Dr. Majken Korsager is currently working with Education for Sustainable development at the Norwegian Centre for Science Education, Norway. In 2013, she finished her PhD in science education at the Department of Teacher Education and School Research, University of Oslo. Her research focuses on international peer collaboration and inquiry-based science teaching.

Dr. James D. Slotta is an Associate Professor with the Department for curriculum, Teaching, and Learning and the Centre for Science, Mathematics, and Technology Education at OISE. His research employs technology-enhanced learning environments to investigate cognitive models of learning and instruction.

Doris Jorde is Professor in Science Education at the University of Oslo. She is currently the director of the Norwegian Center for Science Education.

MAJKEN KORSAGER
Norwegian Centre for Science Education, Norway
E-mail: majken.korsager@naturfagsenteret.no

JAMES D. SLOTTA
Ontario Institute for Studies in Education, University of Toronto, Canada
jslotta@gmail.com

DORIS JORDE
Norwegian Centre for Science Education, Norway
doris.jorde@naturfagsenteret.no

# Global Climate Exchange: Peer collaboration in a "Global classroom"

## Abstract

*This paper reports on student peer collaboration in an online environment in an international shared curriculum, the Global Climate Exchange. Four cohorts of students (age 16 -19) from Canada, China, Norway and Sweden (n=157) were engaged in four wiki-based activities where they collaborated with peers locally and internationally. Previously, impact from Global Climate Exchange on students' conceptual understanding was analysed, indicating a positive impact which might be explained by the amount of interactions with peers and international peer collaboration. This paper looks further into the details of the students' peer interactions in terms of how they communicate in the online Global Climate Exchange learning environment. The study revealed that communication between international peers might be more constructive than when communication is limited to national peers. This might be a possible explanation for our previously findings indicating that international peer collaboration may well be an approach to enhance students' conceptual understanding of climate change.*

## Introduction

Climate change is a complex scientific topic that many people find difficult to understand (Daniel, Stanisstreet, & Boyes, 2004; Dove, 1996; Gowda, Fox, & Magelky, 1997; Papadimitriou, 2004; Rye, Rubba, & Wiesenmayer, 1997). Climate change is also a particularly demanding topic for many students (Cordero, Todd, & Abellera, 2008; Gowda et al., 1997; Liu & Hmelo-Silver, 2009; Mohan, Chen, & Anderson, 2009). The tentative nature of the topic and the great difficulties many students experience, present a unique set of challenges for science teachers, who may find it difficult to identify just what and how the topic should be taught (Groves & Pugh, 2002; Moser & Dilling, 2004; Rebich & Gautier, 2005).

Recognizing the importance of educating people to understand climate change and being aware of the challenges of teaching and understanding the topic, we have developed a new science curriculum called Global Climate Exchange. In Global Climate Exchange students collaborate and communicate with national and international peers in online activities, additional to "offline" activities with national peers. This paper focuses on exploring and comparing national and international peer collaboration and therefore focus is on the online activities in Global Climate Exchange. In our previous study, we found that international peer collaboration within the online Global Climate Exchange might be the reason students' enhance their conceptual understanding of climate change (Korsager & Slotta, 2012). Our results are consistent with prior research in science education, where inquiry-oriented activities involving peer collaboration have been shown to promote autonomous (self-directed) and reflective learners (Scardamalia & Bereiter, 2003, 2006; Slotta & Jorde, 2010) as well as to develop students' understanding (Gerard, Tate, Chiu, Corliss, & Linn, 2009; Howe, Tolmie, Greer, & Mackenzie, 1995; Mork & Jorde, 2004). We recognize that it is not enough simply to place students within a peer collaboration context, i.e., that they do not automatically learn just because they are working together (Dillenbourg, 1999). In this study we look further into the details of the peer collaboration in Global Climate Exchange, in terms of how students communicate with peers. The research questions explored are: 1) How do students communicate when they collaborate with peers in "Global Climate Exchange", and 2) What are, if any the diffferences in communication between national and international peers?

## Previous research on inquiry-based science teaching involving peer collaboration

In this study "peer collaboration" refers to students working together in activities on a common topic. In collaborative activities, students often communicate with each other in order to exchange ideas and progress with their task. The collaborative process can help students to examine their own perspectives and ideas, and to evaluate alternative conceptions to develop and broaden their understanding. Peer collaboration has long been advocated as an approach to helping students develop conceptual understandings because it stimulates individual reflection and peer collaborative learning (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Duschl & Gitomer, 1991; Edelson, Gordin, & Pea, 1999; Fawcett & Garton, 2005; Howe et al., 1995).

Yet, the cognitive value of peer collaboration seems to be reliant on two main factors; discrepancy and active participation. Discrepancy refers to interactions between peers who differ either in competencies or knowledge (Fawcett & Garton, 2005). Discrepancy can promote students' development of conceptual understanding due to productive cognitive conflict, and the challenge of connecting old and new knowledge (Fawcett & Garton, 2005; Howe et al., 1995; King, Staffieri, & Adelgais, 1998). In international peer collaboration, students will likely bring different knowledge to the collaboration, due to cultural and geographic differences.

Hence, students get access to a greater diversity of ideas and perspectives on science issues than when limited to interactions with national or local peers (Slotta & Jorde, 2010). Such cross-cultural knowledge exchange amongst students may lead to new perspectives and insights, and hence a deeper conceptual understanding of science (Slotta & Jorde, 2010; Slotta et al., 2005). Still, discrepancy itself is not sufficient to guarantee that students will improve their conceptual understanding. Curriculum design must support the students to actively engage in conceptual reasoning tasks that require verbal communications such as talking and written peer exchange. Both the number of utterance (Garton, 2007) and the quality of utterances (Mercer, 1994, 2000) have been associated with conceptual development.

This requirement of active participation is not only relevant for success in peer collaboration, but for all forms of learning. Indeed, it is commonly accepted among science education researchers that active construction of knowledge is necessary for understanding (National Research Council, 2005).

