The Social Dimension of Learning through Argumentation: Effects of Human Presence and Discourse Style

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Abstract

In spite of its potential for learning, and in particular knowledge revision, productive argumentation on science concepts is neither easily elicited, nor sustained. Students may feel uneasy critiquing and being critiqued, especially on complex science topics. We report on a controlled study that tested the role of two potential factors that may either relieve or aggravate some of these concerns: the partner's argumentive discourse style (disputative or deliberative) and belief in interaction with a human or a computer agent. Learners interacted in scripted, computer-mediated interactions with a confederate on their understanding of a scientific concept they had just studied (i.e., diffusion). They were led to believe they were either interacting with a human peer or with a conversational peer agent. The peer confederate's verbal behavior was scripted to evoke argumentative discourse, while controlling for exposure to conceptual content and the type of dialogue moves, but differing in argumentive discourse style (disputative or deliberative). Results show that conceptual understanding of participants in the deliberative discourse style condition was higher than that in the disputative condition. Furthermore, even though previous studies have reported that the belief in human interaction benefits learning in consensual interactions, the opposite was found to be true in a setting of disagreement and critique: Higher conceptual learning gains were found for belief in interaction with a computer agent, compared to with a human peer. Implications for theory as well as instructional design are discussed.

Keywords: Argumentation; conceptual change; social presence; discourse styles; belief in human presence

There has been a growing interest in the effects of peer argumentation on students' understanding of complex science topics. Empirical evidence is accumulating from random experiments (Asterhan & Schwarz, 2007; Nussbaum & Sinatra, 2003), from correlational studies (Asterhan & Schwarz, 2009a; Schwarz, Neuman & Biezuner, 2000), from quasi-experimental classroom studies (Cross, Taasoobshirazi, Hendricks & Hickey, 2008; Venville & Treagust, 2008; Zohar & Nemet. 2002) and from case studies (Asterhan, 2013; Chin & Osborne, 2010; Berland & Hammer, 2012). This growing body of research shows that when students are given adequate opportunities and support to critically discuss and evaluate differences between conflicting explanations, their conceptual understanding of complex scientific ideas improves. This advantage is often not visible during or immediately following the interaction, but appears on delayed individual assessments (Asterhan & Schwarz, 2007; Howe, 2009; Howe, McWilliam, & Cross, 2005). This suggests that the likely mechanism behind conceptual growth through argumentation is not so much through reaching consensus or generating correct solutions collaboratively, but through highlighting pivotal contradictions and unresolved issues.

Unfortunately, however, research also shows that productive argumentation is difficult to elicit, in particular on scientific topics (e.g., Asterhan & Schwarz, 2009a; Berland & Hammer, 2012; De Vries, Baker & Lund, 2011). Students often avoid the direct confrontation between their own intuitive conceptions and alternative explanations and prefer to concede upfront or, instead, hold on to their initial standpoint without much cognitive engagement, thereby missing important opportunities for learning (Asterhan, 2013; Asterhan & Schwarz, 2009a; Chinn & Brewer, 1993; Weinberger & Fischer, 2006).

The present study is part of a line of research that explores the motivational, affective and interpersonal processes that may support or inhibit students to critically consider and fruitfully discuss alternative explanations to their own misconceptions of complex scientific topics. Our main argument is that to discuss one's personal (often faulty) understanding of complex scientific ideas with a disagreeing peer is not only cognitively demanding, but also introduces concerns from the social domain, such as social comparison, academic identity, relative competence, and relations issues. However experimental research showing whether and how these processes affect *learning outcomes* are sparse.

In the present study we aim to provide such evidence by experimentally manipulating targeted interaction characteristics that are believed to increase (or decrease) such concerns and investigate how they affect students' learning gains on conceptual change tasks. The social interaction characteristics targeted in this study are the interaction partner's argumentative discourse goals (dispute vs. deliberation) and the belief in social interaction (human vs. conversational agent peer). We will present each factor separately.

Argumentive discourse style

Argumentation is a social activity in which participants attempt to strengthen or weaken the acceptability of one or more ideas, views, or solutions through engagement in reasoning (van Eemeren, Grootendorst, Henkenmans, Blair, Johnson &Krabb, 1996; Walton 2006). The argumentation literature has distinguished between different types of argumentive discourse, each defined by a distinctively different goal and style (Walton, 1992), two of which are particularly relevant for educational settings (Asterhan, 2013; Garcia-Mila, Gilabert, Erduran & Felton, 2013; Keefer et al, 2000; Mercer, 1996; Nussbaum, 2008): In *disputative argumentation*, speakers defend a viewpoint and undermine alternatives to convince an opponent to switch sides. The goal is to win at the expense of one's opponent. In *deliberative argumentation*, on the other hand, the goal of each speaker is to collaboratively arrive at a conclusion by contrasting, comparing and evaluating alternatives. Deliberative argumentation is then both critical, as well as constructive. In other words, argumentation may be viewed as a competition between individuals (who is right?) or between ideas (which idea is right?). Until recently, little attention has been given in the psycho-educational literature to these distinct argumentive discourse types, how they may be elicited by different instructions and task settings, and how they may affect learning.

We argue that it is important to distinguish between disputative and deliberative argumentation, since they are expected to differently affect learning outcomes: A focus on the interpersonal, competitive dimension of social interaction may raise uncertainty and threaten self-competence (Butera & Mugny, 1995; Darnon, Butera & Harackiewicz, 2007; Darnon, Doll & Butera, 2006; Pool, Wood & Leck, 1998), increase positive evaluations of the partner's competence (Darnon, Muller, Schrager, Pannuzzo & Butera, 2006; Gabriele & Montecinos, 2001), and raise concerns about group belonging or interpersonal relationships. Perceptions of interpersonal competition have also been shown to reduce cognitive flexibility and a person's openness to alternative viewpoints (Carnevale & Probst, 1998), and may cause discussants to concede upfront without further consideration and engagement (Asterhan, 2013; Smith, Johnson & Johnson, 1981; Weinberger & Fischer, 2006). Extrapolating to argumentation for learning, learners are expected to be less likely to share their own incomplete ideas, to consider alternative viewpoints, to collaboratively construct new explanations, and to critique their peer's ideas. Since these actions are believed to be the crux of learning through argumentation (De Vries et al, 2001; Keefer et al, 2012; Nussbaum, 2009; Osborne, 2010; Schwarz & Asterhan, 2009), by not engaging in them, learners would then forego important opportunities for learning.

However, even though theorists have discerned between these two types of argumentive discourse style and are in general agreement regarding the superiority of deliberation over dispute (Asterhan, 2013; Keefer et al, 2000; Mercer, 1996; Nussbaum, 2008), to date there is no direct empirical evidence showing a causal relation between them and learning outcomes. Two recent studies have tried to establish such evidence by giving collaborating dyads instruction for either deliberative or disputative argumentation: Felton, Garcia-Mila and Gilabert (2009) showed that deliberative discourse goal instructions improved the quality of students' argumentative essay writing, but not their retrieval of factual knowledge. However, they did not assess changes in students' conceptual knowledge structures. There is some evidence showing that argumentative discourse particularly benefits conceptual understanding, but not factual recall (Asterhan & Schwarz, 2007; Wiley & Voss, 1999), which may explain the lack of effect on learning in this particular study. In a more recent study, Asterhan, Butler and Schwarz (2010) examined the role of discourse goal instructions in a conceptual change task (i.e., natural selection). The effect of discourse goal instructions was found to be contingent on gender: Disputative instructions resulted in more disputative discourse for male dyads, but it led to more deliberative discourse amongst female dyads. Regardless of these different effects of goal instructions on *actual* discourse, however, in both gender groups, actual deliberative discourse was overall associated with better learning outcomes on conceptual change tasks. Unfortunately, due to considerable inter-dyadic variance a *direct* link between interpersonal regulation and individual learning could not be established. The results of the Astrehan et al (2010) study then shows the need for a separate investigation into (1) how goal instructions, and other contextual factors, shape the actual discourse style; and (2) how engagement in different types of discourse affects learning.

