Research in Science Education

Investigating and promoting trainee science teachers' conceptual change of the nature of science with digital dialogue games "InterLoc"

--Manuscript Draft--

Manuscript Number:	RISE-D-14-00091R2
Full Title:	Investigating and promoting trainee science teachers' conceptual change of the nature of science with digital dialogue games "InterLoc"
Article Type:	Manuscript
Keywords:	Online discussion; nature of science NoS; constructive knowledge; online structured dialogue environment; digital games; dialogue games; Interloc
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Abstract:	The purpose of this study is to explore how an online structured dialogue environment OSDE supported collaborative learning about the nature of science amongst a group of trainee science teachers in UK. The software used (InterLoc) is a linear text based tool, designed to support structured argumentation with openers and 'dialogue moves'. A design based research approach was used to investigate multiple sessions using InterLoc with 65 trainee science teachers. Five participants who showed differential conceptual change in terms of their Nature of Science (NOS) views were purposively selected and closely followed throughout the study by using key event recall interviews. Initially, the majority of participants held naïve views of NOS. Substantial and favourable changes in these views were evident as a result of the online structured dialogue environment (OSDE). An examination of the development of the five participants' NOS views indicated that the effectiveness of the InterLoc discussions was mediated by cultural, cognitive, and experiential factors. The findings suggest that InterLoc can be effective in promoting reflection and conceptual change.

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Running head: Online structured dialogue environment

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Key words: Online discussion; nature of science NoS; constructive knowledge; online structured dialogue environment; digital games; dialogue games, Interloc

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Introduction

The value of online dialogues for promoting reflection and the development of understanding in many educational areas has been championed for over two decades now (eg Chen & She; 2012; Sardone & Devlin-Scherer, 2009; She & Liao, 2010). However many have also questioned whether disembodied online interactions can sustain the kind of reflection that leads to changes of views (e.g Miller, Anderson, Morries, Lin, Jadallah, & Sun, 2014). Many experiences of learning through online dialogue have been disappointing and the general conclusion now has to be that a great detail of support is needed if online discussion is to lead to significant educational outcomes (e.g Weinberger et al, 2005). In this context it is important to explore what kind of supports for online dialogue result in desirable educational outcomes and why. This study makes a contribution to the literature of CSCL in exploring not only whether or not an online dialogue game called InterLoc could support the deepening of reflection and understanding in the area of the Nature of Science but also looking in more detail at the affordances of the online dialogue game to analyse which features of the support provided were effective and why.

Because of the structured and explicit nature of interaction mediated by the InterLoc system this study is also able to contribute to the literature on the relationship between interaction and students' conceptual change. While the theoretical frameworks of studies into conceptual change often address students' learning processes, the majority of the empirical procedures investigate the products of students' learning rather than the processes of student conceptual development or conceptual change. Thus, from the current status of research, it can be concluded that major issues of understanding the processes by which conceptual development takes place are still theoretically and empirically vague (Aufschnaiter et al., 2008; Mercer, 2008; Ravenscroft, McAlister, & Sagar, 2012; Tao & Gunstone, 1999). Generally, we cannot yet explain in detail why teaching strategies that attempt to promote conceptual change are often unsuccessful. To

achieve this objective, it is necessary to know how students make sense of learning material offered to them and how this material contributes to and fosters students' conceptual development. In short, it would be necessary to trace how students create meaning out of the learning experiences they are offered and how they deploy their own knowledge and understanding in tasks and problems (Abd-El-Khalick & Lederman, 2000; Aufschnaiter et al., 2008). In this paper, we discuss UK trainee science students' experiences with the online dialogue game to explain how the online discussion facilitates conceptual change in views on Nature of Science (NoS) and students' reflection on the process of the interactions among them. This paper also explores the students' reflections on the affordances of the online dialogue game that facilitate the conceptual change.

InterLoc

InterLoc is an educational learning tool using Instant Messaging (IM) technology. The name comes from interlocutor - one who takes part in a conversation or dialogue, and a person who questions and interrogates. Using this tool students participate in online discussion activities in small groups and become interlocutors for their peers. InterLoc is a web technology for computer supported collaborative learning (CSCL) that is described in Ravenscroft (2007). It uses what Ravenscroft calls 'dialogue games' to get learners thinking together about topics, media or material that is relevant to them. This is achieved by setting up a context and facilitating interaction to achieve synchronous reasoned dialogue, such as critical and creative discussion. InterLoc also allows the participants to generate reusable content from their group experiences. InterLoc supports a dialogue game that allows group discussion to refine the knowledge already gained through readings. The online discussion is designed to encourage thinking and collaborative approaches to understanding issues and to promote the development of general critical thinking, argumentation and discussion skills in learners via scaffolding and support from other participants.

Discussions using the online dialogue game take the form of a threaded series of linked messages organized topically. Threaded discussions are text-based and asynchronous; they develop over time as participants separated in time and space read and reply to

existing messages. Messages in a given thread share a common topic and are linked to each other in the order of their creation. Threaded discussions are significantly different from face-to-face discussions,. To begin with, all students can easily 'take the floor' to have a voice in threaded discussion. It is more difficult for any one student to dominate the conversation than in a face-to-face dialogue. The asynchronous nature of the discussion also makes it more difficult for a tutor to control than face-to-face dialogues (e.g. Swan 2003). The InterLoc tool supports synchronous dialogue games that foster reasoned online discussion and debate that are intended to lead to the development of higher-order conceptual skills (Ravenscroft & McAlister, 2009).

Conceptual change using an online discussion

Within research on science learning and conceptual change about science, there is interest in collaboration in general and social constructivism in particular (Chen & She, 2012; Tao & Gunstone, 1999; Luebeck & Bice, 2005; Miller et al., 2014; She & Liao, 2010). Conceptual change involves techniques of accommodation, restructuring, replacing, or reorganizing a concept (Taylor, 2001). Limon (2001) groups instructional strategies that promote conceptual change into three categories: developing cognitive conflict, applying analogies, and facilitating "cooperative and shared learning to promote collective discussion of ideas" (p. 358). One of the common strategies to foster conceptual change is to confront students with discrepant events that contradict their conceptions. This is intended to invoke a disequilibration or cognitive conflict (Piaget 1985). Conflict arises in peer collaboration when students disagree with each other in their interpretations or approaches to the task. To resolve the conflict, they have to justify and defend their positions and this forces them into reflection. This cognitive conflict is based on the Piagetian perspective which claims that sociocognitive conflict arises when students holding inadequate or differing views work together. "The disequilibration thus engendered demands resolution and this requires students to reflect on their own conceptions" (Tao & Gunstone, 1999, p. 40).