One approach to ensuring active participation is to involve students in inquiry tasks such as diagnosing problems, identifying questions, searching for information, collecting evidence, planning investigations, researching conjectures, interpreting evidence, formulating explanations, communicating findings, debating with peers and forming coherent arguments (Lee, Linn, Varma, & Liu, 2009). An inquiry-oriented perspective on learning contrasts with that of traditional instruction, where lecturing, memorization of scientific facts and practical work are guided by the teacher (Bell, Urhahne, Schanze, & Ploetzner, 2010). The educational principles of inquiry-based science learning are derived from a social constructivist perspective. This theoretical perspective interprets scientific knowledge as being socially constructed, and learning as a social process of knowledge construction involving both individual and collaborative activities (Driver et al., 1994). This perspective further emphasizes the importance of students as active participants in the learning process, making progress through critical thinking and reflection.

## Methods

In this paper we will present a study where students from four different countries were actively engaged in critical reflection with peers internationally in a science curriculum called the Global Climate Exchange. Students collaborated from across three continents to develop wiki pages and discuss relevant science issues in structured online exchanges.

The Global Climate Exchange curriculum design was guided by a pedagogical model for collective inquiry called "Knowledge Community and Inquiry" (KCI) (Najafi & Slotta, 2010; Slotta & Najafi, 2010). Among the design principles for KCI science curricula are to enable students to establish and develop a shared knowledge-base, to enable collaborative inquiry between teachers, designers and researchers, to use technology to scaffold students work and to address learning goals for assessment. We hypothesize that students will gain from such exchanges as a result of their discrepancies, assuming that they actively engage in the designed curriculum activities. We first present the details of the study, including participants, materials and activities, describing how the curriculum was designed to productively engage students and ensure connection to science topics. We then analyse the content and dynamics of communication in peer collaborations.

### Participants and data

In Global Climate Exchange we engaged four cohorts of students (age 16-19) from Canada (n=30), China (n=46), Sweden (n=52) and Norway (n=29). In this study we analyse written contributions from the 157 students who participated in Global Climate Exchange. The students worked within the Global Climate Exchange online environment with a carefully designed sequence of activities for a period of six weeks (Figure 1). Schools, teachers and students were recruited as a convenience sample, with one science teacher and one science education researcher from each country to assure coordination of all student activities.

### Curriculum activities

In Global Climate Exchange, students were guided through a sequence of four distinct activities: *Brainstorm, Issues, Discussions* and *Chat*. The online environment in Global Climate Exchange was created using the Drupal software framework, which is a content management platform with wiki-like functionality for collaborative editing of online written artifacts (i.e., pages). The Global Climate Exchange wiki pages were carefully designed by researchers (the authors and assistants) in collaboration with the participating teachers in terms of their sub-headers and goals for content development, but were otherwise empty of all content, relying on student input and revisions. Instructions given in Global Climate Exchange guided students to add content on brainstorm and issue pages, and to discuss a number of climate change topics. In addition, students could also contribute with additional content, start discussions on self-selected climate change topics, ask questions and have informal conversations. All communication in the online Global Climate Exchange was in written text.

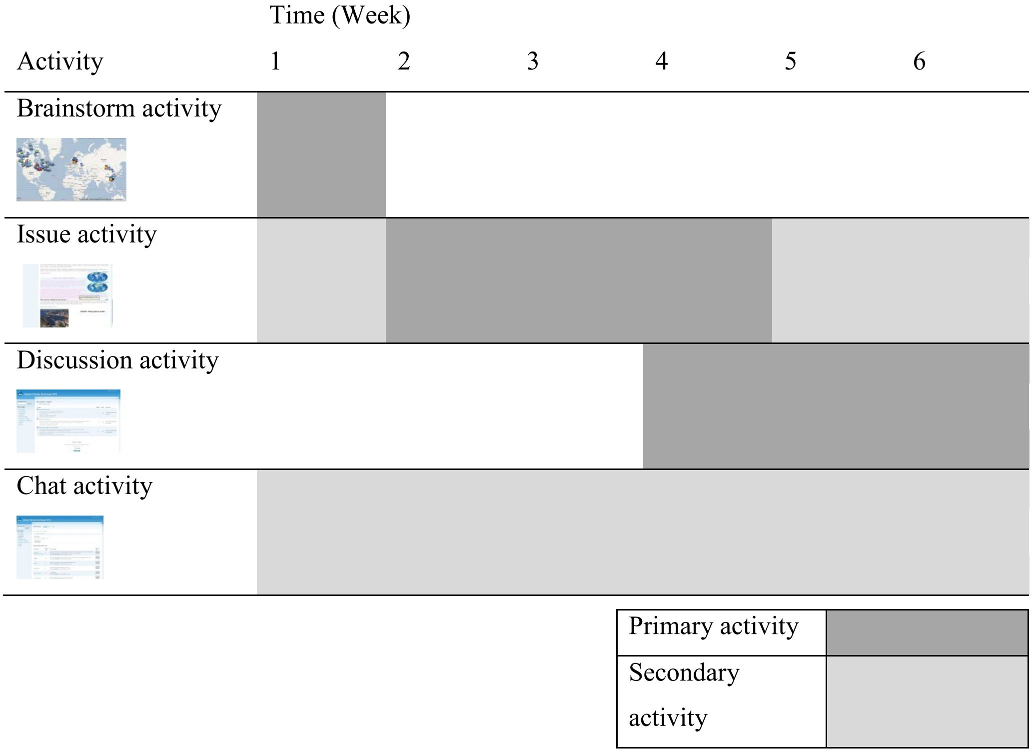


*Figure 1. Overview of activities in Global Climate Exchange during a six week period.*

### Brainstorm activity

In week one, the students were introduced to Global Climate Exchange through a brainstorm activity where their task was to identify national climate change issues, add geographical links to these issues using a *Google Map* that was developed specifically for this activity, and describe those issues on a collaboratively edited "Issue Brainstorm" page. The students named and described as many climate change problems in their own country that they could think of, organized within each country. After the first week, 59 issues had been added by participating students, these were examined by teachers and researchers to identify "cross cutting issues". "Cross cutting issues" meant issues that were relevant for all four countries in terms of issues which students had a prerequisite to have prior knowledge about and could add national examples of. Twelve issues were selected, by teachers and researchers, for this purpose: acid rain; changing acidity (pH) of waterways; changing ocean currents; changing species in ecosystems; changing weather patterns; deforestation; drought and desert formation; erosion and flooding of coastal areas; greenhouse gas emissions from automobiles; melting glaciers and snow; pollution from industry; smog and haze and rising sea levels. These issues were not in themselves climate change issues, but issues that could be explored in relation to global climate change. The aim of the brainstorm activity was to engage students, by promoting their curiosity and eliciting their prior knowledge, and hence to give them ownership of the content.

