Delinquent or criminal? Fostering conceptual understanding of technical terms in computer-mediated collaborative learning

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Abstract: To ensure a complex understanding of the topics addressed in collaborative learning scenarios, learners have to develop a conceptual understanding of the relevant specialist vocabulary. To this end, they have to exchange and discuss their individual knowledge, which is usually gained through individual exploration of different learning materials. Based on the psycholinguistic concept of lexical alignment, the following study analyzes whether providing learners with different technical terms in their respective learning materials has a positive impact on information exchange, term understanding, and learning. Results showed that dyads whose materials contained different terminology exchanged more information and performed better in a subsequent knowledge test than did dyads whose materials contained the same terminology. The inclusion of illustrations containing different terminology enhanced these effects. Implications for the selection and design of learning materials as well as perspectives for further research are discussed.

Introduction

In general, language serves as a main tool by which thoughts, needs, attitudes, etc., are expressed. The main challenge in all verbal and written interactions is to achieve mutual understanding. This holds both for everyday situations, such as referring to a person or a thing when telling a story, and for more formal situations, such as referring to the conceptual knowledge that is usually encoded in specialist vocabulary in peer-to-peer learning situations (Bromme, Rambow, & Nückles, 2001). Focusing on the second scenario, let us imagine a typical situation in the life of university students: Peter writes Linda a message to coordinate the content of a presentation they are preparing for a course dealing with Freudian theory. He writes: "… and suppression is another important defense mechanism we should mention!" Linda answers: "I agree. I'll add suppression to the defense mechanisms." They probably both know the terms "suppression" and "defense mechanism" because they have read various texts to prepare for this exchange and the subsequent presentation. From the perspective of classic communication psychology, this discourse sequence clearly seems to be successful. Peter introduces two central terms and Linda signals understanding by using the terms without asking for clarification of their meaning or showing any other signs of mis- or non-understanding.

Following Clark and colleagues, the process by which interlocutors try to establish that messages have been received and understood is called grounding (Clark & Brennan, 1991). Grounding is an ongoing process during communication that serves to determine, to update, and to expand the so-called common ground (e.g., Clark, 1992; Clark & Marshall, 1981), that is, the assumed shared knowledge that provides the basis for communication. The common ground is inferred on the basis of different types of evidence; Clark and Marshall (1981) described three heuristics that people use to estimate what an interlocutor knows. Because in our example Peter and Linda communicate in written form and thus cannot rely on verbal or visual signs of mutual understanding (Monk, 2003), their assumptions about their shared knowledge are based mainly on word use (*linguistic co-presence heuristic*). In ongoing communication, newly introduced terms are usually repeated; they "become part of a 'discourse record' that is a subset of interlocutors' common ground" (Barr & Keysar, 2006, p. 6). The use of the same vocabulary is called lexical alignment (Pickering & Garrod, 2005) and takes place in both spoken (Barr & Keysar, 2002) and written communication (Bromme, Jucks, & Wagner, 2005). According to Clark and Marshall (1981), it is reasonable and efficient to stick to the lexical decisions made by the interlocutor in order to express one's own intended meaning. Interlocutors thus "minimize their collaborative effort—the work that both do from the initiation of each contribution to its mutual acceptance" (*principle of least collaborative effort*, Clark & Brennan, 1991, p. 135). Lexical alignment has also been demonstrated for technical terms in technical communication (Bromme et al., 2005; Jucks, Becker, & Bromme, 2008) such as that engaged in by Peter and Linda in our example. However, in the context of technical terms – as opposed to everyday terms – the difficulty arises that a term's connotations and complexity have to be transmitted within the choice of words and that an important part of the exchange concerns the underlying concepts. For example, whereas interlocutors in everyday communication may have different concepts of the meaning underlying the term "man," this is not relevant for successful communication ("The man is standing on the street."). In contrast, when interlocutors refer to the meanings underlying technical terms, as in our example, lexical alignment can conceal different meanings of a term that are relevant for discourse. Thus, where the deep understanding of the

meaning underlying a term is concerned (and not simply the reference to an object in the world), lexical alignment may obscure the fact that the interlocutors have different conceptualizations of a term.