Mercer (2008) argues that conceptual change cannot be understood without considering the role of dialogue. People are sharing ideas, considering them and changing them through social interaction (Penttinen, Anto, & Mikkilä-Erdmann, 2013; Wu, Anderson, Nguyen-Jahiel, & Miller, 2013). Social approaches can change the way people feel and think above and beyond the words that are exchanged (Johnson, & Sinatra, 2013; Miller at al, 2014).. In argumentations, learners will articulate reasons for supporting particular conceptual understandings and attempt to justify their views. Others will challenge, express doubts and present alternatives, so that a clearer conceptual understanding will emerge. In such a manner, knowledge is co-constructed by the group as the group interaction enables the emergence of an understanding whose whole is more than the sum of the individual contributions (Newton, Driver, & Osborne, 1999; Luebeck & Bice 2005; Wu et al., 2013).

Online collaborative tools such as the discussion forum are said to provide a platform for students to actively engage in constructing knowledge with their peers and instructor (Huang, Chiu, Sung, & Farn, 2011). Sandoval and Reiser (2004) suggest that online learning environments can provide excellent support for students constructing scientific explanations and support for the knowledge negotiation process in argumentative writing. Online discussion affords participants the opportunity to reflect on their classmates' contributions while creating their own, and to reflect on their own writing before posting messages. This tends to promote more mindfulness among students and can support a culture of reflection in an online course (Hew & Cheung, 2013). A study by Wishart, Green , Joubert and Triggs (2011) investigating different approaches to engaging students in argument and discussion about ethical issues in school Science reported that the online discussions tended to include longer, more thoughtful and better-structured comments than the face-to-face discussions. In a study on high school biology students' understanding of photosynthesis, Lumpe and Staver (1995) found that students working in collaborative groups developed more scientifically correct conceptions than did students working alone.

Research questions

This paper investigates the potential for promoting and supporting conceptual change via online discussion in the context of coursework among trainee science teachers. The key research questions for our study were:

1. To what extent does online discussion using a digital dialogue game (InterLoc) impact on conceptual change and knowledge construction within a group of trainee science teachers.

2. What are the trainee science teachers' views of the affordances of the online dialogue game for promoting conceptual change, if any?

Participants

The students were enrolled on a Post Graduate Certificate of Education (PGCE) course studying to become science teachers at secondary school level in the UK. All sixty five prospective science teachers (thirty five female, thirty male) in the cohort beginning the programme at the university of…. (anonymous for blind review) took part in the InterLoc intervention described here. All had joined the programme having gained a first degree in a science subject. Forty one were specialising in biology, eleven in chemistry and thirteen in physics. The discussion was facilitated by three facilitators who had varying amounts of experience in supporting online learning in real time. Each facilitator was responsible for the moderation of the online discussion of three groups of students. Each discussion group was made up of six to eight students from different specialisms (Physics-Chemistry-Biology).

Research context and the setting of the Interloc activities

The course lecturers decided to focus on the topic of 'the nature of science' in the online discussion activity. This topic was part of the content of the PGCE for individuals studying to be science teachers. The activity was designed to provide some preparation which was carried out by reading of the literature provided and then a discussion was carried out at the dates and times published in the timetable. The students were put in to small groups of six to eight. Nine discussion rooms were created to accommodate all for

the group discussions. Each discussion was supported by a facilitator, thus each lecturer was responsible for facilitating three groups' discussions.

Insert Figure 1 Here: Figure 1: Activity window in InterLoc

The three preparatory activities for the discussion were provided within InterLoc as shown in Figure 1. The topic for discussion was 'The national curriculum for science as currently defined is totally inadequate to meet the purposes of science education and gives a false impression of the nature of science.'

Research design

The study is based on design experiment methodology. A 'design experiment' is a form of qualitative research intended to explore the impact of a deliberately managed change. One of the main purposes of the design experiment reported in this paper is to develop a class of theories about both the process of conceptual change and the means that are designed to support that change. The following chart shows how the InterLoc discussion was embedded into the PGCE science course:

Insert Figure 2 Here: Figure 2: the procedures of the InterLoc Study

Step 1: Students were asked to complete a 'Nature of Science' questionnaire (Nott & Wellington, 1993).

Step 2: Students attended a lecture/workshop entitled 'The Nature of Science' which was intended to encourage them to think about the philosophy of science and develop their understanding of the nature and development of scientific knowledge.

Step 3: Students attended a lecture introducing them to various aspects of ICT including the use of InterLoc. They were given InterLoc passwords and asked to go online to the InterLoc site where they would find three tasks.

Step 4: Students took part in online dialogue using InterLoc for one hour. Each discussion group was made up of five to seven male and female students from each

specialism. These discussions were followed by a face to face discussion involving all students in which they expressed views related to their online dialogue.

Step 5: Students took part in another four online dialogues for one hour in the same groups as on step 4.

Step 6: Two weeks later students were asked to complete the 'Nature of Science Profile' for the second time.

Methods

To search for evidence of conceptual change in online discussion, the following research tools were used.

Nature of Science NOS scale:

The Nature of Science (NoS) scale designed by Nott & Wellington, (1993) was used as a pre-test and post-test to identify some student teachers for whom conceptual change took place. This questionnaire gave them individual scores on the following scales:

- Relativism vs. positivism: truth as being relative or absolute.
- Inductivism vs deductivism: generalising from observation to general laws versus forming hypotheses and testing observable consequences.
- Contextualism vs decontextualism: science as being interdependent with or independent of cultural context.
- Process vs content: science being characterised mainly by processes or by facts and ideas.
- Instrumentalism vs realism: science as providing ideas which work versus a world independent of scientists perceptions.

Online Focused Group interview

Online discussion is convenient in that it links participants across time and space, reducing the difficulty of scheduling. Online group interviews afford more time for participants to reflect and react and for the interviewer to manage and facilitate the discussion and resolve conflicts. Most supports for online dialogue, including InterLoc,

allow for non-linear 'hypertalk', through which participants can contribute to different threads of discussion within a short period of time without disrupting the discussion. In a sense, it offers participants relatively more freedom to participate only in certain parts of discussion and to think and contribute to multiple threads, instead of conforming to the flow of discussion as in face-to-face situations (Lim & Tan, 2001). Online focus group discussions using Interloc with the 9 discussion groups were used to explore their views about engaging in a digitally mediated discussion and how this on-line environment influenced their knowledge sharing, critical thinking and conceptual change in relation to the Nature of Science.

