

Variable name	Description	The range of data

Score	Exam score of PhilSci. This variable represents a student's understanding of the subject.	[18 - 31][5]
Entrance	Exam score in the university entrance exam. This variable represents a student's general intelligence.	[0 - 100]
Gender	Gender	0: female; 1: male
QA	The number of views in QA (student engagement in QA)	[0 - ∞)
GW	The instructor's review of GW (i.e. did not participate, inadequate, adequate, good, very good, excellent)	[0, 1, 2, 3, 4, 5][6]
Bonuseffect	The bonus for student participation in GW[7] is that they can replace one question in the final exam and answer that question. This variable presents the effect of the bonus on the exam score.	0: students who did not participate in GW 1: students participated in GW
Examrepeats	There were five dates on which students could opt to (re)take the exam. This variable presents the number of times that a student participated in the exam.	1 (first time), 2, 3, 4, 5 (fifth time)
1|studID	studID is a six-digit student identity. It was used to consider the effect of individual differences on exam scores.	(0, 1)

Analysis and results

Q1: Does CSCL help to achieve quality teaching in large classes?

There were 76 responses in total to the survey (Male 15, Female 61). First, the answers given by the participants confirmed that collaborative activities had a positive impact on interaction. Students reported positive results for interaction with the instructor (83% in QA,

5 The full mark for the exam is 30, and the minimum mark to pass the exam is 18. If a student performs outstandingly in the exam s/he gets 30/30 *cum laude* and numerically this is typically indicated by 31.

6 Zero indicates students who did not participate in GW. Numbers one to five respectively indicate a scale from "inadequate" to "excellent".

7 The bonus for QA is that students with five good questions or three good answers will gain one bonus point for their final exam mark. We identified these students in our data, and removed this one bonus point from their scores before the mixed regression analysis. Thus, the variable *bonuseffect* only considers the bonus effect of GW since we cannot predict how much it might influence a student's exam score.

52% in GW), interaction with peers (63% in QA, 90% in GW), and interaction with subject content (83% in QA, 86% in GW). Second, students confirmed that feedback had positive impacts, including feedback from the instructor (90% in QA, 97% in GW), as well as feedback from peers (60% in QA, 76% in GW). Students also reported that they had gained general skills from CSCL interactions (53% in QA and 66% in GW). They said critical thinking was better supported by GW (86%) then by QA (50%) but were not convinced that either activity contributed to personalized learning: only 40% reported positive results for QA, 48% for GW. Third, students confirmed that CSCL had a positive impact on learning outcomes. 73% students in QA and 62% students in GW thought the CSCL activities helped them understand key concepts in the course. 60% students in QA and 76% students in GW thought CSCL activities helped them build links among concepts. Fourth, students had conflicting opinions on the negative effects of CSCL. On the one hand, few students (17% in QA and 3% in GW) felt that participation in these two activities was a waste of time, and only 3% students reported process losses in GW. On the other hand, 34% students reported social loafing in GW, and 76% students thought it was more effective for them to learn alone.

Four students participated in the in-depth interview. Two of these students participated only in QA, one student participated only in GW, and one student participated in both QA and GW. The questions in the interview were mainly based on students' comments in the open space of the survey. In addition, we asked questions based on interviewees' specific responses in order to explore issues that emerged during the interview. Table 5 presents the result of this thematic analysis with the data from both the open space of the survey and the interview transcriptions. It confirmed that both CSCL activities had benefits for students' learning including interaction, feedback, and students' understanding of the subject. Unexpectedly, we found social loafing in QA had a positive impact on loafers' learning. Students were identified as loafers if they did not contribute to the informal collaboration in

QA. Specifically, they had not asked or answered any questions in the online forum. However, it appeared they benefited from the activities even when they did not actively participate, but only passively read the questions and answers posted by others.