In the present study, we focus on the latter and adopt more direct approach. Instead of giving goal instructions, the discourse style is directly manipulated by operating a disagreeing confederate that uses either disputative or deliberative rhetoric, while experimentally controlling for all other speech content. Based on the abovementioned rationale, it is expected that both male and female students who participate in deliberative argumentive discourse will show larger gains on conceptual change tasks, than those who participate in disputative discourse.

Belief in human presence

In addition to the way in which the disagreement between participants is regulated, the mere presence of a disagreeing, human discussion partner may in and by itself be enough to cause discomfort and decreases the learner's capability to consider or generate alternative explanations. If that is so, then tuning down the social dimensions of these situations could be expected to benefit learning.

Classic studies on social facilitation have shown that the mere presence of social evaluation negatively impacts performance on non-familiar tasks (e.g., Zajonc, 1965). However, social facilitation research has traditionally focused on the effects of human presence on individual, rather than collaborative tasks. According to social learning theories, verbal interactions are at the heart of learning and development (a/o Littleton & Howe, 2010; Mercer & Littleton, 2007; Resnick, Asterhan & Clarke, in press). Common explanations of the effects of learning through verbal interaction refer to the use of superior cognitive processing strategies during interaction. Among others, in human-human interaction, learners externalize and verbalize their knowledge, elaborate, give and receive explanations, and consider and evaluate different perspectives. In other words, learners are more active and constructive during the learning phase and therefore learn better (Chi & Menekse, in press). If the effects of learning through peer interaction can be solely attributed to the type of verbal acts learners engage in and the information processing that accompanies them, then accomplishing these actions with a non-human interaction partner should lead to similar gains. If, however, the social dimension is key to success in learning through interaction, than a difference in learning gains should be observed.

Digital communication technologies offer new ways to empirically isolate social from cognitive dimensions of learning through interaction. This can be accomplished by letting learners believe that they are either interacting with an avatar (a character that represents and is controlled by a human) or with an agent (a character controlled by the computer), while holding all other interaction features identical. Research indicates that people's behavior changes depending on the extent to which they believe in social interaction (e.g., Aharoni & Fridlund, 2006; Bailenson, Blascovich, Beal & Loomis, 2003 Hoyt, Blascovich, & Swinth, 2003; Schechtman & Horowitz, 2006). However, less is known about the effect of belief in social interaction on learning, particularly if visual features are held constant.

Results from a study by Okita, Bailenson and Schwartz (2008) seem to confirm the social presence hypothesis: Students who posed pre-defined questions on a scientific topic showed larger learning gains when they believed they were receiving answers and explanations from a human peer, rather than a computer agent. The results also suggested this was not due to social presence per se, but rather the belief of taking a *socially relevant* action, which caused learners to be more invested and engaged in the interaction. In another study, Rose and Torrey (2005) found that students' conversational turns included less explanations and elaborations when they believed they interacted with a computer agent tutor (instead of an anonymous human tutor). Taken together, these findings seem to suggest that when learners believe they interact with an intelligent, volitional other, they are likely to invest more cognitive effort in trying to understand the content of the partner's communications, to build a mental representation of his/her thinking and to be more precise and explicate their own thinking.

However, dialogues in the aforementioned studies were of the consensual, informative type. Learners were either asked informative questions and received explanations (Okita et al, 2008) or were tutored (Rose & Torrey, 2005). A reverse effect may be expected for situations in which an equal-status conversation partner critiques a learner's explanation of scientific concepts. That is, believing that one is interacting with a computer agent may reduce the social concerns that arise during critical dialogue with a disagreeing partner, and increase the likelihood of a genuine reevaluation of misconceived explanations in light of critique. This expectation is in line with several recent studies showing that decreased social presence may benefit performance in social situations that elicit evaluation apprehension or other forms of social concerns (Howley, Kanda, Hayashi & Rose, 2014; Tartaro & Cassell, 2006). The current study then aims to test the prediction that students working on conceptual change tasks will gain more from interaction with a disagreeing partner when they believe they interact with a computer agent peer, rather than with a human peer.

The present study

The main aim of the present study is to test our hypotheses regarding the effects of argumentative discourse style and belief in human presence on individual learning of a complex science concept. Individual students were presented with expository texts explaining the scientific concept, after which they solved two transfer items. They then engaged in a scripted, computer-mediated interaction with a disagreeing confederate on their solutions of these transfer items. Participants were either led to believe that they would interact with a same-sex, human peer or with a conversational agent that was modeled on same-sex, equal status peers. To make sure that the only differences between conditions were the belief in human presence and the partner's argumentative discourse style, the confederate's verbal behavior was tightly controlled. Except for linguistic cues indicating either a disputative or deliberative goal, the epistemic nature of the dialogue moves, their order and their content was identical across conditions.

Our predictions are as follows:

H1: Students that participate in deliberative argumentative discourse with a disagreeing partner will show higher individual gains on measures of conceptual understanding, then students that participate in disputative discourse. No differences are expected on measures of factual recall.

H2: Students that believe they interact with a disagreeing computer peer agent will show higher conceptual gains from argumentation, than students that believe they interact with a disagreeing human peer. No differences are expected on measures of factual recall.

To account for potential gender effects, an equal amount of male and female students will participate in each condition. Based on the aforementioned discussion of the Asterhan et al (2010) findings, no particular hypotheses were articulated concerning the role of gender.

Since the goal of the present work is to systematically manipulate social interaction features and test their effects on individual conceptual learning, the interaction itself was scripted and the confederate's behavior tightly controlled. Even though limited in scope, the participants' verbal responses during the interaction may nevertheless give some insights into the workings behind the hypothesized effects. Therefore, a number of interaction behaviors will be assessed that may shed light on the processes mediating the hypothesized effects. These are the extent of disputative rhetoric used by participants, the extent to which they are willing to share their (incomplete) understandings with the partner, their extent of substantive engagement with the topic domain, and the extent to which they experience the social presence of their conversation partner.

The concept of diffusion was chosen as the content domain for this study. The reasons for this are threefold: First of all, diffusion is a central concept in science education. Many chemical processes in living organisms are based on diffusion. It is then part of the high school curriculum in both biology and chemistry classes and is extensively covered in introductory textbooks (Meir, Perry, Stal, Maruca, & Klopfer, 2005). Secondly, even without formal education on the topic, most people have lay theories about diffusion that have been extensively documented in the literature (Westbrook & Marek, 1991; Odom, 1995)

Lastly and most importantly, even after formal instruction, students from secondary school through college majors retain many of these misconceptions (e.g. Chi, 2005; Chi, Roscoe, Slotta, Roy, & Chase, 2012; Meir et al 2005; Odom, 1995). Chi and colleagues (2012) proposed that the concept of diffusion is challenging for students because they mistakenly categorize it as a *sequential*, instead of an *emergent* process: The flow-like, ordered sequential pattern of net flux going from regions of higher concentration to regions of lower concentration, can often be perceived by the senses. It is also familiar to students from everyday experiences, such as the diffusion of tea in a cup of hot water. This observable process has features of a sequential process, with a clear direction, a beginning and an end. However, the net flux movement in fact emerges from an unordered, random and ongoing (Brownian) motion of individual objects (molecules) on the micro level. Whereas students more easily grasp the macro-level attributes and their determinants, the difficulty lies in understanding the micro level process and how the macro level emerges from it.

Method

Participants

Eighty-four undergraduates (42 males and 42 females) from a large university in the Jerusalem area voluntarily participated in return for financial reimbursement or course accreditation. The mean age of the participants was 25.79 (SD = 5.55). Only native Hebrew-speaking students from the Social Sciences and Humanities faculties who had no formal schooling in Biology or Chemistry beyond the standard high school curriculum requirements were selected for participation. Two participants didn't complete the interaction phase due to connectivity problems. Two other participants, one from the human peer/disputative and one from the computer agent/disputative condition, did not return to complete the delayed post tests. Their data was therefore omitted from analyses involving learning gain scores.