### Issue activity

In the following week, each student joined one of the twelve "Issue groups" related to one climate change issue they wanted to investigate further. The students were free to choose groups, according to their interest, but teachers and researchers attempted to include at least one student from each country within each Issue group, to ensure international peer collaboration. However, of the twelve issue groups, four groups failed to have all four countries represented (Table 1).

*Table 1. Topic of issue groups, members of the group presenting number of students (n) from each country.*

| Issue | Country represented by students (n) | Countries represented |
|---|---|---|
| Acid rain | Canada (3), China (2) Norway (2), Sweden (2) | 4 |
| Changing acidity (pH) of waterways | Norway (2) | 1 |
| Changing ocean currents | Canada (2), China (1) Norway (3), Sweden (4) | 4 |
| Changing species in ecosystems | Canada (3), China (4) Norway (4), Sweden (6) | 4 |
| Changing weather patterns | Canada (3), China (3) Norway (2), Sweden (4) | 4 |
| Deforestation | Canada (3), China (2) Norway (3), Sweden (4) | 4 |
| Drought and desert formation | Canada (3), China (3) Sweden (2) | 3 |
| Erosion and flooding of coastal areas | Canada (3), China (4) Norway (2), Sweden (1) | 4 |
| Greenhouse gas emissions from automobiles | Canada (2), China (3), Sweden (2) | 3 |
| Melting glaciers and snow | Canada (1), China (3) Norway (3), Sweden (6) | 4 |
| Pollution from industry, smog and haze | China (3) Norway (2), Sweden (4) | 3 |
| Rising Sea Levels | Canada (3), China (3) Norway (3), Sweden (10) | 4 |

The task of each group was to: describe the issue, give examples from different countries and explain the science related to the issue. This activity progressed for 3 weeks, as shown in Figure 1 and overlapped with the start of the discussion activity in week 2.

## Discussions activity

In the fourth week, students were introduced to the discussion activity which was initiated by driving questions, including: "What is "Global" in Global Climate Change?" and "How can changes in your lifestyle influence climate change?" In these discussions, students contributed explanations to the questions, raised their own questions and commented on other students' contributions. Discussions continued throughout weeks five and six, leading to questions about "What has been done so far, to control climate change?", "What could be done?" and "What might happen if we do nothing?". The students were encouraged and instructed to participate in the discussions, by adding their answers and questions and replying to other students' questions or comments.

## Chat activity

Embedded within the Global Climate Exchange environment was the option for students to create a chat room or visit those already created, at any time. There was no guidance or structure provided on the use of chat rooms, except for ethical rules, which were monitored by researchers and teachers in each country. Chat rooms allowed students to collaborate on tasks, get technical or instructional help, or simply have informal communication with peers.

## Analysis

To address our research questions: what characterizes students' collaboration with peers in "Global Climate Exchange", and 2) what are, if any, the differences between collaboration between national and international peers?, we examined students' contributions in each of the four activities. Note that all student names are pseudonyms.

For all peer interactions that were categorized as being formal (e.g. related to the topic studied), we explored whether peer interactions were international (included peers from more than one country) or national (peers from one country only). The character of peer collaboration can be analyzed in terms of how students communicate, or what Mercer refers to as "collaborative talk" (Mercer, 2004). Since there was no actual "live talk" within the Global Climate Exchange activities, we use the term "collaborative communication" instead of "collaborative talk". The communication between peers was characterized as either *Disputational, Cumulative or Exploratory* (Mercer, 1995) and refers to the nature of students' interactions:

*Disputational communication* is characterized by sequences where students ask questions, agree or disagree without further explanation or reason for their opinions. This kind of communication would typically include questions like:

> "Should all plastic be banned, you mean? What about our bottle used for water?" or utterances such as "I totally agree with you" or "I don't agree with you at all".

In such communication, students have apparently read what others contributed, but it is not clear how much reflection or understanding has gone into their responses.

*Cumulative communication* is characterized by positive, uncritical elaborations, where students add information to existing contributions. In some cases there is no evidence that the students have read and/or evaluated other students' contributions before adding their own ideas and elaborations. In such cases student contributions were the result of working relatively asynchronous and individually before contributing to a common group product e.g. a "divide and conquer" design. In other cases of *Cumulative* communication it was evident that students had read and/or evaluated other students' contributions before adding their own ideas and elaborations. In cases of the latter their contribution was more an "adding on" and little evaluation on what was there previously. Example of such elaboration could be*:*

> Question initiated by researcher/teacher: What have been done and how would it influence the national & global environment?
>
> Student (China): China is trying to reduce the number of old vehicles and ships and, the government inspires people to use the public transports as much as we can.
> Student (Norway): In Norway we are also encouraged to use public transportation instead of cars, but today it might be a bit expensive for students and for people with low income.

*Exploratory communication* is characterized by explanations and agreement or/and disagreement which are elaborated and justified. For example:

> I agree with Bodil: sure this is a problem but it´s not as serious as all of the other environment problems (...) or I don't totally agree. Even though we increased the price, there are still many rich people continuing to use their cars.

In these kinds of contributions it is clear that the students have read and evaluated the statements of other students before making up their minds and adding their own ideas and elaborations.

# Results

## Brainstorm activity

We registered no communication between peers in the brainstorm activity. All the work in the brainstorm activity is therefore considered as *Cumulative,* in which the students contributed information within a common "page construction" task. This was not unexpected, since focus was to *engage* students in thinking about climate change topics, by promoting their curiosity and eliciting their prior knowledge, rather than on collaboration containing online communication. In total 59 issues about climate change were identified and described by the students, like this one added by the Norwegian student Per:

> Because of drastic temperature changes, the snow and ice in Northern Norway will start to melt. The water level will start to rise and this can cause flooding and a lot of animals will die.

