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Abstract

Research suggests that students who are aware of their own confusions and take steps to resolve those confusions are most likely to benefit from a learning experience. At the same time, there are conversational maxims, such as Leech's politeness maxims, that may inhibit a student from expressing and pursuing confusions within a tutorial dialogue. We investigated students' expressions of confusion while working through a series of learning activities with a tutor. We found that, during the times when students were working independently on an activity, their expressions of confusion were reliable indicators of their (lack of) understanding; however, when they were conversing with their tutors, these same students did not express confusion and, in fact, the more often the expressed comprehension, the worse they performed on the post-test. This suggests that student metacognitive statements should not be interpreted without taking into consideration the context in which they were expressed. We briefly consider implications for human tutors and the development of computer tutoring systems.

Introduction

Twenty years ago, researchers were somewhat surprised to discover that students who expressed confusion while studying worked examples were more likely to learn from that activity than students who appeared to easily understand those examples (Chi & Bassok, 1989). The key is in the qualifier "appeared" to understand. Further analyses and additional research confirmed that the students who expressed confusion often followed up by taking steps to resolve that confusion, while many of the students who breezed through a worked example were simply not aware of the fact that they didn't understand why each step was taken and how that process might be applied to related but different problems (e.g., Ferguson-Hessler & de Jong, 1990; Pirolli & Recker, 1994; Renkl, 1997). In other words, accurate metacognition was a necessary precursor to taking remedial action.

This work has led to a number of efforts, both in the classroom and within computer-based tutoring systems, to understand and train metacognitive skills such as self-explanation (e.g., Bielaczyc, Pirolli & Brown, 1995; Chi, de Leeuw, Chiu & LaVancher, 1994; Conati & Van Lehn, 2000; Renkl, Stark, Gruber & Mandl, 1998). Robust findings include the fact that many students do not spontaneously self-explain, but that they can learn this skill and will benefit from this type of training.

Of course, studying a worked example independently is not the same task as working through lesson materials with a tutor. In the second environment, it is possible that conversational maxims, such as those proposed by Leech (1983), may inhibit certain types of verbal expression. Leech proposed that people attempt to follow six maxims when engaged in a conversation. The tact and generosity maxims involve putting the interests and benefits of the listener ahead of those of the speaker. The approbation maxim involves minimizing any criticism and maximizing praise for the listener, while the modesty maxim encourages the speaker to take the opposite position towards him- or herself. The agreement maxim suggests that people are more likely to express agreement than disagreement with their listeners. Finally, the sympathy maxim encourages expressing sympathy, rather than antipathy, towards the listener.

Consider these maxims within the context of a tutorial dialogue. Expressing confusion after a tutor attempts to explain a concept could be seen as a violation of the approbation maxim, as this confusion could be interpreted as a criticism of the tutor's ability to explain. Thus, even if a student is aware of being confused by something the tutor says, the student might not express that confusion freely. If this is true, then it will have implications for effective tutor strategies and it may have implications for the design of computer tutoring systems.

In the rest of the paper we present a study in which we analyzed transcripts to determine whether or not students expressed confusion equally often and with equal validity across both independent and communicative contexts.

Current Study

Data collection environment

A curriculum and learning environment were created to teach basic concepts in basic electricity and electronics. The four-hour curriculum covered the topics of complete and incomplete circuits, series and parallel configurations, voltage and fault detection in a series circuit with a multimeter.

A screenshot of the learning environment used to present this curriculum is shown in Figure 1. The screen was divided into three sections. The upper left-hand section contained the primary lesson material (including didactic text, exercises and discussion questions), which was presented in a slideshow fashion. The participants could scroll through this section at their own pace. The upper right-hand section was the circuit simulator, which allowed the participant to build and manipulate circuits to test their properties. The bottom section was the message window where the participants and tutor interacted by typing.

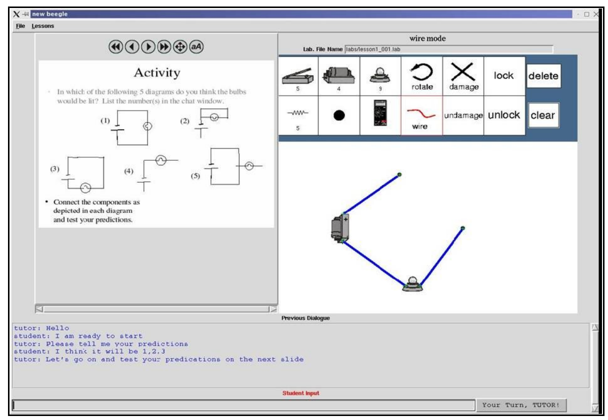

Figure 1: Participant screen.

The tutor and student were not co-located, however the tutor was able to watch everything that was happening in the student's environment, and gave feedback and whatever technical assistance and/or encouragement that he or she deemed appropriate through this same messaging interface.

While working through the curriculum, participants were instructed to direct all of their answers, comments and/or questions to the tutor. Many of the student metacognitive statements were made within the course of a multi-turn dialogue (often centered on a discussion question embedded in the lesson). However, there were times when the student was reading a slide or building, observing and measuring circuits in the workspace and spontaneously sent a metacognitive statement to the tutor, such as, "Oh! I see!" We refer to the first type as a metacognitive statement made within the context of a dialogue with the tutor, and the second type as a metacognitive statement made within the context of an independent activity.

Procedure

After completing informed consent paperwork, participants filled out a demographic questionnaire and took a 38 item multiple choice pre-test. They were introduced to the tutor and given a short demonstration of how to work in the learning environment. The majority of the experimental session was spent with the student working through the lesson material in the learning environment. At the end of the experiment, participants completed a 21 item multiple choice post-test and a reaction questionnaire. They were then debriefed and excused.