Design

A 2X2 experimental design with repeated measures was used. All students received written instructions on the topic of diffusion and then engaged in a computer-mediated, scripted discussion with a same-sex confederate. Two factors were manipulated: Belief in human presence (interaction with a human peer *vs*. a computer agent modeled on a peer) and the rhetorical style of the disagreeing partner's discourse (disputative *vs*. deliberative). Individual participants were randomly assigned within gender to one of the four conditions. Individual conceptual understanding of diffusion processes was assessed on three separate occasions: pretest, immediately following individual text-reading (before the interaction) and a week following the interaction.

Instruments

Social Presence Survey.

The survey consisted of seventeen Likert-scale items that were assembled from different surveys assessing social presence (Biocca, Harms & Gregg, 2001; Caspi & Blau, 2008; Kreijns, 2004; Lee & Nass, 2003). Different measures target different aspects of social presence, depending on the context of a study. Only items that were directly relevant to the context of this study were included, and included items referring to the perceived realism of the situation (e.g., *I felt the interaction was natural; I felt as if I was interacting with a real person)*, awareness and attentiveness (e.g., *I was attentive to my interaction partner; I was aware that my discussion partner was present in the computerized environment*), and the ability to mentally picture each other (e.g., *I managed to imagine my interaction partner; My interaction partner could learn to predict my behavior during the interaction*). Internal reliability of the 17 original Social Presence survey items was Cronbach's Alpha = .804. One test item was deleted from the item set (*I tried to understand why my interaction partner reacted the way s/he did*) to improve the reliability to Cronbach's Alpha = .829

Instructional materials

Each participant studied a 906 words-long text, explaining the process of diffusion. The text was taken from a standard textbook used in the Israeli high school Biology curriculum and was found to be highly similar to alternative standard textbooks. The text contained two parts: (a) A 427 words-long text explaining the process of diffusion in liquids, referring to both the macro and the micro levels and offering an illustration of the former showing the stages of diffusion of tea in water; and (b) a 479 words-long text explained the role of diffusion in the human respiratory system. The latter part included detailed descriptions of the human respiratory system, the organs and the paths of oxygen and carbon dioxide in the process, accompanied by four anatomic illustrations: One of the entire respiratory system and three additional illustrations of the alveoli in the context of the respiratory system/ the blood system.

Assessment of knowledge about diffusion

Conceptual understanding of diffusion. A total of 9 conceptual knowledge test items were chosen and adapted from previous works on conceptual understanding of diffusion (e.g., Chi et al, 2012; Meir et al, 2005) and standard curriculum materials. These included 2 open-ended items and 7 multiple-choice questions with a request for detailed explanations. The items were chosen to each target at least one of 5 key aspects of diffusion that scholars from Science Education and Cognitive Science have identified (see Table 1). Five different items referred to diffusion processes in simplified systems, consisting of two liquid substances (e.g., ink in water). Four additional test items assessed students' understanding of the role of diffusion in a complex biology system. Specifically, these items referred to diffusion of oxygen and CO_2 in the human respiratory system, which was explained in the text excerpt they studied. Students' understanding of diffusion processes was assessed on three different occasions: pretest (3 items), following individual study phase (2 transfer items) and at the delayed post-test (7 items, consisting of the 3 pretest items and 4 novel items). The distribution of items between the test occasions and their characteristics are presented in Appendix A, part I.

Factual knowledge

Students' capability to recall factual information from the instructional materials was separately assessed with six multiple-choice items on the individual posttest. These items focused on propositional knowledge that is not required for performance on conceptual understanding items of the diffusion processes, and included definitions (e.g., What is a bronchus?) and numeric facts (e.g., the concentration of carbon dioxide in the blood). Scores on factual knowledge ranged from 0-100%. The full set of test items appears in Appendix A, part II.

Procedure

All students participated in the following sequence of activities: (1) Individual pretest to assess initial understanding of the concept of diffusion and demographical details; (2) Individual learning phase in which each student studied a standard high-school textbook excerpt from the Biology curriculum explaining the process of diffusion (20 minutes); (3) Individual solving of two novel transfer items on diffusion (pretest after individual study); (4) Computer-mediated dialogue with a disagreeing confederate on the solutions to these items, according to the four experimental conditions (described below in further detail); (5) Individual administration of a survey assessing how the participant experienced the social presence of the confederate during the interaction ; and (6) Delayed post test administered a week later, assessing both factual recall as well as conceptual understanding of diffusion. The total length of an experimental session ranged between 90 to 120 minutes. All surveys and tests were administered individually. Participants received financial rewards and/or course credit upon completion of the post-test.

Following the individual learning phase, each participant was informed they would participate in a short discussion on their solutions of two novel test items, which they were to first solve individually. The first item required participants to describe, on the molecular level, the process of diffusion that occurs when two tanks filled with different liquids are connected by a pipe. The second item required them to predict the rate of gas exchange in the respiratory system in specific conditions (i.e., low oxygen and high CO2 concentrations) and to explain their answer.

The discussion was computer-mediated, using a common synchronous communication tool (Google chat). Half of the participants were told that they were to interact with an anonymous, same-sex, equal-status peer who was in another lab on campus. The other half were told they were to interact with a conversational computer agent that was carefully modeled on the behavior and knowledge of actual equal-status, same-sex peer students. In both cases, the co-actor was in fact a human confederate. The information regarding the interaction partner's identity was conveyed twice: Once immediately following the pretest and before the reading phase, and once at the start of the interaction phase. All students were told to adhere to an interaction script, with clearly defined roles and instructions. The human / computer agent peer was always 'assigned' the role of the question-asker and the student that of answering these questions.

The script was composed of 12 conversational turns by the confederate, that were carefully chosen to ensure that participants would engage in explanation and dialectical argumentation with a disagreeing partner, while controlling for content exposure (see Appendix B for the complete script). The confederate's turns mainly consisted of questions, but also included some topical content referring to common misconceptions of diffusion (i.e., that molecules stop moving once they have "reached their destination"). For each of the two items, the confederate's turns included the following: (1) a request to write the solution to the transfer item, (2) a request to clarify and elaborate on a missing part of the answer, (3) expression of disagreement followed by a critical question, (4) additional request to clarify a different part of the answer, and (5) expression of disagreement followed by an alternative (wrong) explanation. The two final turns consisted of a request to the student to reflect on his/her understanding of diffusion and parting words. The number of actual confederate conversation turns depended on the extent to which the participant elaborated his/her initial solution after the first prompt: Those whose initial answers already contained an elaborated answer referring to all aspects of the question, did not receive additional requests for elaboration. As a result, the number of actual confederate turns ranged between 8 and 12 (M = 10.42). When a participant would divert from the script (e.g., by asking the confederate a question instead of answering) the confederate would write back that s/he was sorry but that s/he cannot answers questions. This happened rarely and when it did, it did not cause any communication breakdowns. Participants would go back and continue the conversation, according to the script and instructions.

The confederate's rhetoric style was manipulated by including linguistic cues in each conversational turn that either conveyed a disputative discourse goal (to win a debate at the expense of one's opponent) or a deliberative discourse goal (to collaboratively arrive at the best solution through critical discourse). Based on previous work (Asterhan, 2013; Brown & Levinson, 1987; Chiu & Khoo, 2003), these included the following cues (see Table 2): (1) Referring to solutions as an outcome of a shared thinking process, as opposed to repartitioned solutions being the result of individual effort; (2) interest in and attempts to understand the other's thinking, as opposed to attempts to disqualify the other's thinking; and (3) decreasing as opposed to increasing face threat during disagreement. Interactions lasted 25 to 30 *min*.