In general explanations of the issues in the brainstorm activity were characterized as being relevant yet fairly unelaborated descriptions.

## Issue activity

In the issue activity, 151 distinct explanation events were registered consisting of formal elaborations (90%), corrections/clarifications/formatting (8%) and 2% which were not applicable. An example of a formal elaboration could be this Norwegian student, Linn, explaining the problems of "changing acidity in waterways":

> Changing acidity (pH) of waterways is a serious problem, which can lead to extermination of different species, like shellfish and also coral reefs. It's expected that organisms producing calcareous shells will have problems. This will happen because calcium carbonate reacts with acid.

Later she elaborates her explanation to:

> Changing acidity (pH) of waterways is caused by us (humans) polluting with carbon dioxide. When carbon dioxide comes in contact with water, it turns into carbonic acid. The carbonic acid makes the oceans more acid, which again can affect and damage life in the water. Acidification can lead to extermination of different species, like shellfish and also coral reefs. Limestone, like shellfish and coral reefs, is mostly made up of the mineral calcium carbonate (CaCO3). If calcium carbonate reacts with acid, it will slowly dissolve.

Since the students were working to create a common group product, all contributions in the issue activity were *Cumulative* in nature, involving no communication. However, since the Global Climate Exchange pages worked fundamentally as a wiki, students' work which was *Cumulative* and relatively asynchronous - was frequently edited and elaborated by themselves and others rather than being contributed as a finished product. During this process, students interacted with the content in various ways - formatting text, correcting text, or cumulating information in a common explanation. Discussions of ideas, or communication were notably absent from such editing. In the eleven groups in which there was more than one country represented, 29% of all edits involved international interaction between peers i.e. in terms of students added, corrected formatted on another student's explanation.

## Discussions activity

The discussion activity consisted of different types of collaborative work. From the 245 contributions that were coded across the five discussions, 24% were direct responses to the initial question posed, such as an explanation illustrated by an example and are coded as *Cumulative*. The following extract is a Norwegian student's response to the posed question:

> How does the climate change in one part of the world affect other parts of the world?

> Lotta: "Global" in Global Climate Change means that the climate change is a problem that affects the whole world. For example, humans polluting CO2 leads to higher temperature over the whole world, not only one country. How does the climate change in one part of the world affect other parts of the world? This is because the whole world is connected in networks that are dependent on each other. For example if it gets warmer and drier in a country that exports vegetables and fruit, and the increase in temperature affects the agriculture, there will be nothing to export.

This extract is informative and is an illustrative example of how one student makes her understanding of Global climate change explicit to others. This student contributes to a common group product – e.g. explaining what is meant by "global".

Of the remaining three-quarters of contributions 22% involved discussions between peers from the same country (national) and 54% involved peers from two or more countries (international).

Several differences were found in discussions between international peers and national peers only (Figure 2). The discussions were dominated by *Exploratory* communication (72% in total), however there were great differences between communication involving only national peers and those involving international peers. 85% of communication between international peers was *Exploratory* whereas only 33% of communication between national peers was *Exploratory*.

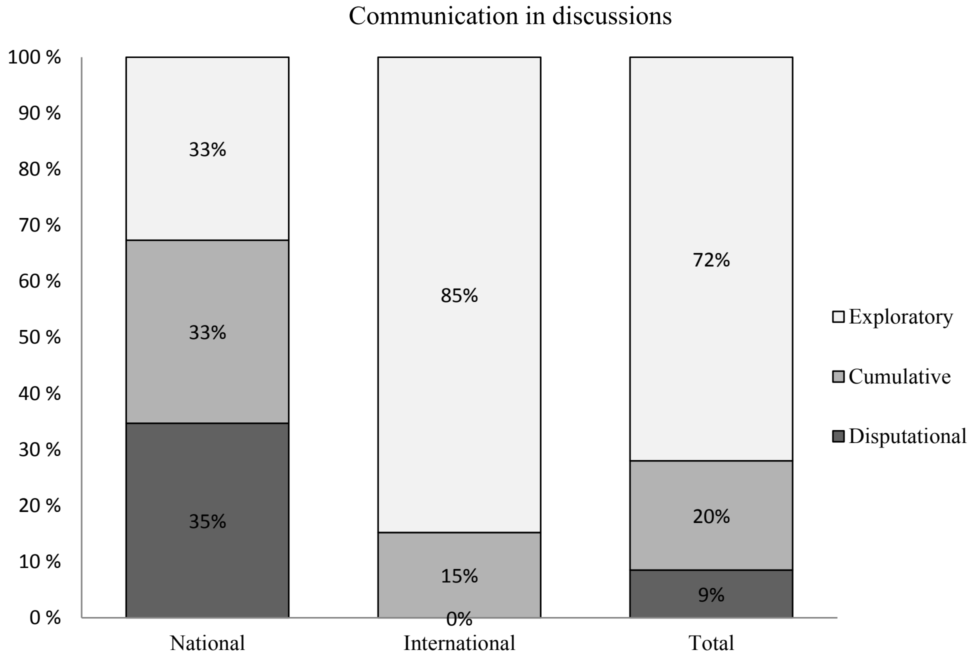


*Figure 2. Distribution of communication in discussion activity.*

The following extract from a discussion in Week 5 illustrates *Exploratory* communication between national peers; three Swedish students:

> What could be done and how would it influence the national and global environment?