Key Event Recall interviews (KER)

Key event recall is a version of 'stimulated recall' or 'critical event recall' that we have developed for the online interview. Online discussion always leaves an external and visible trace that can be analysed in terms of patterns of messages but in addition the inside perspective of what these messages mean to participants is essential to any investigation of changing views. For this reason some have proposed a phenomenological approach to online research (McConnell, 2000) and others the need to develop an online ethnography (Author 1998). Key event recall in which we take an event in online dialogue that we think is significant and replay it for the participant asking them what it meant to them and how they felt at the time, is a way of uniting the more common outside view of discourse with an inside view. Two approaches were adapted to undertaking KER with 5 participants. In the first approach the participant is presented with summary of their pre and post scores on NOS scales.

In the second approach the participants were given the full text of the transcript of the group discussion on Interloc highlighting the texts that the researchers believed represent the conceptual change. In both approaches, all interview participants were presented with both these items in advance of the recall session. so that they might familiarise themselves with the changes on their NOS scales and full text of the online discussion (De Laat, 2006).

Data analysis

Qualitative data analysis of the interviews

To understand and explain how using the text-based structured dialogue environment promotes conceptual change of students' thinking of the Nature of Science, the analysis of the students' key event recall interviews and the online focus group interviews were carried out by using some of the methods of grounded theory including open coding, combining categories into theoretical statements corresponding to axial coding, and action-chain model (Axelsson & Goldkuhl, 2004).

The action model used in this study is based on pragmatic ontological assumptions that the social world is a world of actors and actions, conditions for actions and effects of actions (Axelsson & Goldkuhl, 2004). The text-based structured dialogue environment in which the discussions of PGCE science students are embedded and evidence for how students make sense or view these contexts are illustrated by examples of the verbatim quotations from the key event recall interview and the online focused group interview.

Findings

Changes on nature of science scale assessing the impact of the online discussions using digital dialogue games

44 out of 65 PGCE science students responded to both pre and post NOS scales. The changes between the students' scores on the pre- and post NOS scales were used to establish the evidence for conceptual change of students' views of NOS. The analysis of students' views of NOS on the pre-post NOS Five scales in Table 1 show two types of changes: minimal changes and substantial changes.

On the one hand, Table 1 shows minimal changes of the students views of NOS on the Five NoS scales ranged 2%-25%. These minimal changes include increasing or diminishing changes of the students' scores on the NOS scales but the students remain hold the same views of NOS. For example a student might start the Interloc sessions with a relativism view of science and after the Interloc sessions s/he remains held positivism

view but with a different score on Positivism-Relativism- (PR). To give an example of these minimal changes, Table 1 shows that after participating in Interloc, the scores of 20% of the 44 PGCE students on the Positivism-Relativism- (PR) scale have been changed from less relativism to more relativism views and 11 % of the 44 students' views on the same PR scale have been changed from more positivism to less positivism.

Insert Table 1 Here: Table 1: Percentages of the changes of PGCE science students' views on NOS

On the other hand as shown in Table 1, some of the 44 PGCE students achieved substantial changes which mean changes in their types of NoS profiles. For example a student might start the Interloc sessions with a relativism view of science and after the Interloc sessions s/he remains held positivism view of science. The changes happened to score on the Positivism-Relativism- (PR) scale but also to the type of view of NoS. To give an example of these substantial changes, Table 1 shows that after participating in Interloc, the scores of 39% of the 44 PGCE students on the Positivism-Relativism- (PR) scale have been changed from from positivism to relativism, 39% of the 44 PGCE students' views on the Inductivism– Deductivism (ID) have been changed from Deductivism to Inductivism, 39% have been changed from Decontextualism to Contextualism on the DC scale, 30% have been changed from content to process (CP) and 25% have been changed from Realism to Instrumentalism on the RI scale.

As shown in Table 2, some examples of the NoS items that indicated changes in the students' conceptual change of the NoS aspects were derived from the analysis of the pre and post NoS scales. These NoS examples, alongside the transcript of the group discussions in Interloc highlighting the texts that the researchers believed represent the conceptual change, were selected and shared with participants as a stimulus during "key event recall interviews".

Insert Table 2 Here: Table 2: Examples of Key event recall interviews related to NOS

In the following sections, we present students' expressed perceptions of the factors that led them to change their views about NOS or at least led them to shift or question their views.

Dialogue with and challenging by others

Sixteen students explained that the discussion allowed them to be aware of 'others views and opinions'. Twelve students commented that it gave them a 'broader and better understanding of subject' with seven being specific that InterLoc discussion 'challenged you to think critically/differently'. Many of the students were actively engaged in the discussions' activities. They found their viewpoints and conceptions about NOS challenged not only by readings and research, but by peers. the NOS scales for Charlotte showed that a substantial conceptual change happened to her on two aspects: On the RP [can we articulate this in full please?] sub-scale from +3 to -8 and On the PC [again – less acronyms please] sub-scale from +1 to -3 (See Table 3)

Insert Table 3 Here. Table 3: Charlote's NoS Scales

When we interviewed Charlotte using some examples from Table 3 that showed some changes on her NoS scores and asking her how the changes of conceptual change about NoS happened to her, she explained:

> In school the study was assessment driven so that's how I thought it was – positivist, but then going to university there was a slight change as we learnt that not everything is true and absolute. This was a shock and led to a change of opinion. Dialogue and discussion in interloc has supported this change – agree it has a little bit. Other people's opinions did help as well. It made me realise that the curriculum should be teaching the philosophy of science and not just the theories/facts. Have to make it interesting as well as it can be confusing – philosophy of science. (Charlotte, KER, G9, Chemistry)

Another student teacher explained how sharing knowledge with others challenged his views about NOS. He said:

> You can say something you do not believe yourself but when others add and are positive then the argument develops and u can start to believe it. Ur input can get better from what ppl are saying in return. When people agreed and by judging what everyone says I changed my views. (John, KER, G2, Biology).

John is one of the students whose score on the NoS instrument changed and he claimed that he was aware of the change. He gave reasons for this change saying:

> Possibly the InterLoc discussion has given me a chance to change – as it lets you have a debate which necessarily does not happen in class. Interloc has contributed to the change in score. Sometimes it is about how much depth you think about each statement – write, reflect, return to it, change view…. My views have developed by taking others views on board (John, KER).