It has already been demonstrated that interlocutors' comprehension of the meaning of a technical term may be differently elaborated (Bromme et al., 2001). In particular, research on expert – layperson communication has shown that the underlying meaning of a technical term and the interlocutors' mental representation may differ (Jucks & Bromme, 2007). Whereas experts are usually aware of the complex knowledge encapsulated by technical terms (Schmidt & Boshuizen, 1992), laypersons' understanding of their meaning is often rather vague or even erroneous (Gittelman, Mahabee-Gittens, & Gonzalez-del-Ray, 2004). When interlocutors use the same words, differences in their knowledge of the underlying concepts are very difficult to detect. In general, it is difficult for people to distinguish between their own and their partner's knowledge of a particular subject, as has been demonstrated experimentally by Keysar (1994). In the same vein, Nickerson (1999) has shown that people tend to impute their own knowledge to others and only gradually become aware of others' knowledge states. Gauging others' conceptual knowledge about technical terms poses an additional difficulty: Because the underlying meaning is usually rather complex and the context of definition may vary (Paus & Jucks, 2009), it is very difficult for interlocutors to define an explicit criterion for knowing "enough" about a term.

Let us now return to our example: Peter introduces the words "suppression" and "defence mechanism." Linda absorbs these words without showing any signs of mis- or non-understanding – lexical alignment occurs. However, the assumption of shared knowledge, or common ground, may be mistaken, because Peter and Linda do not necessarily share the same knowledge of the underlying conceptual meanings. Consequently, using the same words can lead to particularly ineffective communication: Interlocutors communicate based on an illusion of common ground that prevents them from exchanging their knowledge explicitly and thereby developing a differentiated understanding of the concepts underlying the specialist terms. Lexical alignment of technical terms can thus be expected have certain costs in the area of learning and understanding. Indeed, Paus and Jucks (2008) have shown that the use of the same lexical encoding may—tacitly—be taken as an indicator of common ground in computer-mediated peer-to-peer learning settings. In an experimental study, university students working on a cooperative learning task gained more individual knowledge and showed more elaborated discourse patterns when the two participants in a learner dyad were provided with different terminology describing the same technical concept. These findings can be interpreted as follows: If linguistic co-presence is interrupted because the learning partners lack a joint vocabulary, their attention is explicitly drawn to their own and their partner's understanding of the terms. Not having the same words available allows them to assume less overlap in knowledge (Wu & Keysar, 2008). To increase their shared knowledge, they discuss the meaning of the terms. Individual knowledge about the underlying conceptual meaning is therefore exchanged more explicitly, thus fostering the development of a differentiated understanding of the meaning of technical terms as well as a better understanding of the topic in general. To conclude, learners' attention has to be focused on their understanding of technical terms.

Research has already shown that scientific illustrations in text materials attract readers' attention (Jucks, Bromme, & Runde, 2007) and "… exert a specific impact on the form and content of replies" (pp. 213-214). Providing learners with content-specific visualization tools is also known to have a positive effect on both communication and problem solving (Fischer, Bruhn, Gräsel, & Mandl, 2002). Nevertheless, the use of a term unfamiliar to the learning partner may initially cause confusion (Wu & Keysar, 2008). Although this confusion should prompt the more explicit elaboration of the meaning of specialist terms, interlocutors may not be aware of the resulting knowledge gain and instead feel a higher level of uncertainty.

Based on these considerations, our hypotheses for the present research were as follows: (1) We expected learning partners who were provided with different terms encoding the same underlying concepts to exchange more information and to gain a better understanding of the terms and the learning content than learning partners who were provided with the same terms. (2) Additionally, because learners' attention is attracted to the information provided in illustrations, we expected the predicted effects to be increased by the inclusion of illustrations in which the main concepts were also encoded by different technical terms. (3) Finally, we examined the effect of different terminology on learners' feelings of uncertainty. We expected learning partners provided with different technical terms to feel more uncertainty about their own knowledge than learning partners provided with the same terms.

Method

Participants and Design

Participants were 72 undergraduate psychology students (47 female, 25 male) at the University of Frankfurt. Mean age was 24.37 years (SD = 4.63). All participants were German native speakers. They were assigned to 36 learning dyads and randomly assigned to three conditions: texts with the same terminology, texts with different terminology, texts with an illustration and different terminology. Participation was voluntary and rewarded with 7 euro. Learning outcomes were assessed for each participant individually (sample size: 72

participants, with 24 in each condition); the communication process was analyzed within dyads (sample size: 36 dyads, with 12 in each condition).