Coding

Conceptual understanding of diffusion

Assessment of conceptual understanding was based on students' individually written explanations to test items. When a correct predefined response was chosen but was accompanied by an incorrect explanation, responses were coded as incorrect. Each correct application of a conceptual principle that was targeted in a given test item was scored one point. Incorrect or no mentioning of the targeted principle in a given test item resulted in zero points. Responses including both a correct application and a contradiction, or responses that did not include enough information to assure that the participant fully applied the principle correctly were accredited 0.5 point. When a principle was correctly mentioned in a test item that did not target it specifically, it was accredited one extra point.

The test items were not designed to specifically target inter-level explanations, that is: explanations referring to how the observable macro-level patterns of diffusion are the results of unobservable, micro-level interactions between particles (Chi et al, 2012). Any time a correct inter-level explanation was offered in a written response to any item, this was accredited 1 point. Two different types of inter-level explanations were identified: (1) A reference to the apparent contradiction between the micro level's random and the macro level's patterned movement and explaining it by referring to differences in probability; or (2) A reference to the apparent contradiction between the micro level's constant movement of particles and the static equilibrium on the macro level, explaining that the movement of particles is invisible.

The responses of 15 participants (19%) on each of the three test occasions were coded by two trained coders, independently and blind to condition. Inter-rater reliability for conceptual understanding was established by comparing the coding (0, 0.5 or 1) of each written answer to a test item on each of the six conceptual principles of diffusions. Extent of agreement was substantial (Landis & Koch, 1977), Cohen's $\kappa = .739$. The mean score for each principle was calculated by dividing the sum of credits awarded per principle by the total number of test items this principle was assessed on. This then yielded 6 mean scores, ranging from 0-1, each assessing performance on a particular principle. Conceptual understanding on a given test occasion was defined as the sum of the principles scores, divided by the maximum score (6) and this quotient was expressed as a percentage (0-100%).

We distinguished between two different measures of conceptual understanding, each assessed by a different set of items: (a) *Conceptual understanding* (0-100%), which was assessed by items requiring students to explain diffusion between two liquid substances in simplified situations, such as ink in water (items 1-4 and 7, see Appendix B); and (b) *Applied conceptual understanding* (0-100%), which was assessed by items requiring students to explain diffusion in a complex biological system, namely the human respiratory system, and required additional knowledge of the anatomy and processes involved in respiration (items 5, 6, 8 and 9, see Appendix B).

Dialogue protocol analysis

The data used for analyses consisted of the written dialogue protocols, and did not include other discourse and interaction properties. The dialogue protocol of one participant (from the disputative computer agent condition) could not be retrieved due to technical difficulties, resulting in a data set of 79 dialogue protocols in all. Turns were automatically parsed by the software interface, each time a discussant posted a new written entry by hitting the “enter” button. Since the confederate’s behavior was controlled by condition, only the verbal content of the participant’s turns were coded. The following measures were obtained:

Overall participation. Following Rodicio and Sanchez (2005), the average amount of words per turn was used to assess the overall degree of participation in computer-mediated interaction.

Substantive engagement. Participants’ extent of engagement with conceptual content was assessed by coding the number of substantive propositions in their dialogue content. A substantive proposition is a domain-related utterance that consists of a single idea. One sentence can consist of several propositions, as is shown in the following example: The sentence "I am not sure, but I think that since the molecules move randomly all the time, there will be fast movement from areas of high concentration to areas of low concentration" was segmented into four different substantive propositions:

(a) The molecules move randomly

(b) The molecules move constantly

(c) The movement will be fast

(d) The movement will be from areas of high to areas of low concentration.

This procedure yielded two measures of substantive engagement: The mean number of substantive propositions per conversation turn (total substantive propositions) and the mean number of new substantive propositions (new substantive propositions). The latter only included new inferences, excluding repetitions of propositional content (verbatim or paraphrased). Fifteen protocols were coded by two trained coders, independently and blind to condition. Inter-rater reliability for mean number of substantive propositions per protocol was high, *ICC* = .82. Inter-rater reliability for new substantive propositions was established by comparing rates of agreement on coding a substantive proposition as a new inference, or not. Reliability for the latter measure was substantial (Landis & Koch, 1977), $\kappa = .69$.

Competitive interpersonal regulation. We assessed the number of turns that included utterances that are indicative of a competitive interpersonal goal, for each discussion protocol. The identification of competitive utterances in argumentative learning interactions was based on an assessment scheme developed and validated by Asterhan and colleagues (Asterhan et al., 2010; Asterhan, 2013). The distinctions are adapted from previous work in communication theory (Brown & Levinson, 1987; Muntigl & Turnbull, 1998) and interaction research (Chiu & Khoo, 2003). Criteria for assessment were similar to the categories used for designing the confederate's disputative discourse prompts (see Appendix B). Examples of competitive utterances are *"So what?", "That cannot be true", “"Look, it's very simple…"*.

Twenty-two protocols were coded by two trained coders, independently and blind to condition. Inter-rater reliability was established by comparing whether a discussion turn was coded as including competitive rhetoric (or not), and was found to be substantial (Landis & Koch, 1977), κ = .79.

Omission of ideas in own explanations. Participants' willingness to share their personal (and often incomplete) understanding of diffusion was measured by whether they omitted ideas from their individually written solutions, when asked to present it in the computer-mediated interaction phase. Since participants were asked to present their solutions to the first item before being exposed to confederate's rhetoric style, omission of ideas was measured for the second item only. Following is an example of omission (the omitted idea is underlined): The solution written down on the individual answer sheet was *"<u>The body needs to absorb oxygen</u>, but when the oxygen concentration is low, the body decreases its breathing rate"*, whereas the solution presented in the on-line interaction was *"As the oxygen concentration decreases the body decreases its breathing rate"*. A total of 22 protocols were coded by two trained coders, independently and blind to condition. Inter-rater reliability was established by comparing whether ideas were omitted from the written response (or not), and was found to be substantial (Landis & Koch, 1977), κ = .75.

Results

The following results are presented: Manipulation checks, effect of conditions on different measures of learning and comparisons of additional interaction features across conditions.

Manipulation checks

To test whether the instructions regarding the interaction partner's identity (human peer *vs*. computer agent peer) had the expected effect on students' subjective evaluations of social presence, student responses to the Social Presence survey were compared. As expected, students who were led to believe they interacted with a human peer reported higher Social

Presence *(M* = 4.63, *SD* = 0.80), compared to students in the computer agent peer condition(*M* = 4.25, *SD* =0.78), F (1, 76) = 4.81, p = 0.031, partial η^2 = .06. No differences were found between the disputative and the deliberative style conditions, F (1,76) = 1.95, p = .167, and no interaction effect was found, F (1,76) = 1.07, p = .305.

To test whether the manipulation of the confederate's discourse style affected the extent of competitive rhetoric target students used themselves, a one-tailed t-test for independent samples was conducted. As expected, the verbal behavior of students in the disputative discourse style included a larger number of competitive utterances per turn (*M* = 0.13, *SD* = 0.19), compared to participants in the deliberative style condition (*M* = 0.02, *SD* = 0.05), t (77) = 3.41, p = 0.001, d = .82.

Effects on learning

Effects of the confederate' discourse style (disputative vs. deliberative) and subject's belief in human presence (computer agent vs. human peer) on individual learning outcomes was separately tested for each of the three performance measures: Conceptual understanding (ranging from 0-100), Applied conceptual understanding (diffusion in the respiratory system, ranging from 0-100) and Factual knowledge (ranging from 0-100%). Gender did not significantly add to any of the predictions. In addition, no interaction effects were found for any of the measures. We therefore omitted reporting on those throughout the following sections. No differences between conditions were found on the pretest score, with $F < 1$ on all comparisons. Distributions were tested for normality by inspecting measures of skewness and kurtosis, Q-Q plots and Shapiro-Wilks tests of normality. In all factorial analyses, homogeneity of error variance was tested with Levene's tests.