Text-based online dialogue and deep reasoning

Responses directly relating to e-discussion and how DDG supports critical thinking were provided by seventeen students. The comments made regarding this were as follows - InterLoc was an 'effective way of sharing knowledge', for which students 'get together and discuss' – and it 'enabled everyone to write their thoughts' (seven students). Three felt that 'ideas were brainstormed' and that 'everyone made good points'. Two students further clarified that e-discussion 'allowed critical thinking - reflect and respond at later date' along with 'multiple threads' which provided both breadth and depth to discussion. This aspect of depth was also pointed out by four students who explained that InterLoc 'allowed to fully explore the subject', 'get you thinking in more depth', and 'developed a good discussion'.

The tool certainly supports challenging of views even if such communication was limited in some discussions - '*format* (was) *appropriate to challenging ideas and debate'* the discussion certainly got them thinking critically about the subject.

> Had come with fixed ideas and thought I knew what was what from university learning. Now I have been challenged and made to rethink. Dialogue / discussion on line can challenge your views.... no one is actually there and you cannot just

> join in passively but have to think and put your point across.' (Peter, online interview)

The prospective teachers expressed that using online discussion affords them the opportunity to reflect deeply on their online group mates' contributions and think critically while creating their own, and on their own writing before posting them. One trainee commented:

> Online was lot more available for people to sit and think….normally this is not what happens in a conversation. People might feel a point has been made and that's it – end of the argument. Interloc helped to share knowledge about NOS. sharing knowledge was good…the textual space allowed you to have a good discussion. In multiple discussion threads, someone can pick one point in a thread and makes them think about point from elsewhere and that makes them put forward another new thought – Interloc gives them a perfect place to do that. In F2f the conversation has moved on and opportunity is lost to make a new point (Andrew, KER).

Some PGCE students compared the nature of text-based dialogue as opposed to oral dialogue. They referred to how the written-down contributions provided an objective record which made reflection easier and deeper. The following quote from a KER interview with a student goes into more detail:

> Verbal vs textual argument – I like text as it allows you to look back with the log and reflect. You can reply to earlier messages. Interact with earlier arguments. Cannot do this in real life! (John, KER).

Some students expressed the view that the shift in their thinking or the conceptual change happened because of the collaborative learning, negotiation and sharing knowledge with other members of discussion community. One said:

> Online discussion made me more open-minded and happy to take into consideration what others think and hear the rationale for their views (Charlotte, KER).

Another student added:

> I agree because it let you re-look at previous comments and perhaps analyse what was being said more than perhaps a face-to-face discussion would - you had time to think about a point and then respond - you don't get that opportunity face-to-face because the discussion has moved on…..it did help you to think critically because it occurred over some sessions which enabled you to reflect on what had been said and to re-look at the discussion papers (Sara, G7, online interview).

Some students claimed that online dialogue allows for more reflection and there is no pressure for an immediate response. One comment said:

> You can write different things about different things at different times… start new discussion or add to previously said themes which is not possible in f2f ……I think it was useful to have text dialogue. In f2f cannot compare what people said at once. Having the dialogue log allows me to have the time to think and is not coloured by what you thought it was like. it allows to compare the views in front and have time to see all statements as well time to think about them before giving response (Andrew, KER).

The impact of the use of a pre-set list of openings to structure online dialogue

All students had some comments to make about the use of many openers for the start of their message. Sixteen students felt they were 'distracting, limiting, frustrating', and that they were 'having trouble with pre-formatted words'. Seven commented that there were some openers that did not allow messages to be added and took away their option to explain further in the same message. Nine students felt the openers 'should be more user friendly – a single list so option to use any, more general or made specific for each discussion'. Further six suggested that 'maybe use of openers should be optional or removed'. Only one considered that the openers 'do not aid critical thinking' while another stated that choosing of the right opener did make him think about his contribution. Two students identified that the openers would be considered 'very useful in helping younger students structure their discussion'.

The use of openers was reflected upon by students and facilitators in allowing for a structured discussion to take place. Indeed students who had some experience using other linear text chat like MSN felt openers were good and allowed a structured approach to forming their responses.

> Openers – liked them and its quite fun. Have to find a way of how to start the sentence (Peter).

Some students claimed that the openers structured their responses which encouraged them to think critically.

> I think that the way that we had set sentence openers that we had to use made me think about how exactly I had to respond to comments that I was replying to. I think that this made me have to explain things in a different and possibly clearer way (Nicola, G5, online interview).

Text-based online dialogue promotes Confidence

Students expressed the view that Asynchronous-textual discussion affords participants who have problems with participation in f2f talk the opportunity to reflect freely their thoughts. One student teacher said:

> Interloc was good. I Liked it. Can be anywhere and still participate. you might say something which would be easier than f2f, more confidence. Shy and less talkative can also have their input here rather than in f2f where you need to be pushy (John, KER).

Students highlighted being invisible behind the screen when discussing controversial issues helped them to open up their views and to be more open to others views too. One student said:

> Benefit of Interloc – can address touchy subjects (if you are shy or embarrassed) and the virtual environment means you are not visible – maybe does not mean so much. Freedom as no one knows me gives me space and confidence to say things. If people were not liking your view, in f2f . You would keep quiet while in Interloc you cannot see others and so can continue saying what you want to. Lot

> more open to others views by reading on the screen. Sometimes in f2f you can ignore people who you do not get along with (John, KER).

Another comment said:

> Interloc was good as people were not in front of u. so not as easy for someone to shut you up and allowed people to think and write a response (Carole, KER).

Text-based online dialogue and dominancy

Text-based online dialogue supported the improvement of depth and breadth of understanding of the subject (Nature of Science). The tool encouraged participation since people are not present in person it allowed everyone to participate and contribute without anyone dominating the discussion. InterLoc was an effective way of sharing knowledge, which allowed students to get together and discuss thereby enabling everyone to write their thoughts. Students felt that '*ideas were brainstormed'* and that *'everyone made good points' (*students' responses from focus group interview). The multiple threads allowed for depth and breadth of discussion. One comment from a critical event interview said

> I suppose some people might feel happier contributing to a more anonymous form of discussion. What I meant about it being anonymous - which it obviously isn't! I meant that not having to have a voice and have people look at you when you are talking could be an advantage to some people. I think the conversations can still be dominated. (Sara, G7, online interview)

Some students claimed that Text-based online dialogue, as a main feature of Interloc, allows everyone to have their say without fear of possible criticisms of what they said, and helps all voices to be heard equally, and not talk over each other or to be controlled as it can get rowdy in face to face talk. They claim that all of these features supported their critical thinking. One comment from a critical event interview said:

> F2f vs online – find online easier as some people in group are opinionated and find it hard to get a word in f2f. So people cannot dominate and gave me space to raise my voice without feeling intimidated or worried what they are thinking as

> you are not directly in contact. Good to see different views at the same time. can read them as people are thinking. Good as it was in real time to allow u to think and reply to whole opinion and not bits of info. Shift in score – content to process, positive to relativism and to instrumentalism (Charlotte, KER)

Discussion and conclusions

The educational activities that were the subject of this research emphasized learner-centred instructional design. Contrary to instructor-led discussion, students were encouraged to lead the online discussions and facilitate discussions. The interaction between the facilitators and the discussants also represents an important aspect of online interaction. During online discussions, the students can choose which issues related to science to discuss (e.g. group1 discussed 'biology in society', group2 discussed 'science and religion'). The facilitators' roles mainly focused on keeping the discussants on track and posing questions to deepen or to widen the discussion.