Procedure

Two students participated in each trial. They were tested individually in separate rooms and were assigned gender-neutral pseudo-email addresses to prevent them from making any assumptions about each other. Note that we decided on email rather than chat as the communication medium due to practical aspects of data collection. Each room was equipped with the necessary technology and an experimenter was present throughout. Access to external Internet sites was blocked to prevent participants from using information sources other than the texts provided. First, it was ensured that the participants' computer skills met the demands of the experiment. The partners in each dyad were then given different texts to read and understand with no time limit. They were then set a collaborative task, to be discussed and completed with their partner at their own pace via e-mail. To ensure that the learning scenario was as realistic as possible, no further instructions were given on the procedure and/or the collaboration process (e.g., length, structure, etc.). After the collaborative task, the learning materials were removed to ensure independent knowledge generation in the knowledge tests. Participants provided with an illustration were asked to rate the perceived importance of the illustration for solving the collaborative task. Moreover, all participants were asked to rate their feeling of uncertainty with regard to their knowledge of the topic covered. Afterwards, they were administered a knowledge posttest comprising a cloze task (Taylor, 1957) and a multiple-choice test. Finally, demographic data including the frequency of computer usage were obtained.

Materials

Learning texts

The learning texts were original extracts from two child psychiatry textbooks (Herpertz-Dahlmann, 2005; Schmeck, 2004). Both extracts dealt with the development of a social behavior disorder; each was around 500 words long. Except for some abridgements to ensure that the two texts had the same length and format, no modifications were made. Although both texts addressed the same topic, there were differences in the description of theoretical models and in the detail of the information presented. Both texts covered all information assessed in the knowledge posttest.

Manipulation of the learning material

We first drew up a list of terminology specific to the topics covered. Fifteen key concepts were identified. Some of the terminology used to designate the same underlying concept in the original texts differed (e.g., prevalence vs. frequency); some of it was the same (e.g., monozygotic). In cases where the terminology was the same in both texts, we looked for synonyms in a dictionary of foreign words (Wermke, Klosa, Kunkel-Razum, & Scholze-Stubenrecht, 2001). Each term was matched with a synonym that had the same meaning in the present context. Two different versions of the text material were then constructed by manipulating the usage of the 15 key concepts. In the different terminology condition, the 15 key concepts were used in one encoding (e.g., prevalence) in one text and in the other encoding (frequency) in the other text. In the control condition, the same terminology (prevalence) was used in both texts. When matching the words, we sought to maintain a balance across the texts in the use of terms stemming from Latin or Greek and terms with German roots. The illustrations were both taken from the respective textbooks. They contained 5 vs. 6 of the 15 manipulated terms as well as further terms relating to the development of a social disorder. The terms in the illustration were adapted to the terminology used in the respective version of the text.

Collaborative task

We set participants two questions to be worked on collaboratively. The questions were designed to support the integration of factual knowledge on the topic at hand as well as the production of inferences during the learning process. To answer the first question, they had to refer to the case study of a 13-year-old boy with behavioral problems. They were asked to list all factors that might have influenced his behavior. The second question concerned the prevalence of social behavioral disorders in boys and girls. Learning partners had to exchange the information contained in their individual texts in order to succeed in the collaborative task.

Dependent Measures

Three sets of outcome measures were considered: information exchange, individual knowledge gain, and subjective measures.

Information exchange

Three measures were used to assess information exchange within the dyads:

Communication. To assess information pooling during communication, we determined the number of questions asked and the number of explanations given within each dyad. We restricted the assessment to questions and explanations relating to the relevant terminology. Participants' questions and explanations were transcribed and analyzed (by a second rater) according to predefined criteria. Interrater reliability for the numbers of questions asked (K = 1.0, p < .001) and the number of explanations given (K = 1.0, p < .001) was satisfactory.

Knowledge exchange items. The multiple-choice test included questions tapping knowledge of contents that were included in only one version of the text (six questions for each text). These items were intended to measure information pooling between the learning partners, regardless of the usage of technical terms. Learning partners could answer these items correctly only if they had exchanged their individual knowledge. Additionally, for the two conditions in which learners were provided with different terms, we counted the number of technical terms from the partner's learning material that were used in a cloze procedure to determine how many of these terms had been absorbed from the partner.

Individual learning outcomes

Individual knowledge gain was measured by the following indicators:

Multiple choice test: General understanding of the contents covered was assessed by a multiple-choice test with 28 tasks, each with four response alternatives. All distractors were chosen such that an uninformed participant perceived them as being correct with the same probability (Bortz & Döring, 1995). One point was given for each correct answer, and one point was subtracted for each incorrect answer. Hence, the maximum number of attainable points was 28.