Effects on conceptual understanding

The raw pretest and the posttest means are presented in Table 3, per condition. A between-subjects ANCOVA was conducted to test the effect of discourse style (deliberative vs. disputative), belief in human presence (computer vs. human) and gender (male vs. female) on individual students' posttest conceptual understanding scores (diffusion in simplified systems). Measures of conceptual understanding on the pre-test and immediately after individual study were used as covariates and were each found to be statistically significant, F (1, 70) = 10.74, p = .002 and F (1, 70) = 32.96, p = .000, respectively. Homogeneity for the regression line slopes was examined by testing the interaction effects between factors and covariates, separately and in combination. Slopes were not found to be different, $p > .350$. Estimated marginal means of conceptual understanding on the posttest (adjusted for the covariates) are presented in Table 4, per condition.

A significant main effect of partner's discourse style was found, F (1,70) = 5.48 p = .022, partial η^2= 0.07, such that participants in the deliberative discourse condition showed better conceptual understanding (*EMM* = 60.25 , *SE* = 2.30) than those in the disputative condition (*EMM* = 52.63, *SE* = 2.30).

A main effect of belief in human interaction was also found, F (1,70) = 4.36 p = .040, partial η^2 = 0.06: Learners who believed they interacted with a computer peer agent scored higher on conceptual understanding (*EMM* = 59.92, *SE* = 2.33) than those who believed they interacted with a human peer (*EMM* = 52.95, *SE* = 2 .33) .

Since participants also received information about the identity of their interaction partner (human or computer agent peer) *prior* to the individual learning phase it is possible that this information affected their individual preparation and caused them to process the textual information better. To test the possibility that the expectation of interaction with a human *vs.* computer agent peer affected participants' individual gains from reading the text book, a one-way ANCOVA was conducted. The effect of belief in future interaction was tested on students' conceptual understanding scores on the two transfer items, that is: immediately following the individual learning phase and prior to the interaction phase. Individual pretest score was not found to be a significant covariate and was therefore omitted from the model.

The results showed that immediately following the reading phase, participants who believed they were about to interact with a computer agent later on had in fact *lower* conceptual understanding scores (M = 47.28, SD = 25.56.) than students who believed they were about to interact with a human agent (M = 57.24, SD = 19.97), F (1, 78) = 3.94, p =.051, $\eta^2 = 0.05$.

Even though the difference in mean scores is only marginally significant, the direction of the difference is opposite of what would have been expected, if the overall benefit of belief in interacting with a computer agent on the posttest scores would have been due to an improved text-processing. It then provides further support in favor of the conjecture that superior posttest performance in the computer agent condition should be attributed to the processes during the interaction phase, and not the preparation phase.

Effects on applied conceptual understanding

The outcome variable *applied conceptual understanding*, or: students' understanding of diffusion in a complex biological system, was not found to distribute normally. Sixty-nine percent of the participants either did not receive any credits on the items measuring this variable, or only showed understanding on the item that tested principle 1 ("*Diffusion is the net movement of particles from an area of high concentration to an area of low concentration*"). A dichotomous variable was then created, based on the posttest scores only: Participants who showed understanding that extended beyond diffusion principle 1 only (i.e., a score higher than 33) were categorized as showing conceptual understanding (31% of the sample), the rest were categorized as showing little to no conceptual understanding of diffusion in the respiratory system. The percentage of students in the deliberative condition showing conceptual understanding of diffusion in the human respiratory system (38%) was not statistically significantly different than that in the disputative condition (25%), χ^2(1, N = 80) = 1.46, p = . 23). No difference was found between the computer peer agent (30%) and the human peer (33%) conditions, χ^2 (1, N = 80) = 0.06, p = .81.

Effects on factual knowledge recall

An analysis of variance (ANOVA) was conducted to test the effect of discourse style and belief in human presence on students' on factual knowledge recall. Since factual knowledge was not assessed prior to the post test, the model did not include covariates. Belief in human presence was not found to affect performance on the factual knowledge measure, F < 1. Similarly, factual knowledge scores in the disputative (M = 54.58, SD = 19.85) and the deliberative style (M = 58.97, SD = 21.43) conditions were not found to differ, F (1, 74) = 19.36, p = .14, partial η^2 = .013.

Additional interaction behavior characteristics

Omission of ideas

To test whether students were less likely to share their own (incomplete) ideas with discussion partners when that partner engaged in disputative discourse, we compared the number of students who omitted ideas while copying their solutions from the individual, pen-and-paper pretest to the online discussion. In alignment with our expectations, a significant difference was found between the disputative and the deliberative condition: In the disputative condition, thirteen students omitted ideas (33%), whereas in the deliberative condition only 5 did so (12.5%), χ^2 (1, N = 79) = 4.87, p =. 027.

Degree of participation in the interaction

Degree of overall participation was measured by counting the mean number of words per conversational turn. Participants who believed they interacted with a human peer participated significantly more (M = 28.91, SD = 12.44) than students who believed they interacted with a computer agent (M = 23.03, SD = 10.42), F (1, 76) = 5.27, p = 0.024, partial

$\eta^2 = .065$. Mean participation rates in the disputative (*M* = 24.22, *SD* = 11.22) and the deliberative discourse condition (*M* = 27.73, *SD* = 12.20) were not found to differ, F (1, 76) = 5.27, $p = .175$. No interaction effect was found, $F < 1$.

Substantive engagement with the topic domain

Whereas word count provides coarse information about participation in the most general sense, it does not reveal much about the participants' extent of substantive engagement with the topic domain, that is: diffusion. Table 5 presents the mean number of substantive propositions per turn and the mean number of new substantive propositions per turn, for each of the four conditions. Even though conversation turns in the belief in human presence condition contained a larger number of words, compared to the belief in computer agent interaction (*M* = 3.80, *SD* = 1.89), they did not contain a larger number of substantive propositions (*M* = 4.50, *SD* = 2.03), F (1, 75) = 2.63, $p = .109$, partial $\eta^2 = .03$, nor a larger number of new substantive propositions (*M* = 3.17, *SD* = 1.74 and *M* = 3.63, *SD* = 1.61, respectively), F (1, 75) = 1.36, $p = .248$, partial $\eta^2 = .02$.

No differences were found between the disputative and deliberative conditions, neither on the overall number of substantive propositions, F (1, 75) = 1.26, $p = .265$, nor on the number of newly generated propositions F (1, 75) = 1.50, $p = .225$. No interaction effects were found for either score, $F < 1$ in both cases.

Discussion

There is increasing consensus among scholars in the Learning Sciences that argumentative dialogue has great potential for learning, especially when learning involves the transformation and re-construction of existing knowledge structures (conceptual change). However, very little is known about the conditions in which argumentation may benefit and when it may inhibit learning. Even less is known about the social dimensions of argumentation for learning. This is surprising, since even though the expected effects of argumentative dialogue on learning are of a cognitive nature (knowledge revision), argumentation itself is first and foremost a social endeavor, in which two or more participants critique and evaluate ideas. The present study then sought to experimentally isolate two aspects of the social dimension, belief in human presence and argumentive discourse style, and explore how these affect learning from argumentation. Taken together, the findings show that learners gain better conceptual understanding from argumentation with a disagreeing peer when the situation leads them to focus less on the interpersonal, social dimensions of the situation: deliberative instead of disputative style and belief in interaction with a computer agent peer, instead of human peer. Before turning to a detailed discussion of these main findings, we first discuss the outcomes on the other two measures of learning: Factual knowledge recall and applications of conceptual understanding to a complex system.

Even though the two social factors were found to affect conceptual understanding scores they did not affect students" recall of factual knowledge. This corroborates with earlier studies that reported effects of argumentive activities on conceptual understanding, but not on recall of propositional knowledge (Asterhan & Schwarz, 2007; Wiley & Voss, 1999). It may also explain why Felton et al (2009) did not find an effect of discourse goal instructions on students' factual knowledge about science topics. Together, these findings seem to indicate that deliberative argumentation may not have any particular benefits for learning that involves simple recall of new information, or "gap-filling" (Chi, 2009).