Table 5 The result of thematic analysis (excerpt)

Themes	Quotation (translated from Italian)	Data source
Interaction	More interaction with the teacher who had the opportunity to show us how to answer properly.	Survey (QA)
	I had the opportunity to meet with a classmate, to exchange opinions and to address some concepts that were unclear to me.	Interview (GW)
Feedback	It was helpful to have the teacher's feedback on the questions and answers.	Survey (GW)
Understanding	Although I did not participate actively in asking questions or giving answers, reading the contributions of others helped me to clarify various points.	Survey(QA)
	I had the opportunity to meet with a classmate, to exchange opinions and to address some notions that were unclear to me.	Survey(GW)
	It was helpful when I was unclear about some point because I could discuss it with other people. Maybe in class I would not be able to consult anyone, but with the online platform, because this was the purpose of the forum, I could get answers from other people and also from the teacher. Also reading others' posts, I could see: *Hey, I did not fully understand this point; let us see how they reply.* Sometimes I thought I understood something well but in fact had not understood it fully, so when I saw the questions, I realized that I was not that clear.	Interview (QA)
	I really enjoyed reviewing the work of others. I had to study that part for the exam too. Before reading the work of others, I had not reflected on the subject so much, and this helped me to see the relevant questions, the author's points, and how his view related to other authors. Therefore, group work resulted in more	Interview (GW)

	complete understanding. In fact, I feel I understood the author I studied with my work group better than the other authors I studied in the course because I had a chance to reflect more on his/her work.	
Social loafing (positive)	When I focused on Philosophy of Science, many questions had already been posted in the forum, so I just read it and it was not necessary that I post questions.	Interview(QA)
	Although I did not participate actively in asking questions or giving answers, reading the contributions of others helped me to clarify some points.	Survey (QA)
Process losses	I want to say that I find group work a waste of time because you have to get many people to agree and discuss the matter, as well as arrange meetings, etc.	Survey (GW)

Since students in GW used their forum as a place to upload their final written report rather than as a place to collaborate with group members, data collection from forum logs focused on the QA forum. We downloaded the logs from the Moodle. In total, there were 3844 views from 220 students[8]. Table 6 presents a summary of posts in QA. The huge difference between the number of contributors and the number of viewers and views indirectly showed that the posts were helpful for learning as students frequently checked updates in the forum.

Table 6 A summary of posts in QA (excerpt)

Topics	Num. of reply by whom	Num. of views[9]
Clarification on the class of February 21th	Student:2; Instructor:1	227
Logic: Deduction	Student:1; Instructor:1	203
Poincaré and the idea of science	Student:4; Instructor:3	240

8 This number of views was calculated within the academic year in which the study was conducted.

9 The number of views only refers to student views.

Science and metaphysics	Student:2; Instructor:3	150
Galileo Galilei	Student:2; Instructor:2	110
The problem of verificationism (logical empiricism)	Student:3; Instructor:2	157
Logical empiricism	Student:8; Instructor:5	323
Ambiguity of the word "verification"	Student:0; Instructor:1	117

Q2: Does traditional lecturing blended with CSCL result in a higher quality of teaching compared to only traditional lecturing in large classes?

With the aim of understanding if traditional lecturing blended with CSCL in large classes can result in a higher quality of teaching compared to only traditional lecturing, we used a mixed regression model to account for both observed and latent variables. The multiple regression analysis was conducted in R 3.2.0 using the lme4 package (Bates et al., 2014). Table presents the analysis results. Among the observed variables, university entrance exam and forum participation were two factors that made a statistically significant contribution to students' academic performance. Further, students who received the bonus in GW showed a 3-point improvement in the exam score. The Akaike Criterion (AIC) and the Bayesian Information Criterion (BIC) are indices of fit that take into account the parsimony of the model. Smaller AIC and BIC values are indicative of a better fit to the data. LogLik denotes the log-likelihood of this mixed linear model, whereas studID denotes the standard deviations of this latent variable. In this model, the latent variable studID is assumed to be normally distributed with zero means and unknown standard deviations. Fig.3 presents a screenshot on the result of extracting the modes of the random effects in this model. Each studID had an independent intercept, which confirmed that the existence of individual differences (such as learning motivation and engagement) influenced academic performance.