Cloze procedure. We developed a cloze test requiring participants to fill in words that had been removed from a text to determine whether they could reproduce the topic-relevant terminology in a continuous text, thus demonstrating an understanding of the underlying concepts (Taylor, 1957). A rational deletion procedure was used to identify the 10 words that were omitted; only content words (subjects, objects, adjectives, and verbs) were removed (Kobayashi, 2002). Eight of the omitted words were drawn from the list of manipulated terminology. We were thus able to test the participants' understanding of the terms. The remaining two items tested the main topics covered in the two texts. Participants were given one point for each gap filled correctly. Thus, the maximum number of attainable points was 10.

Subjective ratings

Relevance of illustration. Participants were asked to rate the perceived relevance of the illustration on a 5-point scale ranging from *not true* to *true*.

Feeling of uncertainty. Likewise, participants were asked to rate their perceived uncertainty on a 5-point scale from *not true* to *true* to determine whether the provision of different terminology influenced their feeling of uncertainty.

Results

In this section, we report the effects on the three sets of outcome measures. Unless otherwise indicated, analyses were performed using SPSS 17. Participants in the three conditions did not differ in frequency of computer usage, $F(2,69) = 0.92$, $p = .402$, frequency of internet usage, $F(2,69) = 0.14$, $p = .873$, or subjective self-ratings, $F(2,69) = 0.64$, $p. = .53$.

Information Exchange

Communication. The length of communications was M = 587.36 words (SD = 215.37); there was no effect of condition, $F(2,33) = 3.10$, $p > 0.05$, *ns*. MANOVAs with the number of questions/explanations relating to the manipulated vocabulary as dependent variables revealed a main effect of condition, $F(4,66) = 2.79$, $p < 0.05$, $\eta_p^2 = .15$. However, a univariate analysis revealed no differences in the number of questions across the three conditions, $F(2,33) = .88$, $p > 0.05$, *ns*. In contrast, a univariate analysis of the number of explanations revealed a main effect of condition, $F(2,33) = 6.67$, $p < 0.05$, $\eta_p^2 = .15$, with participants in the different-terminology with illustration condition giving more explanations (M = 5.92, SD = 3.0) than participants in the different-terminology without illustration condition (M = 3.92, SD = 3.2) or participants in the same-terminology condition (M = 1.67, SD = 2.27). Most explanations related to the terms "prevalence," "frequency," "social pressures," "age group," "adolescence," "psycho-social risk factors," and "genetic."

Knowledge exchange items. An ANOVA revealed an effect of condition on the number of correctly solved multiple-choice items designed to measure information exchange, $F(2,69) = 11.17$, $p < 0.001$, $\eta_p^2 = .25$. A post hoc test (S-N-K) showed that the same-terminology group differed from the different-terminology group with illustration ($p < 0.05$) and from the different-terminology group without illustration ($p < 0.05$), whereas no difference was found between these two groups ($p > 0.05$, *ns*).

In the cloze task, participants in the different-terminology condition used $M = 0.75$ ($SD = 0.98$) terms from their partner's learning material to fill the gaps and $M = 3.25$ ($SD = 1.90$) terms from their own material. However, the difference between groups in term usage was not significant, $t(46) = -.29$, $p > 0.05$, *ns*.

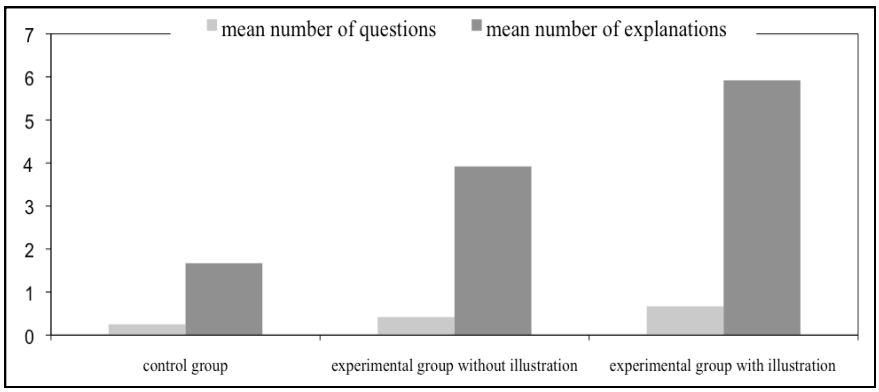

Figure 1. Mean number of questions asked and explanations given in the communication process

Individual Learning Outcomes

To examine the effects of condition on students' learning performance, we conducted a MANOVA on the number of points attained in the multiple-choice test and in the cloze test. Pillai's trace showed an effect of condition, $F(4,138) = 6.65$, $p < 0.001$, $\eta_p^2 = .16$.