The results of the study show that using this online structured text-based interaction support tool (InterLoc), facilitated higher-order thinking. This apparent benefit for the written word in higher- order thinking is supported in a study of questioning and cognitive functioning. It was found "that interaction in the on-line context was more intellectually demanding that that found in face-to-face" (Blanchette, 2001, p. 48). A possible explanation is the asynchronous nature of written communication where the students have more time to reflect (Hew & Cheung, 2013; Luebeck & Bice, 2005). Using Interloc a discussant cannot post a new message until the other discussant has posted his/her note. In this respect, Garrison and Anderson (2003) argue that text-based communication has a special affordance for facilitating critical discourse and reflection and to support collaborative, constructivist approaches to learning and conceptual change. Clark et al. (2003) argue that text-based communication may also facilitate discourse in science inquiry because learners have more time to formulate well thought out contributions. This finding concurs with Choi, Hand, and Lori Norton-Meier (2014)' findings indicated that students were actively engaged in the online discussions about inquiry investigations and were focused on providing more evidence and backing for claims and negotiating evidence.

The evidence from student feedback has been that the postgraduate student science teachers were aware of the type of thinking together that was performed, and they explicitly used such terms as: ‘sharing knowledge’; ‘critical thinking’; and ‘thinking in more depth’ in their feedback. They appreciated that using online dialogue ‘challenged you to think critically/differently’, and that they came away with a ‘broader and better understanding of [the] subject’ (Sardone & Devlin-Scherer, 2009; Wishart et al., 2011). The students also commented on the active use of concise reading resources, supplied within the activity, before and during the discussion which helped lead them to new learning (Hew & Cheung, 2013; Luebeck & Bice, 2005). The feedback from these students, critical as well as positive, informed further developments of InterLoc by the development team led by Dr Andrew Ravenscroft (Ravenscroft et al., 2012; Yuan, Moore, Reed, Ravenscroft, & Maudet, 2011)

The findings of study give empirical support to the claim that text-based communication used in online digital games can facilitate higher-order and critical thinking. In this respect, Hand, Prain, Lawrence and Yore (1999) argues that students need to understand that their own writing, and that responding to the writing of others, can provide interactive and constructive opportunities to clarify their own knowledge about particular concepts and the bases of this knowledge as well as clarify their understanding of scientific methods and their representation in writing. The effective use of the aspects of writing including reflection, revision and reorganization produce a more richly connected text and persuasive argument (Goodyear & Zenios, 2007). Frequently this kind of dialogical writing can develop their reasoning skills, epistemological processes and understandings, as well as broaden their conception of the nature of science as they become scientifically literate (Scardamalia & Bereiter, 2006). It is precisely this emphasis on meaning generation as a semiotic process that holds the key to learning science through writing (Sardone & Devlin-Scherer, 2009; Wallance et al., 2007).

The findings of the study signified that asynchronous discussion through digital games affords participants the opportunity to reflect on their classmates’ contributions while creating their own, and on their own writing before posting them which in turn supported the students’ conceptual change about NoS. Working with others often increases task

efficiency and accuracy, while giving each team member a valued role to play grounded in his or her unique skills. Vygotsky (1978) explains that learning in collaboration with others is necessary for the development of one's own cognitive processes. In addition, Sardone and Devlin-Scherer (2009)'s study which took place in classroom settings, indicates that digital games have the potential to engage students, foster positive attitudes toward learning, enhance focus, as well as encourage collaboration, healthy competition, and involved discussions.

The findings of the study suggest that the structured online dialogue environment using openers (I agree, I disagree, can you say more about this?, etc.) helped students to structure their arguments and to share knowledge which in turn helped them questioning their own views which led with some cases to shift these views or at least considering and acknowledging other people's views. Learners may not know what it actually means to explain and argue and analyse ideas, they may not have been taught how to do so, or they might not be well practiced in the skills of explanation, argumentation, analysis and other aspects of high-level discourse in a collaborative setting. These labels on contributions act as scaffolds by providing an explicit framework for the production of an elaborated argument (See Markauskaite, Sutherland, & Howard, 2008). It is now widely accepted that learners construct their understanding of science through the social negotiation of meaning (Chen & She, 2012; Luebeck & Bice, 2005; Wallance et al., 2007).

This study contributes to the field of research on the effects of text-based online communication on scientific learning in school when writing is used to assist a knowledge construction process requiring conceptual change. The study indicates that text-based online communication can be successfully introduced in the science learning for scientific knowledge construction and reconstruction processes. This shows that when structured online dialogue is used within a meaningful activity, it contributes to facilitating students' conceptual understanding and leads them to perceive Computer-Mediated Communication (CMC) itself as a more useful and effective tool to be used by them in their future career as teachers.

However, the findings of this study are suggestive rather than conclusive. Further, longer, studies of using this type of software are needed to confirm them. A major limitation of the study is the relatively short time spent by students working with the online dialogue game.

The authors ensured that the research was not harmful to any students involved in this study but instead the findings of the study were of great benefit to them and the PGCE science course. In order to conduct the study, the authors obtained ethics approval from Exeter University. The authors fully followed the Committee on Publication Ethics (COPE) guidelines when carrying out the research or preparing it for publication. (COPE website http://publicationethics.org/).

Acknowledgement. InterLoc was developed by a team led by Andrew Ravenscroft with funding from the UK JISC (Joint Information Systems Committee) 'e-learning tools' programme, and from the JISC Capital Programme.