Table 7 The result of the mixed model analysis

$score \quad entrance + gender + QA + bonuseffect + GW + examrepeats + (1 \vee studID)$				
	Estimate	SE	*t*	*p*
Latent variables:				
studID	2.829e-07			
Observed variables:				
intercept	16.129429	1.137188	14.184	< .001
entrance	0.129642	0.020777	6.240	< .001
gender	-0.735783	0.675223	-1.090	0.27684
QA	0.025200	0.008459	2.979	<0.01
bonus effect	3.052136	2.272658	1.343	0.18043
GW	-0.619763	0.561907	-1.103	0.27104
exam time	0.502276	0.338405	1.484	0.13893
Goodness-of-fit statistics:				
R^2	0.166			
AIC	1537.89			
BIC	1570.342			
LogLik	-759.945			
Deviance	1507.5			

```
> ranef(lmer(score~entrance+gender+QA+GW+bonuseffect+examrepeats+(1|studID), data=posdat))
$studID
         (Intercept)
115353 -2.758000e-14
141368  1.383411e-14
147160 -1.792840e-14
148722 -5.744789e-14
151248 -2.827056e-15
151425  6.520281e-14
152893 -1.878545e-14
153142 -8.488512e-15
153358  2.044472e-14
153361 -2.547125e-14
153368  4.992607e-14
153371  4.095587e-14
153380  4.293355e-14
153394  4.651657e-15
153422  3.478209e-15
153425 -1.925050e-14
153427  2.327932e-14
```

Fig.3 conditional modes of the random effects (partial)

Q3: Do different forms of CSCL have different effects on quality teaching in large classes?

Based on the results of the survey, we found the two forms of CSCL had common benefits in terms of quality teaching but different effects on learning. With respect to the common benefits, first, students confirmed that they got feedback from peers (60% in QA, 76% in GW) and from the instructor (90% in QA, 97% in GW). Second, both activities helped students understand key concepts in PhilSci (73% in QA, 62% in GW) and build links among concepts in PhilSci (60% in QA, 76% in GW). Third, both activities improved students' general skills for interaction such as formulating ideas and discussing with others (53% in QA, 66% in GW). Finally, both activities provided valuable materials to improve students' understanding of the subject content (83% in QA, 86% in GW).

There were two different effects on learning in terms of the collaboration form. The first effect concerned interactions in learning. 83% of students thought QA was helpful for interacting with the instructor (52% in GW), and 90% of students thought GW was helpful for interacting with their peers (63% in QA). The second effect concerned the social loafing effect. In GW, social loafing decreased active participants' contribution to group work. In QA, it did not affect active participants' contribution, and these contributions provided material for inactive participants to learn from.

A possible explanation of these different effects was the activity design. In QA, the instructor checked the forum posts regularly, and commented on the questions and answers posted by students. There was a strong teaching presence in QA based on the Community of Inquiry framework (Garrison et al., 1999). In GW, the instructor's presence was limited to observation and to the conclusive phase of the work: at the beginning, the teacher mainly presented the activity and assigned the learning materials for each group, and assessed the group products at the end. Between these teacher inputs, students worked closely with their group members, and were therefore more aware of student-student interaction in GW. Apart from GW, QA provided an informal collaborative learning activity, in which all the students were in a single large group and helped each other to learn, and there was no group assignment required at the end. In GW, groups were composed of two to four students, and each group had to submit a report by the end. Thus, students cared if their group members contributed or not, because they worked together on the group product.

Discussion

Q1: Does CSCL help to achieve quality teaching in large classes?

This study aimed to explore the impact of CSCL on three main dimensions of quality teaching in large classes: understanding, interaction and motivation. In particular, we wanted to explore whether these activities increased feedback for students during the learning process, enhanced individual learning outcomes, i.e. their performance on the exam, whether they improved interactions with other students, with the subject content, with the teacher and whether they raised students' motivation or instead had a negative impact on motivation.