Multiple-choice test. On average, participants scored 14.46 ($SD = 7.61$) of the available 28 points. Univariate analysis revealed a main effect of condition on points attained in the multiple-choice test, $F(2,69) = 12.8$, $p < 0.001$, $\eta_p^2 = .27$. A post hoc test (S-N-K) revealed that the same-terminology group differed from both different-terminology groups ($p < 0.05$). Moreover, the two different-terminology groups differed from each other ($p < 0.05$).

Cloze test. On average, participants correctly filled in 5.46 ($SD = 2.53$) of the 10 gaps. An ANOVA showed a main effect of condition, $F(2,69) = 10.53$, $p < 0.001$, $\eta_p^2 = .23$. A post hoc test (S-N-K) revealed that the same-terminology group differed from both different-terminology conditions ($p < 0.05$). However, no difference was found between the different-terminology conditions with and without illustration ($p > 0.05$, *ns*).

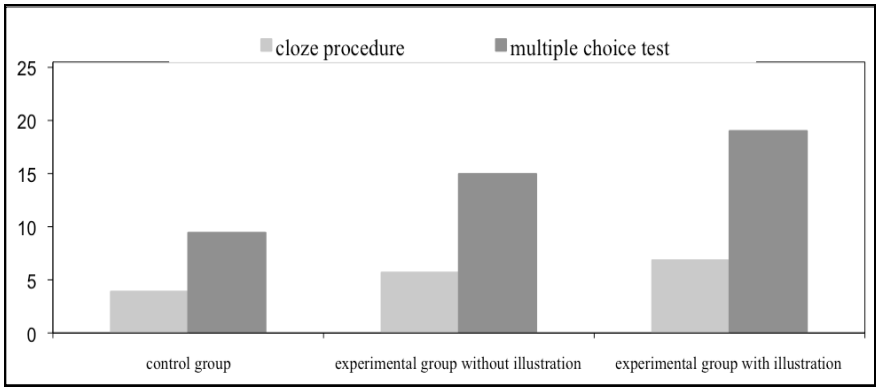

Figure 2. Mean scores in the cloze test and multiple-choice test

Subjective Ratings

Relevance of illustration. On average, the illustration was rated as being rather helpful ($M = 3.46$, $SD = 1.41$). To test how this perception related to objective learning outcomes, we correlated the subjective rating of the illustration's relevance for learning with the objective learning outcome in the multiple-choice test. The correlation was not significant, $K = .251$, $p > 0.05$, *ns*.

Feeling of uncertainty. Participants reported little uncertainty about their knowledge ($M = 1.71$, $SD = 0.86$). An ANOVA revealed no difference between the three groups, $F(2, 69) = 0.39$, $p > 0.05$, *ns.*

Discussion

These results emphasize the pivotal role played by technical terms in the development of a conceptual understanding of learning contents. We hypothesized that presenting learners with materials containing different lexical encodings of the same concept would initiate more reflection on their own and their partner's knowledge. We therefore expected learners to realize that their knowledge differed from that of their partner, which would prompt them to exchange knowledge and to elaborate the meaning of the technical terms in more depth. In the following, we discuss our findings with regard to information exchange, individual learning outcomes, and additional subjective self-ratings.

Information Exchange

In accordance with our hypothesis, learners in the different-terminology condition with an illustration made more explanatory statements about this terminology than did learners in the same-terminology condition. Taking into account that our experimental manipulation was limited to the lexical encoding of 15 key concepts, we interpret these results as evidence for the role of word choices in learning situations. The findings indicate that exposure to different terminology prompts learners to communicate in a more productive way, exchanging information about the underlying meaning of the terms. We attribute this difference to the use of different terms in their communication on the collaborative task making participants being more aware of potential problems of understanding. In particular, the results highlight the specific role of illustrations for information exchange in the given learning setting. As hypothesized, illustrations strongly focused the learners' attention on their own learning material, making them more aware of differences in the terminology used. To establish a common ground, they provided an explanation for the terms they used. In contrast, the explicit exchange of information did not seem necessary for dyads in the same-terminology condition, who assumed their partners to have similar understanding of the term as themselves (*knowledge effect*; Bromme et al., 2001).