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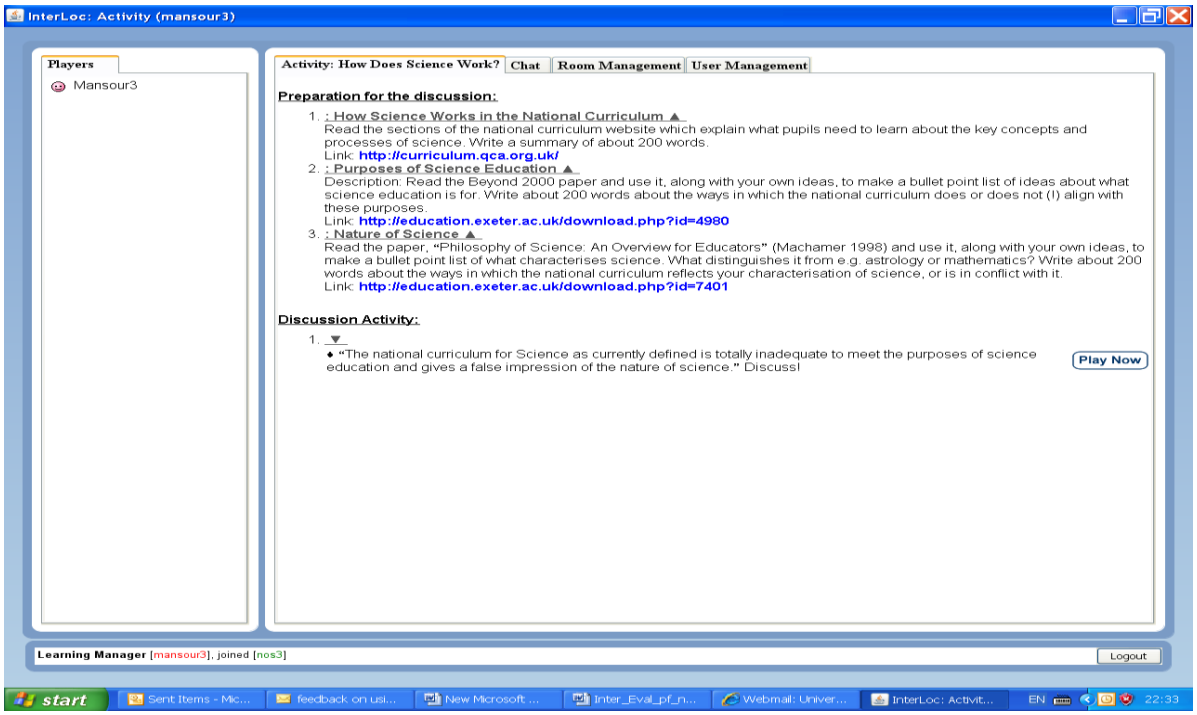

Figure 1: Activity window in InterLoc

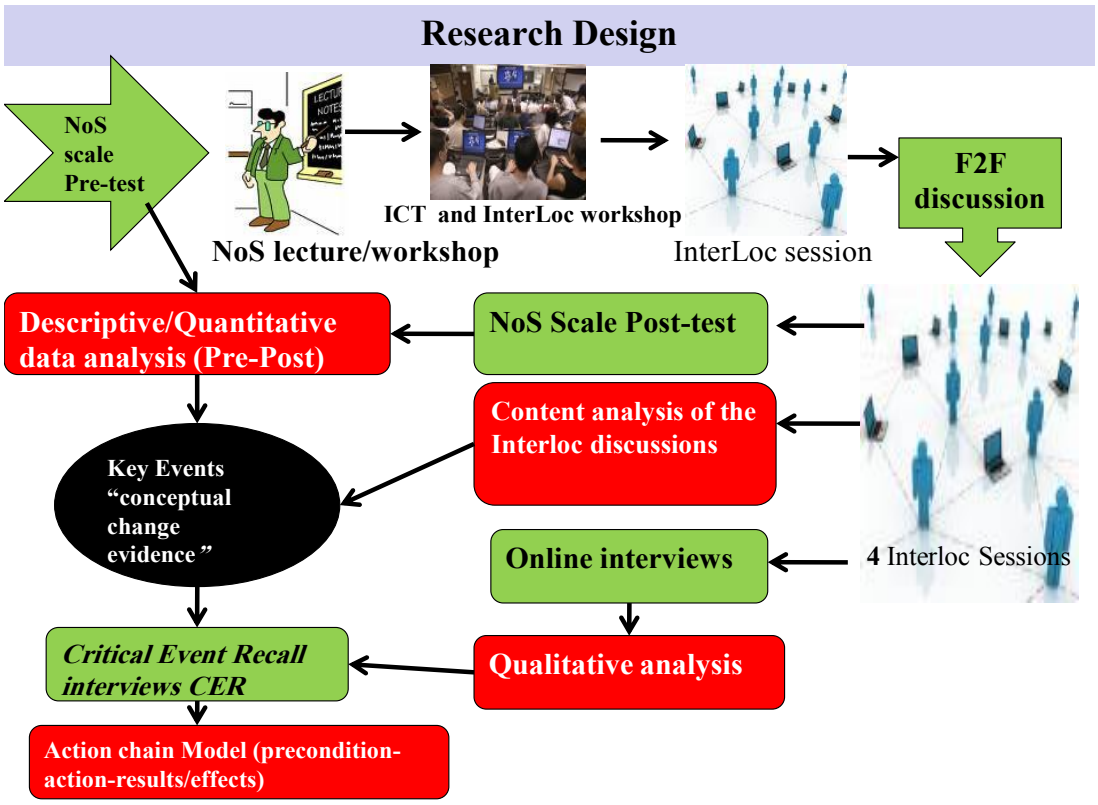

Figure 2: the procedures of InterLoc Study

Table

Aspects of NOS	Changes on the nature of science scales					
	A substantial change		A minimal change			
Positivism-Relativism- (PR)	From positivism to relativism	39%	From more positivism to less positivism	11%	From less relativism to more relativism	20%
Inductivism– Deductivism (ID)	From Deductivism to Inductivism	39%	From more Deductivism to less Deductivism	9%	From less Inductivism to more Inductivism	2%
Contextualism-Decontextualism (CD)	From From Decontextualism to contextualism	39%	From more Decontextualism to less Decontextualism	20%	From less contextualism to more contextualism	2%
Process-Content (PC)	From content to process	30%	From more content to less content	11%	From less process to more process	16%
Instrumentalism-Realism (IR)	From realism to instrumentalism	25%	From more realism to less realism	16%	From less instrumentalism to more instrumentalism	25%

A substantial change is a change on the type and score of NoS scales
A minimal change is a change on the score within the same NoS type

Table 1: Percentages of the changes of PGCE science students' views on pre-post NOS scales