Corpus

The corpus includes dialogues from each of thirty participants distributed across three experienced tutors. The average age of the participants was 22.4 years (standard deviation = 5.0) and exactly half of them were male. The entire corpus includes 8,085 dialogue turns taken by the student and tutor, and 56,133 tokens (words and punctuation).

Coding

Two independent raters identified and coded the metacognitive statements made by the student and the tutor with very high reliability (kappa = 0.99). Metacognitive statements were defined as statements that contained the speaker's feeling about his or her understanding, but did not include domain content. Metacognitive statements were further classified as positive or negative. Positive metacognitive statements were defined as statements that expressed understanding (i.e. "I got it", "That makes sense", etc), whereas negative metacognitive statements expressed confusion (i.e. "I don't understand", "I am confused", etc).

Results

Overall, students made significantly more positive metacognitive statements (mean = 12.9, standard deviation = 8.3) than negative metacognitive statements (mean = 1.8, standard deviation = 2.0), paired $t(29) = 8.7$, $p < 0.05$.

The total number of metacognitive statements made across the entire dialogue was significantly negatively correlated to performance on the post-test ($r = -0.48$, $p < 0.01$). In addition, both the number of positive metacognitive statements and the number of negative metacognitive statements were significantly negatively correlated to performance on the post-test ($r = -0.46$, $p < 0.05$ and $r = -0.39$, $p < 0.05$, respectively).

As explained earlier, the metacognitive statements were divided into those made within the context of a dialogue with the tutor and those made spontaneously by the student as he or she conducted an independent activity.

Most of the metacognitive statements were made within during ongoing content-based dialogues with the tutor. Within this context, students made positive metacognitive statements (average = 10.9, standard deviation = 6.7) significantly more often than negative ones (average = 0.5, standard deviation = 0.78), paired $t(29) = 8.8$, $p < 0.01$. In addition, in this context, the number of positive metacognitive statements made per student was significantly negatively correlated with post test performance, $r = -0.51$, $p < 0.01$, however the number of negative metacognitive statements made was not correlated.

Considering the metacognitive statements that the students made within the context of conducting an independent activity, there was no statistically significant difference in the average number of positive and negative metacognitive statements made per student (average = 1.4, standard deviation = 1.8 and average = 1.3, standard deviation = 1.6, respectively).

In addition, in this context the number of negative metacognitive statements made per student was significantly negatively correlated with post test performance, $r = -0.41$, $p < 0.05$, however the number of positive metacognitive statements made was not.

Finally, the number of negative metacognitive statements spontaneously made by students during independent activities was not correlated with the number of metacognitive statements made within the context of the tutorial dialogue, however it was correlated with the number of positive metacognitive statements made during dialogue, $r = 0.63, p < 0.01$.

Discussion

Our results showed that, when working independently (reading lesson slides or completing an activity within the circuit simulation workspace), students were equally likely to spontaneously generate statements indicating confusion as they were to generate statements indicating comprehension. In addition, the statements indicating confusion appeared to be meaningful, as the more of these statements a student made, the lower that student scored on the post-test. This may seem to conflict with previous research, but a more likely (and unfortunate) explanation is that accurate metacognition is a necessary but not sufficient condition to yield effective learning, and our students may not have been able to resolve their confusions as well as we would have hoped.

In contrast, these same students rarely expressed confusion within the context of a dialogue with their tutor. In fact, the more often a student expressed confusion during an independent activity, the more often that student expressed comprehension during a dialogue.

It should be noted that this cannot be completely explained by pointing to the remedial dialogues that the tutor initiated after the students' statements of confusion, because of the large disparity in raw frequency counts. Recall that students only made an average of 1.3 negative metacognitive statements during independent activities, but made an average of 10.9 positive metacognitive statements during their dialogues with tutors.

These findings suggest that there is something fundamentally different between the context of working independently and interacting with a tutor. We propose that linguistic conventions, such as Leech's principles of politeness, may constrain a student's willingness to express confusion to a tutor.

It appears as if tutors should be suspicious of any student statements expressing comprehension made within a dialogue context and should probably rely on other means of assessing student comprehension. On the other hand, tutors may be able to take student statements of confusion made during independent activities seriously and initiative effective remedial strategies.

It is somewhat of an open question how faithfully results found with human tutors are generalizable to computer-based tutoring systems. An important next step, therefore, is to attempt to replicate these results with a computer-based tutoring system. However, should these results generalize, system developers will need to implement tutorial strategies that accommodate the unreliability of student metacognitive reports given within the context of the tutorial dialogue. For example, instead of asking if the student understands, tutors could ask content-based questions to gauge a student's comprehension. Of course, the data presented here do not speak to the effectiveness of this strategy, and research is also needed to determine the most effective pedagogical strategy.

While we have presented some data suggesting that conversational maxims are in competition with certain effective metacognitive learning skills within a tutorial dialogue context, there were several limitations to this study that must be taken into account. One issue is that only typed comments sent to the tutor were evaluated, and other indicators of confusion (for example, facial expressions) were not captured. In addition, the coding system applied to the transcripts only allowed a student turn to be coded as a pure metacognitive statement or a statement dealing with domain content. It is likely that some statements can serve both roles simultaneously. Our analyses were limited to those statements that were "pure" metacognitive and did not include any domain content.

In addition to overcoming these limitations, future research is necessary to determine the generalizability of this finding and appropriate strategies for overcoming this situation. Finally, this work only touched on a small portion of Leech's conversational maxims, and further explorations into how they may support or undermine the goals of a tutorial dialogue could be very instructive.

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