Even though deliberative discourse style and belief in interaction with a computer agent increased students' performance on measures of conceptual understanding of diffusion in simplified systems, it did not improve their ability to apply these concepts to a more complex biological system, such as the respiratory system. We propose that this lack of effect is most likely to have been the result of a floor effect: Solving the respiratory system test items correctly requires not only an understanding of diffusion processes, but also declarative knowledge of the complex anatomy and processes in the respiratory system. Moreover, many students have additional, specific misconceptions about breathing (such as, *Plants release only* CO_2) which may have added to the complexity of applying the diffusion concept to respiratory systems. In support, posttest scores showed that more than two-third of the participants showed none to very little understanding of diffusion in the respiratory system, regardless of condition. The text reading phase may then have been too short or insufficient for students to be able to adequately process the detailed information about the respiratory system *and* to additionally understand the role of diffusion in it.

We now turn to a discussion about the main findings concerning argumentive discourse style and belief in human presence on conceptual understanding, their theoretical implications and their limitations.

Argumentive discourse style.

The first social characteristic explored in this study concerned argumentive discourse style. Previous work (Asterhan et al, 2010; Felton et al, 2009) has examined the effect of different discourse goal instructions, but failed to establish a direct relation between discourse style and learning. In the present study, argumentive discourse style was then directly manipulated by means of a confederate and a dialogue script. In a controlled setting in which the epistemic content of a dialogue partner's contribution was held constant, students were exposed to the same ideas and asked the same critical questions, they showed more conceptual gains when the disagreeing partner's discourse style was deliberative, as opposed to disputative.

This finding provides first experimental evidence for the benefits of deliberative over disputative argumentation for learning. It corroborates with theoretical models and case study evidence that have highlighted the pivotal role of constructive criticism in argumentation for learning (Asterhan, 2013; Asterhan & Schwarz, 2009b; Mercer, 1996; Keefer et al, 2000;

Nussbaum, 2009). The added value of the current study is that by adopting a stringent experimental approach the effect of other potentially confounding variables, could be ruled out, such as differences in content exposure, extent of critique and other naturally occurring differences between dispute and deliberation in educational settings.

In contrast to previous findings (Asterhan et al, 2010), gender was not found to play a significant role in this study, neither on the participants' discourse style, nor on its effects on learning. Similar to the Asterhan et al (2010) study, learners (were led to believe that they) interacted with a same-sex partner. In the present study the discourse style itself was directly manipulated, instead of providing learners with instructions to engage in a certain discourse style. It is likely that in these controlled conditions, there may not have been enough room for such naturally occurring differences in discourse style to emerge. Thus, the fact that no gender differences were found in this study does not imply that gender differences do not exist in natural settings. It does seem to indicate, however, that argumentive discourse styles *when engaging in them* have similar effects on male and female learners.

The present study also provides some first, albeit limited, insights into the processes that may account for the advantage of deliberative over disputative argumentation for conceptual learning: First of all, the effect cannot simply be explained by reduced attention to conceptual content in the disputative style condition. Learners did not differ in the amount of new substantive propositions they introduced during the interaction. When asked to post their personal explanations to their discussion partner, however, students in the disputative discourse condition were found to omit ideas more often. This omission tendency may signify a decreased willingness to open up, to publicly share one's own, incomplete understanding and subject it to peer critique under more competitive circumstances. Models of productive classroom dialogue emphasize discussion as an importance means for revealing and correcting errors and misconceptions collaboratively. Learning from error and failure is also at the heart of several other instructional techniques, such as productive failure (Kapur, 2008) and learning from erroneous examples (Durkin & Rittle-Johnsson, 2012). Based on the findings reported here, the effectiveness of such instructional techniques may be undermined by messages of competition and social comparison, since students are less likely to publicly share their erroneous and incomplete explanations with others under these circumstances

In addition to a decreased willingness to share, disputative discourse may also have caused learners to be less attentive to peer critique. Unfortunately, this possibility could not be examined with the current data set. Future research should further explore this direction by, for example, examining the extent to which learners recall or recognize verbal content that was introduced by the discussion partner.

Belief in human presence during argumentation

The findings concerning the effects of belief in human presence on conceptual learning are intriguing. Regardless of a partner's discursive style, students gained more from argumentation with a disagreeing peer when they believed him/her to be a computer agent that was modeled on equal status peers, as opposed to a human peer. The conversation partner's verbal behavior was tightly controlled in this study. Thus, even when the learners engaged in the same epistemic dialogue moves (e.g., providing an explanation, elaborating, justifying), beliefs about the interaction partner's humanness affected the outcome.

At first glance, the finding that mere belief in human presence interfered with learning seems in direct contradiction with empirical studies reporting positive effects of belief in human presence (Okita et al, 2008; Rose & Torrey, 2005), as well as with social learning theories which emphasize the affordances of human interaction for learning. In contrast to those previous works, however, the present study did not focus on consensual discourse, but on argumentation with a disagreeing peer. Thus, human presence during verbal learning interactions may be a two-edged sword: It may improve learning from consensual interactions, but inhibit learning from interactions that involve critique. Research into the role of belief in human presence on learning is still in its infancy and future research should further examine this prediction with direct comparisons between consensual and argumentive dialogue.

More research is also needed on what mediates such effects. The interaction analyses presented here showed that students who believed they interacted with a human peer posted more elaborate conversational turns, as expressed in the overall word count per turn (see Rose & Torrey, 2005 for similar findings). The two conditions did not differ in the number of substantive propositions on the topic domain they introduced to the discussion, however. This finding corroborates with research comparing face-to-face and online learning dialogues (e.g., Jonassen & Kwon, 2001; Sins, Savelsbergh, Joolingen, & van Hout-Wolters, 2011): When social presence increases, learners use more words to phrase their contributions to the dialogue, but it often does not result in more conceptual engagement with the topic domain. The effect of belief in human presence in the present study can therefore not be explained by differences in conceptual engagement or number of self-explanations during the interaction.

Based on the theoretical framework outlined in the introduction, it was proposed that interacting with a disagreeing partner on a complex topic may in and by itself cause discomfort and threaten perceptions of self-esteem and competence (Butera & Mugny, 1995; Darnon et al, 2006; 2007). Knowing that this disagreeing partner is a computer agent, instead of another (albeit anonymous) human being, could have alleviated some of these concerns, allowing learners to be more open to criticism and rethink their incorrect explanations. This conjecture corroborates with recent research that explores the effect of human *vs.* computer agent presence in social situations that elicit apprehension, such as help-seeking (Howley et al., 2014) and collaborative play for children on the autistic spectrum (Tartaro & Cassell, 2006). Future research should investigate these hypothesized mediating processes directly by, for example, inserting short self-report prompts during the interaction processes. Finally, future endeavors should systematically investigate and specify the type of learning interaction (tutoring, explanatory talk, argumentation, lecturing), the role of the discussion partner (expert, tutor, peer) and the type of domains and topics to be learned (e.g., skill development, conceptual change, factual knowledge acquisition). In the present study, we focused on one particular cell in such a matrix, namely conceptual change learning and verbal, argumentive interaction with an equal-status peer. Within the present design, we cannot rule out the possibility that as a result of increased social presence, learners in the human agent condition showed fewer gains because they were more inclined to adopt elements of the human partner's misconceptions, than learners from the computer agent.

Limitations of the present study

The effect sizes of discourse style and belief in human presence reported in this study were statistically moderate. Given the short intervention, which only consisted of less than 24 conversation turns with an unknown partner under tightly-controlled lab conditions, and given the fact that naïve ideas about diffusion have been documented to be particularly resistant to change (e.g., Chi, 2005; Chi et al, 2012; Meir et al 2005; Odom, 1995), they are nevertheless noteworthy. The results of the present study first and foremost provide important proof of concept. Instructional interventions in authentic educational settings are likely to be more intensive and have a larger impact.