The results show that CSCL activities provided opportunities for students to interact with the instructor, with the subject content and with their peers as well as to receive feedback from the instructor and their peers. These findings are consistent with previous studies (Leger et al., 2013; Hommes et al., 2014).

Q2: Does traditional lecturing blended with CSCL result in a higher quality of teaching compared to only traditional lecturing in large classes?

As in previous research (McInerney & Fink, 2003; Kelly et al., 2010), we compared two groups: one that did some collaborative learning activities and another that did not, which served as the control group. However, while in other studies students were not free to decide whether to join the collaborative activity group or the control group, in our research participation in one or the other group was voluntary. In addition, in comparing the achievements of the two groups we tried to take into account the general intelligence factor, measured using the scores obtained by students on their university entrance exam which assesses general capacities related to reasoning and understanding. We constructed a mixed regression model to include as much of the available information as possible in order to address the complexity of an authentic learning situation. The result confirmed that general intelligence was a significant contributor to students' academic performance, which is consistent with previous studies (Furnham & Chamorro-Premuzic, 2004; Chamorro-Premuzic & Furnham, 2008). In addition, one of our CSCL activities – the Questions and Answers (QA) Forum – was shown to make a statistically significant contribution to students' academic performance. Since academic performance is the main indicator of deep understanding and therefore also one of the main aims of quality teaching, this result demonstrates that at least some forms of CSCL can contribute to improving students' performance in large classes. This result is particularly interesting because it indicates that collaborative learning activities per se can contribute to students' understanding of the subject content – an important element in quality teaching, which has not been addressed by any of the previous studies that used quantitative evidence. Further, this result indicates that not all forms of CSCL activities have the same impact on students' deep understanding and suggests that we should dedicate more attention to the issue of how CSCL activities can be best designed in order to contribute to quality teaching.

Q3: Do different forms of CSCL have different effects on quality teaching in large classes?

QA was designed as an informal CSCL activity while GW was designed as a formal CSCL activity. Previous studies (see, in particular, Hommes et al., 2014) concluded that formal learning groups result in better academic performance than informal learning groups. On the contrary, the quantitative evidence from student scores shows that the informal CSCL activity (QA) significantly contributed to improved academic performance, while the formal CSCL activity did not. This difference might be due to the fact that the formal or informal character of CSCL activities is not what really matters in terms of their efficacy with respect to deep understanding. Other factors might instead determine their efficacy or inefficacy. Certainly, students must be motivated to participate in the CSCL activities by the offer of a bonus. The students' survey clearly shows that the bonus was the main if not the only reason why they invested time and resources in these activities. However, motivation alone is probably insufficient to explain why the QA forum was more efficacious than GW: in fact, both groups received a bonus and even though different bonuses were received for the two activities, students confirmed that both kinds of bonus were an attractive incentive for them. Thus, there must be other factors that determine whether a specific CSCL activity has a higher or lower impact on deep understanding. In the activities we designed, QA focused more on teacher-student interaction while GW focused more on student-student interaction: this might be the reason why QA was more effective. Another reason might be that in QA the student's active contribution was individual rather than collective. Besides, students' field-dependent and field-independent cognitive styles might also be a factor that influences their preference for working in groups or alone as well as the impact of teacher-student interaction and student-student interaction on academic performance (Witkin, 1972; Witkin, Moore, Goodenough & Cox, 1975). Further studies are needed to determine the precise characteristics of the most effective activities.

Still, even though we cannot specify general criteria for designing more effective CSCL activities, our study shows that the activity called QA has particularly positive effects. In fact, not only – as we pointed out above – did participation in QA increase students' performance, it also helped to bypass – and even to exploit – certain well-known negative effects of collaborative learning such as social loafing and process losses.