Examples of the NoS items that show some changes of students views of NoS used in the Key Event Recall interviews	Key Event Recall interviews' questions	Changes on the students' NoS sub scales
Science facts are what scientists agree that they are. (changed from +2 to -1)	In the Interloc discussion, you argued that we should encourage pupils to be skeptical and inclusive.	On RP sub-scale from 1 to -10
There is such a thing as a true scientific theory. (changed from 0 to -4)	Also, you highlighted that a scientist should keep an open mind and be willing to change their mind.	
In practice, choices between competing theories are made purely on the basis of experimental results. (changed from+3 to -2)	So, can you tell what did challenge you to change your views on NoS sub-scales? I can see change from positivist views to relativist views.	
There are certain physical events in the universe which science can never explain. (changed from 0 to -2)	How do you think scientific knowledge from other kinds of knowledge? I can see a change on your views the role of scientists and experiments on forming theories? Can you explain why this change took place?	
Science is essentially a masculine construct (changed from +4 to 0)	How do you think is leading the scientific development? Man or woman? Your Interloc group have some girls, did there views challenge your attitude toward a female scientist?	On CD sub-scale +8 to -6
Science facts are what scientists agree that they are. (changed from +2 to -1)	I can see a shift on your views about who is responsible about what can be consider as science facts. Who else can be responsible about science facts? Why consider them now?	
In practice, choices between competing theories are made purely on the basis of experimental results (changed from +3 to -2)	What other contexts you consider to assess theories? Did you think about these contexts or factors before the discussion with your InterLoc group?	

Table 2: Examples of Key event recall interviews related to NOS

NoS sub scale	NoS Items	Changes on the scores before and after the intervention
Relativism vs. positivism	3. Science facts are what scientists agree that they are.	changed from +2 to -1
	21. There are certain physical events in the universe which science can never explain.	changed from 0 to -1
	12. There is such a thing as a true scientific theory.	changed from 0 to -2
	18. In practice, choices between competing theories are made purely on the basis of experimental results.	changed from +1 to -1
	20. Scientific knowledge is different from other kinds of knowledge in that it has a higher status.	changed from +1 to 0
Process vs. Content	7. Science education should be more about the learning of scientific processes than scientific facts.	changed from 0 to -3
	9. The most valuable part of a scientific education is what remains after the facts have been forgotten.	changed from +2 to 0
	24. Essentially, science is characterized by the methods and processes it uses.	changed from +1to -1

Table 3: Charlote's NoS Scales

Appendices

Appendix A: Online focus group interviews
I am ……. Our discussion today should focus on our experience with using Interloc on e-discussion and how it was easy or not to use, how it was useful or not for sharing knowledge and how it influenced the co-operative learning comparing with Face to face discussion.

To run the discussion well, I will post the question and I want all of you to reply first to the question. After you have a chance to contribute to my question, you can start reply to the other team's comments and ideas. Please reply to my question first before you start the discussion. When we finish discussing the first question I will post another one and so on.

Influence of interloc on the learning process

- How did using the InterLoc electronic discussion forum help you to think critically within the group about the nature of science and the National Curriculum for science?
- Do you think the Interloc tool will be useful to use with your students at school? Why?
- Having had e-discussion, do you think you have learnt something new about National curriculum or NoS?
- Is this e-discussion challenged some of you views about Natural of science or the National curriculum?
- How do you think the Interloc tool could be used with school students?
- Have you found the Interloc an easy tool to use on e-discussion? Why?
- Do you have any other comments to make about the Interloc activity?
- Can you reflect on the advantages and disadvantages of using interloc as compared with face-to-face discussion or an unstructured discussion forum such as WebCT?
- Affordances:
- Openers:
- Do you think the Interloc tool has enough openers to help your critical thinking? Do you have any suggestions for openers that could be added?
- Do you remember which openers helped you to engage more with the discussion?
- What are your views regarding the 'openers'?

Chat room

- Did you find the chat room useful as it is for a social conversation? Or do you have any suggestion to improve it?

e-facilitators

- From your point of view, how could the e-facilitator can be effective in improving the discussion?
- What do you think about the number of the facilitator's intervention; was it more or less than you would like?
- What did you expect form the facilitator and you didn't get it?
- What did you expect the facilitator to do?
- How do you think the e-facilitator could promote useful discussion?

Appendix B: Key Event recall interview KER

- I can notice a slight change on you views about the scientific theory? Can explain?
- What do you think about your experience with having e-discussion about NoS? Did it add to you something new? Did it challenge your views about the scientific knowledge?

- I can see a change on RP sub-scale from relativism to positivism, have you noticed this change? Do you have comments on this change?
- So, can you tell me what did challenge you to change your views on NoS sub-scales?
- I can see a change on you views from positivist views to relativist views. Can you explain?
- Have you had discussion about the NoS before you started this course? If yes how it was? How is it different from e-discussion?
- Do you think discussion with a group with a different scientific background from yours (Chemistry-physics- biology) challenged your views or shifted them?
- Have you gained new ideas from your InterLoc group about Nos or teaching NoS?
- Which of these challenged you views about NoS? (the lectures, reading list, face to face discussion, or e-discussion.

The Ethical Statement

The authors ensured that the research was not harmful to any students involved in this study but instead the findings of the study were of great benefit to them and the PGCE science course. In order to conduct the study, the authors obtained ethics approval from Exeter University. The authors fully followed the Committee on Publication Ethics (COPE) guidelines when carrying out the research or preparing it for publication. (COPE website http://publicationethics.org/).

Dear Dr. Deborah Corrigan

Thank you for the opportunity to improve our paper. We found the comments of the reviewers very helpful. Our responses are included below in red.

COMMENTS FOR THE AUTHOR:

Reviewer #1: This is a well organised paper that makes a useful contribution to the literature. It is a pity that the study (undertaken in 2008) was not published sooner but it is still very relevant. With some revisions I feel it should be accepted by RISE.

Specific comments:
1. The last paragraph of the abstract is repeated.

The repeated paragraph has been removed.

2. I feel there is somewhat too much mention of the name of the software - InterLoc. What is of more interest is not specifically an evaluation of this product but an examination of the features on on-line discussion that enable at least some learners to improve their understanding.

All uses of the term ‘InterLoc’ have been examined and the majority have now been replaced with more generic references to software supporting online discussion.

3. I feel the authors need to add some sort of 'Declaration of Interest' - e.g. was there any involvement of the authors in the development of InterLoc or do any of the authors stand to benefit from InterLoc's wider uptake?

InterLoc was developed as an academic project with funding from JISC and there is no financial interest for any of the authors. A clarification of this has been given in the form of an acknowledgement at the end of the paper.