The confederate in the present study did not provide the correct explanation at any point. This design decision is based on previous research which showed that mentioning the correct explanation does not predict individual gains from peer-to-peer argumentation, whereas reasoned disagreement does (Asterhan & Schwarz, 2007, 2009; Howe, 2009). The confederate's responses even hinted at common misconceptions, as would have been expected in natural dyadic interactions. Even though these were designed to accentuate the lack of logic in common misconceptions about diffusion (e.g., "How do the molecules *know* that they have to go the other side?”), learners still had to generate the correct explanation by themselves. One could argue, that learners in the human agent condition paid more attention to the confederate' contributions and were, therefore, more inclined to adopt elements of the human partner’s misconceptions into their own thinking. Whereas this argument cannot be empirically refuted within the present design, we argue that the opposite is also, or even more, plausible: A computer agent is often perceived as more authoritative than a human lay person, such as a peer student. Simple adoption of incorrect content from the discussion partner, if it happened, is then more likely in the computer agent condition. In any case, future research into the role of human presence in learning interaction should further examine the role of exposure to correct and incorrect explanations during dialogue.

Interactions with intelligent agents are increasingly more common in different facets of everyday life. Even so, the average student is not very likely to have had extensive experience with educational intelligent agents at the time of this study, and even less so with agents that are capable of conversing in natural language. It could then be argued that learners in the computer agent condition may not have fully understood the situation or may not have fully believed that their conversation partner really was a computer agent. To prevent misunderstandings, participants in the present study received detailed, yet common-sense explanations about conversational agents in general and how the peer agent was modeled on standard student responses. However, we did not directly assess the extent to which participants understood or believed the conversation partner was indeed a computer agent or a human peer. We did informally probe the first 20 participants to report on their experiences immediately following the interaction with a computer agent. Only one participant expressed suspicion about the authenticity of the computer agent. However, these are based on voluntarily given reflections in reaction to open prompts. A more systematic assessment with forced-choice items would have provided more decisive information.

*Practical implicatio*ns

The findings presented here also have practical implications. A great deal of effort has been and is being invested in the development of computer agents that can talk, behave, look and/or sound like humans. Educational applications are already being implemented in formal education, most prominently in the form of intelligent tutoring systems (e.g., van Lehn, 2011; Koedinger & Corbett, 2006). Based on recent advances in the development of virtual peers that are becoming increasingly more sophisticated in mimicking essential aspects of children's talk (e.g., Ogan, Finkelstein, Mayfield, Matsuda, & Cassell, 2012; Rader, Echelbarger, & Cassell, 2011), a similar trend may be expected for learning interactions with virtual peers. Questions concerning the effectiveness of these conversational agents are then timely. Our findings add to other research (e.g., Howley, Kanda, Hayashi, & Rose, 2014; Tartaro & Cassell, 2006) showing that, contrary to common assumptions, believing that one is interacting with a virtual agent may under specific circumstances have advantages compared to interacting with a human peer.

Finally, the findings on the effects of disputative and deliberative discourse may have important implications for the design of argumentative tasks and goal instructions in classrooms, especially if such activities are intended as a means to achieve conceptual gains on complex scientific content. This study shows that emphasizing the competitive and adversarial dimensions of argumentation, as is often done in classroom debating activities, may be counterproductive for content learning.

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APPENDIX A

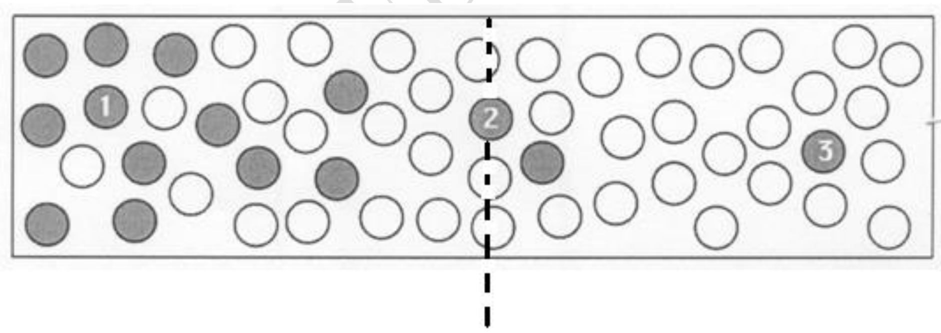
Test items for Assessing Conceptual and Factual Knowledge of Diffusion

I. Conceptual understanding

Test item 1 (pre-and posttest, target; principle 1)

If you pour some raspberry juice concentrate into an empty glass and then fill the glass carefully with water (making sure that the water doesn't get mixed with the concentrate) and then you wait for a while, you will find the water gradually getting colored red. This process is called diffusion. Explain the process.

Test item 2 (Pre- and posttest; target: principle 2)



Imagine this is an illustration of molecules in a specific moment (t). The grey molecules are diffusing in water (the white molecules) in a tube. The broken line in the center is an imaginary line dividing the tube into two areas (area A and area B). Where will molecule no.2 most probably be located in moment t+1?

a. In the same place
b. It will probably move to area A of the tube

c. It will probably move to area B of the tube

d. The probability of it moving to area A or B is equal

Explain your answer

Item 3 (pre- and posttest; target: principle 3 and 4)

Four drops of ink were dropped into a swimming pool, what will happen?

a. The ink particles will eventually disperse over the entire pool, but the process will be very slow. When the process will come to an end the ink molecules will stop moving.

b. The ink will disperse over the whole pool only if the water in the pool will be stirred or heated up. When the stirring or the heating will be stopped the ink molecules will stop moving.

c. The ink particles will eventually disperse over the entire pool, but the process will be very slow. When the process will come to an end the ink molecules will stop moving.

d. The ink will disperse over the whole pool only if the water in the pool will be stirred or heated up. When the stirring or the heating will be stopped the ink molecules will continue moving.

Explain your answer

Item 4 (individual reading test; target: principles 1,2,3 and 4)

Imagine two tanks: one full with blue ink and the other full with water. The tanks are connected by a pipe, enabling transition of the liquids between the tanks. What happens after the connection of the two tubes by the pipe, describe the process on <u>the molecular level</u>? Does the molecular movement come to an end? If it does- when?

Item 5 (individual reading test; target: principle 5)

Dina is staying in an unventilated room (the oxygen concentration is low and the carbon dioxide concentration is high). What will be the rate of oxygen and carbon dioxide exchange in her lungs, in comparison to the average rate?

a. The exchange rates of both gases will be higher than average
b. The exchange rates of both gases will be lower than average
c. The exchange rates of both gases will be average
d. The exchange rates of one of the gases will be higher than average, and the other one will be lower

Explain your answer.

Item 6 (posttest; target: 1)

Explain the process of the oxygen particles transition from air inside the alveoli to the blood.

Item 7 (posttest; target: principle 5)

You a have a rectangular aquarium full with water. You drop a big drop of ink close to the right wall of the aquarium. The water in the center of the aquarium begins changing its color after a minute. How long will it take until the water close to the left wall will begin changing its color?

a. Less than two minutes since the ink was dropped
b. Around two minutes since the ink was dropped
c. More than two minutes since the ink was dropped
d. Its impossible to determine

Explain your answer

Item 8 (posttest; target: principle 5)

Yossi entered a room in which the carbon dioxide (CO_2) concentration is higher than average, but still lower than its concentration in his blood. What will happen to the CO_2 concentration in his blood after a few minutes?

a. The CO_2 concentration in his blood will increase

b. The CO_2 concentration in his blood will not change

c. The CO_2 concentration in his blood will decrease

Explain your answer.

Item 9 (posttest; target: principle 2)

In the diffusion process of oxygen in the lungs

a. The oxygen molecules move only from the alveoli to the blood

b. Most part of the oxygen molecules move from the alveoli to the blood, but a small part of the molecules also transits from the blood to the alveoli.

c. An equal part of the oxygen molecules transits from the alveoli to the blood and back.