Previous studies indicate that social loafing and process losses have negative effects on collaborative learning (McBroom & Reed, 1994; McCorkle et al., 1999; Hansen, 2006; Shimazoe & Aldrich, 2010). Students who participated in GW also confirmed this point in the open space of the survey. However, both these effects were overcome in QA. Here, the students carried out their portion of the work individually at home, thus eliminating process losses. As for social loafing, in QA this effect was particularly strong due to the significant contrast between the number of contributors (12 students and the instructor) and viewers (220 students) (cf. Table 6). However, this did not lead to a negative effect on students' learning. Indeed, students who actively contributed to the forum were not affected by loafers (viewers) but developed their understanding in the process of making contributions. Their questions were answered by peers and by the instructor and helped improve their understanding of the subject. On the other hand, loafers benefitted from the forum since they improved their understanding of the subject by reading the posts of others. In this way, they incrementally increased their interaction with subject content. The written questions and answers in the forum provided a stable archive for students to reflect on what they had learnt which helped them to enhance their understanding of the subject content. The loafers in QA could be also interpreted as legitimate peripheral participants, as suggested by the theory of Community of Practice (Lave & Wenger, 1991).

Conclusion and implications for future work

In this study, we designed and implemented two online collaborative activities in a large university class (with around 200 students) to investigate the impact of CSCL on quality teaching in large classes. Data were collected from the survey on learning experiences, in-depth interviews, forum logs, and students' exam scores. Our results indicate that CSCL helps support quality teaching in large classes because it facilitates different types of interaction and feedback in the learning process.

Evidence shows that different forms of CSCL had common benefits for the quality of teaching but had some different effects on quality teaching. The common benefits were due to the nature of collaborative learning such as enhanced opportunities for feedback, increased motivation, and interaction with the teacher, the subject content and other students. Moreover, traditional lecturing blended with CSCL resulted in higher quality teaching compared to only traditional lecturing in large classes because it improved students' exam performance which is the main indicator of deep understanding. The regression analysis showed, in particular, that one of the two CSCL activities, the one called QA, was a significant contributor to students' academic performance as measured by exam scores. This last activity turned out to be particularly valuable because it also avoided some of the negative effects associated with collaborative work such as social loafing and process losses. In fact, social loafing had a negative effect in GW but facilitated loafers' learning in QA, and – because of the way in which the QA task was designed – it incurred no process losses.

The findings of this study indicate that large class instruction can achieve higher quality teaching by making good use of technologies and various learning activities. In addition, it shows that differently designed collaborative activities may result in different effects on teaching and learning. Thus, in order to design interventions for effective collaboration among students, it is crucial for instructors to think about the learning experiences and outcomes s/he wants to achieve.

This study had some limitations. Unfortunately, we could not recruit more participants to share their learning experiences for both the survey and the in-depth interviews. For the survey, it would have been preferable to administer a pre-test to ensure reliability and corroborate the statistics with students' test scores. Moreover, the data we collected may have been influenced by some factors we could not control. Attendance at the traditional lectures was optional for students, and there was no attendance sheet for recording students' participation. For this reason, we could not include lecture attendance in the mixed regression model. Furthermore, since the final exam consisted in open questions and not multiple-choice questions, at least a minimum degree of imprecision cannot be excluded. In our opinion, open questions are a better method than multiple-choice questions for assessing in-depth understanding of subject content, however – even though the teacher tried to establish strict and stable criteria for assigning scores – the outcome of this kind of evaluation is by nature less objective than one based on multiple-choice questions.

Given that our quantitative analysis of student scores shows in the mixed regression analysis that one of the two activities we designed was more effective than the other for deep understanding, a possible line of investigation for future work is to explore what collaborative task designs maximize deep understanding and minimise the negative impacts of social loafing and process losses by considering students' cognitive styles as a potential factor in learning behaviour and academic performance. In addition, a quasi-experimental study with more variables that represent as much as the complex teaching and learning reality as possible is crucial to further investigate the impacts of CSCL on quality teaching.

Statements on open data and ethics

a. The package of supplemental materials is open to the public and can be accessed by clicking this link.
b. We received ethical approval from the ethics committee of our university, and we also followed the BERA 2011 ethical guidelines to conduct this study. Informed consent was obtained from all individual participants in this study.

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