> Lotta: We must become more aware of environmental problems and be taught more about how and what we can do to help. We have to incorporate environmental thinking into our everyday to make a change. Buy or acquire: rechargeable batteries, organic products, public transportation when you can, mild detergent, fewer products with better quality, we can buy more locally produced goods, sort garbage, low energy lamps. You can also attempt to use climate friendly electricity, such as solar energy, hydropower and wind power as much as possible. Electric cars are also a good solution; they do not let out any harmful substances. So it is completely environmentally friendly. You can also use other environmentally friendly fuels such as biogas, ethanol and RME.
> Pernilla: Agreeing with Lotta, but can't see it really happen. What you are suggesting has got a point. Although the human is far too lazy to change the ways they are using electricity. Think of a regular everyday person, working and making money to pay for his/her living but not that much more. They can't afford to change into for example solar energy cells. To provide their house with solar cells costs a lot of money and is mostly used in places where the power lines can't reach. An example for those places is lighthouses or satellites. What I am saying is that in present times this kind of energy source is not going to be installed in private homes. Well, not for a while. Maybe if the price went down it would be more likely that it would be more popular. But the popularity depends on price and location. On a place where the sun does not shine that much, it is not worth the cost to install it.
> Karin: In Sweden, solar cells would never be enough. In countries like Sweden that don't have a lot of sun, solar cells would never work as well as they would in a warmer country. It would be a great thing to have if you had another kind of energy source. But I don't think that solar cells are worth the money when you live in Sweden. And as Pernilla said, it's very expensive for a regular working person.

In this example, Lotta gives an explanation and shares her ideas to the posed question to which Pernilla and Karin reply, agreeing or/and disagreeing, but also justifying their opinion by a further elaboration and own ideas. The content of the discussion is of a universal character e.g. the remediation suggested can be applied globally, hence they manage to relate this to a national context of what is possible in their own country, Sweden. The example demonstrates the potential of communication between students with diverse ideas, having the same geographic and cultural background.

There were also *Exploratory* communications involving international peers (Figure 2, 85%) that show the potential of sharing ideas between students with different geographic and cultural backgrounds. For example, in response to the question "*How can you make small changes in your lifestyle which can reduce your contribution to global climate change?"* in week 5, students from China and Sweden had the following exchange:

> XiYung (China): Low carbon" (低碳) is a rather new concept in China. It means that everything you do shouldn't release too much carbon dioxide, $CO_2$. The following are some advices: 1. Use energy-saving air-conditioning, (...)
> Paulina (Sweden): I agree! It's important to use less $CO_2$. There is a lot you can do to decrease the emissions of $CO_2$ by yourself.
> XiYung (China): Yes, $CO_2$ is one of greenhouse gases. It stops the heat from escaping into the universe, and helps keep the earth warm. But with too much $CO_2$, the weather will become warmer and warmer.
> ZaHio (China): I agree with you, low carbon is a rather new concept in China, all of us ought to support it and we should develop new energy instead of petrol.
> XiYung (China): "Yes. Burning petrol will not only release $CO_2$, but also waste energy."

This example shows the value of *Exploratory* communication between international peers. XiYung explains the national (China) view on the concept *"Low carbon"* and gives universal suggestions related to personal lifestyle. The communication hereafter loops around the concept *$CO_2$*, and illustrates diverse student contributions. The example also visualizes how XiYung enhances his explanation (and perhaps understanding) based on the other student utterances (explaining the concept, suggesting remediation, elaborating the concept). In all contributions of *Exploratory* communication it was clear that the students have read and evaluated other students' statements, before making up their mind and adding their own ideas and elaborations.

The second most common communication in discussions, were *Cumulative* (Figure 2, 20% in total). 15% of communication between international peers was *Cumulative* compared to 33% between peers from the same country (National). The following extract between a Canadian and a Swedish student illustrates *Cumulative* communication between international peers:

> Posed question: What might happen if we do nothing? What will be the consequences to the global environment, especially in the countries where the peers you collaborated with come from?
>
> Sara (Canada): First of all there will be an increased probability of droughts and heat waves. Some parts of the Earth will become wetter due to the change in climate, but some will be extremely dry and be affected by droughts and heat waves. The most severe droughts are expected to happen in Africa and parts of Europe. Second of all, there will be more natural disasters that affect the economy. Every time there is a hurricane, or a flood, the damage is worth billions of dollars. Third of all, the huge glaciers are constantly melting. The excess water from these glaciers will flood rivers, lakes, and oceans. The National Snow and Ice Data Centre estimated that if all the glaciers in the world melted, the sea level would rise 230 feet. The ice caps are made of fresh water. When they melt they will desalinate the ocean that will disrupt the ocean currents, ecosystem, etc. The ice caps are white in colour and reflect a great portion of sunlight, therefore cooling the Earth. If all these ice caps melt, the temperature would greatly rise, because land would absorb a lot of the heat.
> Nettan (Sweden): Ice can melt and sea levels could rise dramatically. This means that animals living at the north pool might die and all the towns close to the sea will be flooded, leading to climate refugees.

In this example we notice that Nettan does not seem to reflect on or comment on what Sara says about melting glaciers and floods. Nettan is basically adding on her own ideas about flooding. In general, *Cumulative* communication is characterized by positively but uncritical elaborations, adding on information, without evaluating comments to prior contributions. As opposite to *Exploratory* communication, there is sometimes no evidence that the students read and evaluated other students' statements, before adding their own ideas and elaborations. Even though there is no visual evidence of exchange of knowledge between students in *Cumulative* communication, other students might gain from reading these extracts and reflecting on them.

The least common communication in the discussions was *Disputational* communication (9% in total) (Figure 2). No *Disputational* communication was found between international peers compared to 35% of communication between national peers. This is mainly sequences were students agree or disagree, without further explanation or reason for their opinions:

> Posed question: How can you make small changes in your lifestyle which can reduce your contribution to global climate change?
>
> Peter (Norway): All these "things we can do in our life" do not have so much to say. Now, if some do it, it's great, but it's not helping that much. It's all about that everybody having to participate if it's really going to change the world.
> Lars (Norway): Good thinking Peter!

## Chat activity

47 chat rooms were created in Global Climate Exchange, in which we registered a total of 495 contributions from students. Only two chat rooms containing 3 postings did not involve peer interactions. The students created 50% of the chat rooms for informal communication with peers, 10% for technical – and 8% for instructional - help and 32% for formal communication. Informal communication students mostly talked about their groups' climate change issues.

In total, 67% of these communications were *Cumulative* in which the students added on their own ideas or information without elaborating on prior contributions (Figure 3). *Cumulative* communication was significantly more common in communication between national peers (83%) than between international peers (56%). An example of *Cumulative* communication between international peers is the extract from a chat named "greenhouse gas emissions from automobiles" created by Yu from China.