Explain your answer.

II. Factual knowledge test items (posttest only)

1. What is "Brownian motion"?
   a. Net motion of particles
   b. Constant random movement of particles
   c. Movement of particles against the gradient of concentrations
   d. Movement of particles according to the gradient of concentrations

2. What is "Net motion of particles"?
    a. Brownian motion of particles
    b. Constant random movement of particles
    c. Movement of particles against the gradient of concentrations
    d. Movement of particles according to the gradient of concentrations

3. What are the four factors that affect the rate of diffusion?

4. Where in the human body does the exchange of gases through diffusion occur ?
    a. Only between the alveoli and the blood cells
    b. Between the alveoli and the blood cells and also between the blood cells and the rest of the body cells.
    c. Between the blood cells and all respiratory organs: nose, trachea, bronchi, and the alveoli .
    d. Only in the nose

5. What are the bronchi?
    a. A system of differently sized pipes
    b. Two pipes extending from the tranchea
    c. Small spherical sacs
    d. A group of alveoli

6. What are the carbon dioxide (CO_2) concentrations inside the alveoli and in the blood system?

a. Inside the alveoli: less than 1%, in the capillaries: higher than 1%

b. Inside the alveoli: less than 1%, in the capillaries: less than 1%

c. Inside the alveoli: around 40%, in the capillaries: higher than 40%

d. Inside the alveoli: around 40%, in the capillaries: less than 40%

APPENDIX B

The Full Script of the Confederate's Dialogue Moves, According to Rhetoric Style Condition

Move	*Deliberative argumentation*	*Disputative argumentation*
Elicits answer	Alright, let's see how *we* can solve item 1 *together*. What's the answer you wrote down?	Alright, let's see how *you* managed to solve item 1. What's the answer you wrote down?
Ask for elaboration (optional)	*I am sorry, I may not have understood completely. Could* you explain a bit more about what happens to the water / ink molecules?	*Your* answer is not clear. *You did not* explain, for example, what happens with the water / ink molecules?
Challenge	*I am not an expert in this, but is it really true* that X? *We have* not yet explained how the molecules know that there is a lower concentration in the other tank?	*Your answer does not make any sense at all. Do you really think* that X? *How do you* explain the molecules know that there is a lower concentration in the other tank?
Ask for elaboration (optional)	[if the S did not explicitly refer to it] Will the molecules stop moving or will they continue to move?	[if the S did not explicitly refer to it] Do you think that the molecules will stop moving or will they continue to move?
Challenge	*Are you sure? Haven't* they already arrived at the place where they should be**..?** *Are you sure? Wasn't it*	*Clearly that cannot be true***.** They already arrived at the place where they should be! *Clearly that cannot*

	written in the text that they are always in motion?	*be true***.** It was written in the text that they are always in motion!
Evaluation and elicitation of answer	I am not *really* satisfied with *our* explanation, but we already have to move on to item 2. Which alternative did you choose: a, b, c or d?	I think *your* explanation is *wrong*, but we already have to move on to item 2 now. Which alternative did you choose: a, b, c or d?
Elicitation of answer	*Interesting, I chose something else. Could you explain* why you think the rate becomes higher / lower / remains the same / we can't know?	*I think you are mistaken. How did you arrive at the conclusion* that the rate becomes higher / lower / remains the same / we can't know?
Challenge (optional)	[if the S did not explicitly refer to it] *If I remember it correctly*, it said in the text that the oxygen exchange rate is related to its' concentration gradient *we haven't explained this yet***.**	[if the S did not explicitly refer to it] *But, I clearly remember* the text stated that the oxygen exchange rate is related to its' concentration gradient**.** *You didn't mention it at all/ clearly.*
Ask for elaboration (optional)	[if the S did not explicitly refer to it] *OK, and what can we say about* the effect of the high concentration of carbon dioxide?	[if the S did not explicitly refer to it] *Let's suppose you're right…*What is the effect of the high concentration of carbon dioxide?
Challenge	*I'm not sure… Don't you think* that if the oxygen's exchange rate increases [decreases] then the carbon dioxide	*I don't think so… It's clear to me* that if the oxygen's exchange rate increases [decreases] then the carbon

	exchange rate will increase [decrease]?	dioxide exchange rate will increase [decrease].
Ask for reflection	In conclusion, is there anything that *we* may have missed or wasn't completely clear?	In conclusion, is there anything that *you* may have missed or wasn't completely clear to you?
Parting words	OK*, thanks…It was nice…*bye!	OK, bye!

Tables

Table 1.

*Assessment of student's conceptual understanding of diffusion process according to five key principles**

Description of principle	*Reference to macro or micro level of diffusion*
1. Diffusion is the net movement of particles from an area of high concentration to an area of low concentration	Macro
2. Diffusion results from the random motion and/or collisions of particle	Micro
3. Diffusion continues until the particles become uniformly distributed in the medium in which they are dissolved	Macro
4. The particles are in constant motion, even after the system reaches equilibrium (dynamic equilibrium)	Micro
5. Diffusion rate increases as the concentration gradient increases	Macro

* Based on and adapted from Chi et al (2012), Odom (1995) and Meir et al (2005)

Table 2

Examples of scripted turns conveying different rhetoric phrasing (differences in italics)

	Deliberative rhetoric	*Disputative rhetoric*
Referring to solutions as an outcome of a shared thinking process / repartitioned solutions that are reached through individual effort	Alright, let's see how *we* can solve item 1 *together*. What's the answer you wrote down?	Alright, let's see how *you* managed to solve item 1. What's the answer you wrote down?
Attempts to understand / disqualify the other's thinking	*I am sorry, I may not have understood completely. Could you explain a bit more about* what happens with the water molecules*?*	*Your answer is not clear. You did not explain, for example,* what happens with the water molecules?
Decrease / increase face threat during disagreement	*Are you sure? Haven't they* already arrived at the place where they should be..*?*	*Clearly that cannot be true. They* already arrived at the place where they should be*!*

Table 3.

Raw means (and SD) of conceptual understanding scores on pretest and delayed posttest , by discourse style and belief in human presence (*N* = 80)

Discourse style		*Belief in interaction with*		
		Computer agent peer	*Human peer*	*Total*
Disputative	pretest	30.25 (16.58)	29.00 (14.47)	29.63 (15.38)
	posttest	44.50 (17.64)	40.40 (16.90)	42.45 (17.17)
Deliberative	pretest	29.50 (10.50)	33.50 (21.59)	31.50 (16.88)
	posttest	53.10 (24.09)	51.35 (21.41)	52.23 (22.51)
Total	pretest	29.88 (13.70)	31.25 (18.28)	
	posttest	48.80 (21.29)	45.88 (19.83)	

Table 4

Estimated marginal means (and SE) of conceptual understanding scores on delayed posttest, by discourse style and belief in human presence (*N* = 80)

Discourse style	*Belief in interaction with*		
	Computer agent peer	*Human peer*	*Total*
Disputative	54.71 (3.26)	50.55 (3.26)	52.63 (2.30)
Deliberative	65.14 (3.30)	55.36 (3.31)	60.25 (2.30)
Total	59.92 (2.33)	52.95 (2.33)	

Table 5

Mean number (and SD) of total substantive propositions and new substantive propositions per turn in the participant's dialogue, by experimental condition (N = 79)

Discourse style		*Belief in interaction with*		
		Computer agent peer	*Human peer*	*Total*
Disputative	Total propositions	3.36 (1.33)	4.44 (2.30)	3.91 (1.94)
	New propositions	2.80 (1.19)	3.55 (1.71)	3.19 (1.51)
Deliberative	Total propositions	4.21 (2.25)	4.57 (1.79)	4.39 (2.02)
	New propositions	3.57 (2.10)	3.70 (1.56)	3.63 (1.83)
Total	Total propositions	3.80 (1.89)	4.50 (2.03)	
	New propositions	3.17 (1.74)	3.63 (1.61)	