4. What is meant by 'IM technology' (p2). I suggest all abbreviations are spelt out the first time they are used.

IM stands for Instant Messaging and this has been expanded in the text as have all other abbreviations the first time that they are used.

5. OSDE (p4) seems a surprising acronym for 'Online Discussion using Digital Dialogue Environment'. Is it used widely?

OSDE has now been removed from the text.

6. I think the term 'verbal' is sometimes used to mean 'oral' [e.g. on p12].

The term ‘verbal’ has been replaced by the term ‘oral’ except when it is being used by students in extracts from data.

7. There are no references more recent than 2009 yet there is a huge literature out there on on-line learning. Some such literature should be discussed, whether specific to science education or more generic.

More recent literature has now been added including:

Chen, C.-H., & She, H.-C. (2012). The impact of recurrent on-line synchronous scientific argumentation on students' argumentation and conceptual change. Educational Technology & Society, 15 (1), 197–210.

Choi, A., Hand, B., & Lori Norton-Meier (2014). Grade 5 students' online argumentation about their in-class inquiry investigations. Research in Science Education, 44, 267–287. DOI 10.1007/s11165-013-9384-8.

Goodyear, P., & Zenios, M. (2007). Discussion, collaborative knowledge work and epistemic fluency. British Journal of Educational Studies, 55 (4), 351–368.

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Huang, L., Chiu, C., Sung,K., & Farn, C. (2011). A comparative study on the flow experience in web-based and text-based interaction environments. Cyberpsychology, Behavior, And Social Networking, 14(1-2), 3-11.

Johnson, M. L., & Sinatra, G. M. (2013). Use of task-value instructional inductions for facilitating engagement and conceptual change. Contemporary Educational Psychology, 38, 51- 63. http://dx.doi.org/10.1016/j.cedpsych.2012.09.003.

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Miller, B., Anderson, R., Morries, J., Lin, T.-J., Jadallah, M. and Sun, J. (2014). The effects of reading to prepare for argumentative discussion on cognitive engagement and conceptual growth. Learning and Instruction, 33, 67-80.

Penttinen, M., Anto, E., & Mikkilä-Erdmann, M. (2013). Conceptual change, text comprehension and eye movements during reading. Research in Science Education, 43, 1407-1434.

Ravenscroft, A., McAlister, S., & Sagar, M., (2010). Digital Dialogue Games and InterLoc: A Deep Leaning Design for Collaborative Argumentation on the Web, In Pinkwart, N. (Ed) Educational Technologies for Teaching Argumentation Skills, Bentham Science E-Books.

Sandoval, W. A. & Reiser, B. (2004). Explanation-driven inquiry: integrating conceptual and epistemic scaffolds for scientific inquiry. Science Education, 88(3), 345-372.

Sardone, N., & Devlin-Scherer, R. (2009). Teacher candidates' views of digital games as learning devices. Issues in Teacher Education, 18 (2), 47-67.

She, H.C. & Liao, Y.W. (2010). Bridging scientific reasoning and conceptual change through adaptive web-based learning. Journal of Research in Science Teaching, 47(1), 91-119.

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Wu, X., Anderson, R. C., Nguyen-Jahiel, K., & Miller, B. (2013). Enhancing motivation and engagement through collaborative discussion. Journal of Educational Psychology, 105, 622-632. http://dx.doi.org/10.1037/a0032792.

Yuan, T., Moore, D., Reed, C., Ravenscroft, A. and Maudet N. (2011) "Informal Logic Dialogue Games in Human-Computer Dialogue", Knowledge Engineering Review, 26 (2), pp159-174.

Reviewer #2: This is an interesting study which adds to our understanding of the how applications that facilitate on-line dialogue among students can be used. It was of interest that the authors reported the students evaluation of the tool and what they saw as strengths and weaknesses, although one might have guessed that many of these could have been anticipated. Since the data was collected in 2008, one is left wondering whether later versions of this tool or others have lead to any changes that answer students' concerns, or whether developers have persisted with such design features believing, although students may have concerns, the benefits of the feature outweighs such concerns.

The findings of this study fed into further iterations of InterLoc reported in later papers by the development team. We refer to this in the text in the third paragraph of the discussion section. The two later papers now referenced are:

Ravenscroft, A., McAlister, S., & Sagar, M., (2010). Digital Dialogue Games and InterLoc: A Deep Leaning Design for Collaborative Argumentation on the Web, In Pinkwart, N. (Ed) Educational Technologies for Teaching Argumentation Skills, Bentham Science E-Books. (2010)

Yuan, T., Moore, D., Reed, C., Ravenscroft, A. and Maudet N. (2011) "Informal Logic Dialogue Games in Human-Computer Dialogue", Knowledge Engineering Review, 26 (2), pp159-174.

One of the weaknesses of the study that is not dealt with is the short nature of the study: a couple of lectures and workshops. We all know and some of us have experienced lectures that changed our way of thinking, and even, in seeing the world differently. But that is rare. It may be the authors may wish to say that 'there seemed to be a start in the ways some students understood …. (this or that)'. As well although graduate students in 2008 were tech savvy, even so the relatively short period of time they worked with this application was probably not enough for them to fully explore it nor appreciate why some features worked the way they did. So again this limitation may well be something the authors should consider noting.

Clear mention of this limitation has been added at the end of the concluding section.

The following paragraph (The start of is quoted and found on page 15) did not make sense to me: "On the a NoS question (Scientific knowledge is different from other kinds of knowledge in that it has a higher status.), Andrew changed his view from -3 (before the interloc to +1 (after the interview) score from +2 to -1 Science facts are what scientists agree that they are. I asked him this question on the interview:"

This confusion happened because of problems with the layout of Figure 3 (in the old version of the paper). We converted this figure to a table to make things clearer, table 2.

Page 21:
By using the key even???? (event???) recall interview with her and asking her how the changes of conceptual change about NoS happened to her she said:

This has now been rephrased and corrected.

References need updating: nil references for the years 2014, 2013, 2012, 2011; then 2 from 2010, 1 from 2009, 4 from 2008 and there are 74 references in all. Surely there has been some relevant insights found in the literature in the last four years, and surely more than 7 from the last 7 years (that is only a tenth of the total number of the references used), given the extent to which this approach is now used in both secondary and tertiary classrooms.

14 more recent references have now been added. These are detailed above.

However overall this is a useful piece of work which was worth reading but I think it needs a major revisions dealing with at least the issues outlined above.

Thank you for these comments. We have revised the article extensively and think that it is better as a result.