> Yu (China): Let's talk about something about greenhouse gas. For example, how does the greenhouse gas affect our country?
>
> Eli (Sweden): Last winter in Sweden was really cold and snowy, which was the first time in about 10 years. We know that the greenhouse gas effect gives us a warmer climate, but last winter it was the opposite to warm! This confuses us…
> Maria (Canada): I looked up the average temperature for Canada during the winter and realized that the temperature this winter has been 4-6 degrees above normal. There is a graph on this website: http://www.ec.gc.ca/adsc-mda/

As in the example above, a question or some information about an issue is often initiated and followed by peer interactions where students positively build on what others have said and occasionally ask (uncritical) questions. The remaining 33% of all collaborative communication was coded as *Exploratory* communication; 17% of communication between national peers and 44% of between international peers. No *Disputational* communication was found in the chat rooms.

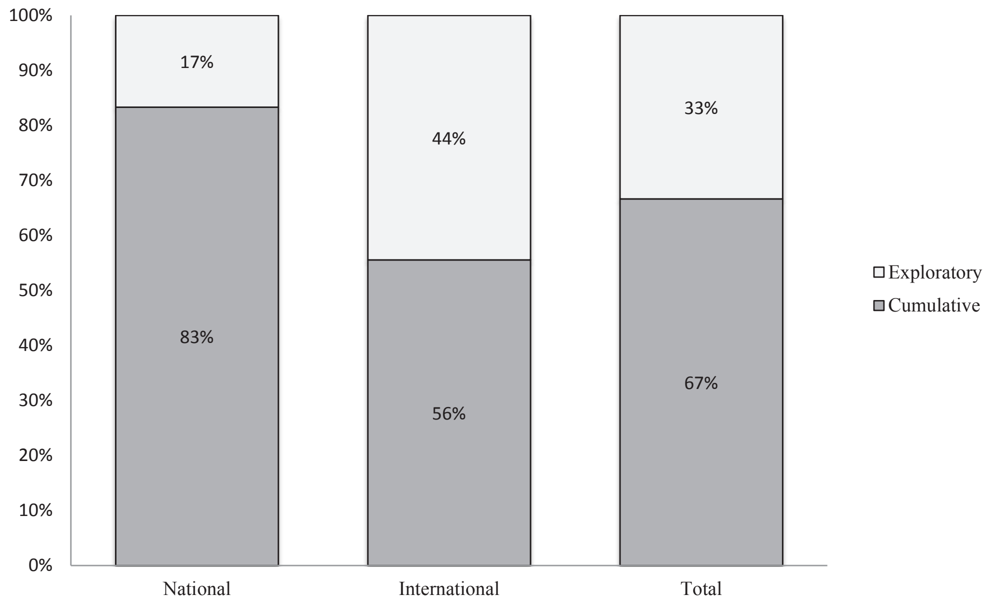


*Figure 3. Distribution of commutation in chat rooms.*

## Discussion

Participation in Global Climate Exchange required students to communicate in English. In a post survey, less than 15% of the students considered their English language ability to be a "barrier" to their participation. Language barriers certainly played a role in the volume and frequency of some students' engagement. However, the evident interaction between peers with native languages different from English (Chinese, Norwegian and Swedish) makes it clear that students at this level (secondary school) have a global language for communication, and that they master this language so well that it allows them to communicate about a rather advanced subject such as climate change. Language is therefore considered as an asset allowing students to communicate across nationalities rather than a barrier.

In this study we have investigated how students interact with peers when working within the online Global Climate Exchange curriculum, by looking further into the details of students' peer communication in four online activities: *brainstorm, issue, discussion* and *chat*.

This study revealed that the students had different kinds of communication in the activities. It was apparent that the brainstorm and issue activity particularly gave students opportunities to *Cumulatively* whereas the discussion and the chat activity gave students more opportunities for *Exploratory* communication.

The brainstorm activity *engaged* the students in the process of starting to think about climate change issues but offering limited opportunities for elaborations and communication. Even though we did not find evidence of direct communication between peers in the brainstorm activity, it was still valuable because it engaged the students in a process that got them to start thinking about climate change issues, and hence elicited their prior knowledge. Since students wrote down their ideas in the Global Climate Exchange wiki, they were made accessible to peers.

The issue activity offered opportunities for *Cumulative* work, but limited communication. In the issue activity, students were mainly guided by three tasks: describe, give example from each country, and explain the science behind the issue. In the activity we didn't register any evident communication, but *Cumulative* work in terms of students elaborated each other's explanations. We know from our prior study (Korsager & Slotta, 2012) that students' elaboration of explanations usually leads to development of their conceptual understanding. In the 29% of the elaborations that involved international peers, we can assume that students read what others wrote, and thereby to some extent shared knowledge with each other.

In the brainstorm activity and the issue activity, there were apparent discrepancies in the task where students showed different knowledge when giving examples of climate change issues from their own country. Many students were active in the activity by contributing with explanations and elaborations, yet, the showed little evidence of active exchange of knowledge and communication.

### Communication

In both the discussion and the chat activity, we found obvious communication between peers in 75% of interactions in the discussion activity and one-third in the chat activity. In the discussion activity the remaining formal contributions were direct responses to the posed question and obviously did not involve peers. Nevertheless, they were valuable even when not replied on because they might still have been read by other students thus initiating their own thinking of ideas, and also when replied upon, they function as a catalyst for collaborative communication.

Our analysis of the communication revealed that *Exploratory* communication dominated the peer communication in the discussion activity, and *Cumulative* communication was the second most frequent.

In the chat activity, *Cumulative* communication occurred slightly more frequently than *Exploratory* communication. Only a small part of the communication in the discussion activity was *Disputational*, and none in the chat activity.

Productive communication might well involve all three types of collaborative communication and can be useful for dynamic interaction between peers (Mercer, 1994). However, there are essential differences which have implications for how productive the communication is for students learning. *Cumulative* communication is valued because students share their knowledge; make it explicit to themselves and visible to others. In *Cumulative* communication in Global Climate Exchange we observed that different students acquired diverse and global knowledge about climate change issues, and that this knowledge becomes accessible to peers through their communication. Still, there was little apparent evidence in *Cumulative* communication that the students really evaluated other students' statements before adding their own ideas and elaborations. The *Cumulative* communication mostly reflects individual reasoning, and it is therefore difficult to say anything about its genuine value for shared learning.