Moreover, learners who exchanged more information were more familiar with the contents of their partner's learning material: Participants in the different-terminology conditions were better able to solve the multiple-choice items designed to measure information exchange. However, the same did not apply to recall of technical terms: In the cloze task, participants clearly reverted to the technical terms used in their own material. Hence, whereas increased information exchange led to more knowledge about non-shared contents, learners stuck to their own material on the lexical level.

Individual Learning Outcomes

We examined learners' individual learning outcomes in terms of their conceptual understanding of the topic and their understanding of the technical terms used. Performance on the multiple-choice test differed across all three groups, with participants in the different-terminology with illustration condition achieving the highest scores. These findings support our hypothesis that elaboration of learning content can be improved by placing different vocabulary in cooperative learning texts and that this effect can be further enhanced by including an illustration. Besides focusing learners' attention on the technical terms used, illustrations also help them to better understand the relations between the concepts (Larkin & Simon, 1987). In the cloze task, participants in the different-terminology conditions outperformed participants in the same-terminology condition. However, provision of an illustration had no additional influence here. In conclusion, it seems that inclusion of an illustration using different terminology to encode the same concepts has a positive effect on the development of a differentiated understanding of learning contents, but does not particularly affect term understanding.

Participants also reported that the illustration helped them to understand the learning contents. However, this perception was not systematically related to objective learning outcomes.

Limitations and Future Perspectives

In contrast to our hypothesis, participants' subjective ratings of uncertainty did not differ across conditions: Participants in all conditions reported little uncertainty about their knowledge. It is likely that the meaning of most of the manipulated terms could simply be deduced from the context. This interpretation is supported by the finding that the number of questions asked to clarify the underlying meaning of terms did not differ across conditions either. Participants only explicitly queried the meaning of very specific terms that are not used in everyday language. It seems that communication partners exchanged knowledge not because they were unable to understand each other, but because the different terminology used in the learning materials signaled different knowledge and thus led to perspective taking. Participants realized that their knowledge was not necessarily the same and thus started to explain their individual understanding of the term. It seems likely that this spontaneous provision of explanations directly reduced uncertainty and, in turn, the need to request more details. It remains an open question whether the lack of questions formulated can be attributed to characteristics of the terms or to the fact that the meaning was already clarified. Paus & Jucks (2009) have shown that learners' perceived understanding is affected by the origin of terms (e.g., Greek, Latin, Germanic).

In Germany, terms with Germanic roots are more easily accessible, perceived to be more familiar, and better understood. To address this question, the characteristics of the terms used in collaborative learning situations could be varied more systematically in future research. Individual factors, such as the degree of expertise in the field (see Gittelman et al., 2004; Schmidt & Boshuizen, 1992) or foreign language skills, may also affect perceived understanding of terms. Additionally, the correspondence between subjective assessments of the cooperation process and the perceived difficulty of the learning materials warrants analysis. It is important to find out whether and how learners perceive themselves to learn in collaborative learning environments and to identify how much pressure they face in coming to a mutual understanding. Future research should thus assess the mental processes underlying the learners' behavior; for instance, in retrospective analyses. Last but not least, it remains unclear what role social expectancy plays in admitting a feeling of uncertainty about one's knowledge.

The experimental setting investigated in this study can be considered a typical learning situation at university. However, although learning partners often do not know each other, especially in distance universities, the question arises of how their level of acquaintance affects communication behavior. It can be assumed that learners are acting in social roles predefined by previous interaction situations and that motivational and social-psychological aspects of discourse behavior are strongly influenced by those roles. In the present study, for instance, participants made assumptions about their partner's gender based on his or her way of formulating messages and coordinating the interaction. Future research should clarify whether our findings can be transferred to other learning situations: What is the impact of group size? How does the medium influence communication behavior? Are there any differences in comparison to face-to-face learning scenarios? Characteristics of the learning partners should also be taken into account. Spiro, Coulson, Feltovich, and Anderson (1994) argued that humanities students can be expected to use heuristic procedures to solve problems and to debate different alternatives. These students can thus be able to recognize that two terms may exist to describe the same underlying concept. In addition, learners' age can be expected to impact the development of assumptions about knowledge. Several researchers have concluded that this development proceeds stepwise (King & Kitchener, 1994; Kuhn, 1991; Perry, 1970). The validity of the present results should thus be verified for other learners, such as school students.

In summary, our findings indicate that the terminology used in learning materials impacts learning behavior in discourse. Moreover, the notation of knowledge contents (text vs. illustration) influences the way learners elaborate information. These aspects should therefore be considered in the design and selection of learning materials.

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