In both *Disputational* and *Exploratory* communication students apparently read what other students wrote. The *Disputational* communication was dominated by sequences where students agree or disagree to the statements of others about climate change issues, but without further explanation or reason for their opinions. This communication contributed to collaborative interaction, but it was uncertain how well their contributions were an indication of individual reflection and understanding of climate change issues.

In *Exploratory* communication it was apparent that the students had read and evaluated other students' ideas or explanations about climate change issues before making up their own mind and adding their own explanation. These *Exploratory* communications reflected a combination of collaborative interaction and individual reasoning and can therefore be interpreted as the most evident indication of peer collaboration which stimulates a productive learning environment (Mercer, 1994; Mercer, Dawes, Wegerif, & Sams, 2004; Rojas-Drummond & Mercer, 2003).

To summarize, even though *Disputational* communication in Global Climate Exchange contributed to collaborative interaction, these contributions were not stimulating further discussions and hence a productive learning environment. *Exploratory* communication, on the other hand, both reflected a combination of collaborative interaction and individual reasoning and stimulated further discussion. *Exploratory* communication can therefore be interpreted as the most evident indication of peer collaboration for stimulating a productive learning environment (Mercer, 1994; Mercer et al., 2004; Rojas-Drummond & Mercer, 2003).

## Differences in communication between international and national peers

From our prior study (Korsager & Slotta, 2012), we know that students' conceptual understanding of climate change was somewhat heterogeneous to start with and became more homogenous during six weeks of collaboration indicating that the students indeed learn from their peers in Global Climate Exchange. We also found that those students who interacted most with international peers have the greatest conceptual development in terms of use of concepts, linking causes and effects together and understand global causalities the most during Global Climate Exchange.

Our analysis in this study show great differences between communication involving only national peers and those involving international peers in both discussion and chat. *Exploratory* communication was far more common in communication between international peers than between national peers only and *Disputational* communication was *only* registered between national peers.

Hence, both of these studies support the idea that collaboration between international peers is more productive than collaboration between national peers.

A possible explanation could be that students make an extra effort when they collaborate with unknown peers. From our pilot study of Global Climate Exchange in 2009, students' and teachers' comments, point toward this explanation as exemplified by the following statement:

> I've made an extra effort because the other students were going to read it" (student) and the teacher said: "they [the students] think it's exciting when other students read and comment on their contributions, so they want to do their best. I experienced that they really study the subject in order to provide good answers.

What students and the teacher are expressing here is an important aspect of a constructive learning community. Each student has a responsibility to assure the quality of one's own work by consulting others when constructing their understandings in a domain (Engle & Conant, 2002). Also recent research show that the quality of reflection and critical thinking in discussions correlates positively with the amount of unknown peers in a learning community (Levinson, 2012).

Another or supplementary explanation might be explained by discrepancy between peers who have different knowledge. The communication therefore becomes more productive, because students get direct access to a greater diversity of ideas and perspectives on science issues (Slotta & Jorde, 2010; Slotta et al., 2005). As shown in most of the examples in this study, students have different knowledge which they share and argue for. In some cases it is evident that students enhance their conceptual understanding when referring and commenting on other students' utterances. Much of the discrepancy in "Global climate exchange" might be a result the international peer collaboration, because students have different knowledge due to cultural and geographic differences.

## Conclusions and implications

The combination of peer collaboration involving different kind of interactions and communication between peers has been proven to be effective to consolidate conceptual understanding (Tao, 1999). Yet, peer collaboration does not automatically improve conceptual understanding. Most researchers argue that key elements for effective peer collaboration are some kind of discrepancy and active participation, where exchange of knowledge happens through verbal communication (Fawcett & Garton, 2005; Howe et al., 1995; King et al., 1998; Mercer, 2000). To increase the effect of peer collaboration, it is recommended to design tasks which ensure that students actively exchange knowledge and communicate. Such tasks can for example include problems that cannot be solved solely with one type of knowledge, or have the main focus on common understanding of the problem explored after more individually work (Dillenbourg, 1999).

Conclusively, implementing a science curriculum similar to Global Climate Exchange can support teachers when teaching a complex topic such as climate change. The Global Climate Exchange gives students good opportunities to learn complex topics because they can collaborate and communicate with peers across borders, who are both unknown and who likely have different knowledge. Such science curriculums are not meant to replace other teaching methods but to complement classroom activities and hence enrich the "local classroom" with a "global dimension".

## Acknowledgments

We acknowledge the important contributions of Q'in Weiwei, from Nanjing Normal University, and Zhao Naxin, from the University of Toronto, who helped us configure "Global Climate Exchange" and manage all student accounts and activities.

## References


Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: models, tools, and challenges. *International Journal of Science Education, 32*(3), 349-377.

Cordero, E. C., Todd, A. M., & Abellera, D. (2008). Climate change education and the ecological footprint. *Bulletin of the American Meteorological Society, 89*(6), 865-872.

Council, N. R. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom*. Washington, DC: The National Academies Press. Division of Behavioral and Social Sciences and Education.

Daniel, B., Stanisstreet, M., & Boyes, E. (2004). How can we best reduce global warming? School students ideas and misconceptions. *International journal of environmental studies, 61*(2), 211-222.

Dillenbourg, P. (1999). What do you mean by collaborative learning? In P. Dillenbourg (Ed.), *Collaborative-learning: Cognitive and Computational Approaches* (pp. 1-19). Oxford: Elsevier.

Dove, J. (1996). Student teacher understanding of the greenhouse effect, ozone layer depletion and acid rain. *Environmental Education Research, 2*(1), 89-100.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing Scientific Knowledge in the Classroom. *Educational Researcher, 23*(7), 5-12.

Duschl, R. A., & Gitomer, D. H. (1991). Epistemological perspectives on conceptual change: Implications for educational practice. *Journal of Research in Science Teaching, 28*(9), 839-858.

Edelson, D., Gordin, D., & Pea, R. (1999). Addressing the challenges of inquiry-based learning through technology and curriculum design. *The Journal of the Learning Sciences, 8*(3), 391-450.

Engle, R. A., & Conant, F. R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners classroom. *Cognition and Instruction, 20*(4), 399-483.

Fawcett, L. M., & Garton, A. F. (2005). The effect of peer collaboration on children’s problem solving ability. *British Journal of Educational Psychology, 75*(2), 157-169.

Garton, A. F. (2007). Learning through collaboration. Is there a Multicultural Perspective? In F. Salili & R. Hoosain (Eds.), *Culture, Motivation, and Learning: A Multicultural Perspective* (pp. 195 - 215).

Gerard, L. F., Tate, E., Chiu, J., Corliss, S. B., & Linn, M. C. (2009). Collaboration and knowledge integration. In International Perspectives in the Learning Sciences: Proceedings of the 8th International Conference of Computer Supported Collaborative Learning (pp. 188–193). Rhodes, Greece: International Society of the Learning Sciences, Inc.

Gowda, M. V. R., Fox, J. C., & Magelky, R. D. (1997). Students’ understanding of climate change: Insights for scientists and educators. *Bulletin of the American Meteorological Society Boston MA, 78*(10), 2232-2240.

Groves, F. H., & Pugh, A. F. (2002). Cognitive illusions as hindrances to learning complex environmental issues. *Journal of Science Education and Technology, 11*(4), 381-390.

Howe, C., Tolmie, A., Greer, K., & Mackenzie, M. (1995). Peer collaboration and conceptual growth in physics: Task influences on children’s understanding of heating and cooling. *Cognition and Instruction, 13*(4), 483-503.

King, A., Staffieri, A., & Adelgais, A. (1998). Mutual peer tutoring: Effects of structuring tutorial interaction to scaffold peer learning. *Journal of Educational Psychology, 90*(1), 134.

Korsager, M., & Slotta, J. (2011). From Local to Global Understanding of Climate Change: students’ ecological understanding. Paper presented at ESERA, September 4th - 9th 2011, Lyon, France.

Lee, H.-S., Linn, M. C., Varma, K., & Liu, O. L. (2009). How do technology-enhanced inquiry science units impact classroom learning? *Journal of Research in Science Teaching, 47*(1), 71-90.

Levinson, R. (2012). *Promoting constructive discourse in philosophical issues through an online forum*. Paper presented at the 9th conference of european researchers in didactics of biology, Berlin, Germany.

Liu, L., & Hmelo-Silver, C. E. (2009). Promoting complex systems learning through the use of conceptual representations in hypermedia. *Journal of Research in Science Teaching, 46*(9), 1023-1040.

Mercer, N. (1994). The quality of talk in children’s joint activity at the computer. *Journal of Computer*

*Assisted Learning, 10*(1), 24-32.
Mercer, N. (1995). *The guided construction of knowledge: Talk amongst teachers and learners*. Clevedon: Multilingual Matters Ltd.
Mercer, N. (2000). *Words and minds: How we use language to think together*. London: Routledge.
Mercer, N. (2004). Sociocultural discourse analysis. *Journal of Applied Linguistics, 1*(2), 137-168.
Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: ways of helping children to use language to learn science. *British Educational Research Journal, 30*(3), 359-377.
Mohan, L., Chen, J., & Anderson, C. W. (2009). Developing a multi-year learning progression for carbon cycling in socio-ecological systems. *Journal of Research in Science Teaching, 46*(6), 675-698.
Mork, S., & Jorde, D. (2004). We know they love computers, but do they learn science? Using information technology for teaching about a socio-scientific controversy. *Themes in Education, 5*(1), 69–100.
Moser, S. C., & Dilling, L. (2004). Making climate hot. *Environment: Science and Policy for Sustainable Development, 46*(10), 32-46.
Najafi, H., & Slotta, J. D. (2010). Analyzing equality of participation in collaborative inquiry: Toward a knowledge community. In K. Gomez, L. Lyons, & J. Radinsky (Eds.), *Learning in the disciplines: Proceedings of the 9th International Conference of the Learning Sciences, 1* (pp. 960-967). Chicago, IL: International Society of the Learning Sciences.
Papadimitriou, V. (2004). Prospective primary teachers' understanding of climate change, greenhouse effect, and ozone layer depletion. *Journal of Science Education and Technology, 13*(2), 299-307.
Rebich, S., & Gautier, C. (2005). Concept mapping to reveal prior knowledge and conceptual change in a mock summit course on global climate change. *Journal of geoscience education, 53*(4), 355.
Rojas-Drummond, S., & Mercer, N. (2003). Scaffolding the development of effective collaboration and learning. *International Journal of Educational Research, 39*(1–2), 99-111.
Rye, J. A., Rubba, P. A., & Wiesenmayer, R. L. (1997). An investigation of middle school students' alternative conceptions of global warming. *International Journal of Science Education, 19*(5), 527-551.
Scardamalia, M. (2003). Knowledge building environments: Extending the limits of the possible in education and knowledge work. In A. DiStefano, K. E. Rudestam, & R. Silverman (Eds.), *Encyclopedia of distributed learning* (pp. 269-272). Thousand Oaks, CA: Sage Publications.
Scardamalia, M. & Bereiter, C. (2006). Knowledge building: Theory, pedagogy, and technology. In K. Sawyer (Ed.), *Cambridge Handbook of the Learning Sciences* (pp. 97-118). New York: Cambridge University Press. (Note: Cambridge University Press has contracted with Educational Scientific Publishing House for a Chinese simplified language edition).
Slotta, J. D., & Jorde, D. (2010). Towards a design framework for international peer discusssions: Taking advantage of disparate perspectives on socio-scientific issues. *Research and Practice in Technology Enhanced Learning, 5*(3), 161–184.
Slotta, J. D., & Najafi, H. (2010). Knowledge Communities in the Classroom. In P. Peterson, E. Baker & B. McGaw (Eds.), *International Encyclopedia of Education* (Vol. 8, pp. 189-196). Oxford: Elsevier.
Tao, P. K. (1999). Conceptual change in science through collaborative learning at the computer. *International Journal of Science Education, 21*(1), 39-57.