Do Tutors' Content Knowledge and Beliefs About Learning Influence Their Assessment of Tutees' Understanding?

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Abstract

Research has established that tutors often have difficulty with accurately assessing a tutee's understanding. However, it is a completely open question which characteristics of tutors might affect their assessment. In an empirical study with $N = 22$ tutor-tutee dyads, we used a methodology developed by Chi, Siler, and Jeong (2004) to examine the influence of the tutors' content knowledge and beliefs about learning on their assessment accuracy. Results replicated previous research in showing that tutors overestimated a tutee's correct understanding and underestimated a tutee's incorrect understanding. In addition, more accurate assessments were positively related with tutees' learning. Finally, content knowledge had a positive impact on assessment accuracy, whereas beliefs about learning were not strongly associated with assessment accuracy. Thus, assessing a tutee's understanding seems to be important for the effectiveness of human tutoring. Moreover, the results suggest that the tutors' assessment accuracy is largely influenced by their content knowledge.

Keywords: assessment accuracy; beliefs about learning; content knowledge; human tutoring

Introduction

In educational psychology, it is widely acknowledged that for learning to be effective instruction should be tailored to a learner (Kalyuga, 2007). However, such learner-tailored instruction makes it necessary to assess a learner's individual understanding. Therefore, the ability to collect diagnostically relevant information about a learner is a central component that constitutes teaching competence (Wittwer & Renkl, 2008).

One-to-one tutoring is a form of instruction where tutors can make intensive use of the possibility of freely interacting with a tutee in order to assess a tutee's understanding. Accordingly, tutors can be expected to have a detailed "model of the student" (Putnam, 1987). However, research has shown that tutors often have difficulty with gleaning diagnostically relevant information about a tutee. For example, Chi, Siler, and Jeong (2004) examined tutoring in biology and found that tutors appeared to be relatively accurate in knowing the tutees' correct understanding but they failed to assess the tutees' incorrect understanding including their false beliefs and flawed mental models. The researchers interpreted this finding as evidence that tutors mainly used their own normative perspective as a basis for estimating what the tutees did and did not know. Similar findings were obtained by Graesser, Person, and Magliano (1995), who showed that tutors rarely diagnosed a tutee's incorrect understanding. Instead, their actions were largely based on a curriculum script that determined which skills and concepts were to be learned by the tutees (see also Putnam, 1987).

In light of these findings, the question arises as to what influences the tutors' assessment of a tutee's understanding. In this article, we shed light on two characteristics of tutors that might impact their assessment of tutees. Specifically, we look at the tutors' content knowledge and beliefs about learning. To theoretically elucidate the role of these tutor characteristics, we draw on research in the field of human tutoring and classroom teaching.

Tutors' Content Knowledge

There is widespread agreement that having a deep understanding of a subject matter is an important condition for effective teaching. Research has shown that teachers with higher content knowledge show, for example, a greater understanding of important concepts in a domain and of the relationships among them (e.g., Borko & Putnam, 1996).

However, the question as to how content knowledge specifically affects the assessment of learners in the process of teaching has not been the object of much research (cf. Baumert & Kunter, 2006). For example, Krauss et al. (2008) found that teachers with higher content knowledge tended to

have more knowledge about a learner's misconceptions. The influence of this knowledge on the teachers' practices in classroom, including their assessment of the learners, was, however, not examined.

Similarly, in the context of tutoring, little is known about the relationship between the tutors' content knowledge and their assessment of tutees. For example, Schmidt et al. (1993) found that tutors with higher content knowledge were generally more effective in promoting tutees' learning when compared to tutors with lower content knowledge. The researchers attributed this finding to the fact that tutors with more content knowledge engaged in content-related activities that helped tutees to acquire knowledge. Even so, the role of the tutors' assessment practices for the tutees' learning was not investigated in this study.

Overall, the findings suggest that tutors with higher content knowledge might assess a tutee's individual understanding more accurately than tutors with lower content knowledge. This is assumed to be because tutors with more content knowledge normally have a deeper understanding of the concepts to be learned by a tutee (Borko & Putnam, 1996). Accordingly, tutors can be expected to show a more differentiated understanding of a tutee's conceptual knowledge (Nickerson, 1999). For example, tutors with higher content knowledge might be more likely to think at a deeper level about the conceptual aspects of a tutee's comprehension difficulties (Chi, Feltovich, & Glaser, 1981). Similarly, tutors with higher content knowledge might more likely infer from a tutee's particular misunderstanding which related mis-understandings and misconceptions can occur (Person et al., 1994).

Tutors' Beliefs About Learning

Apart from the teachers' content knowledge, their beliefs about how learners learn might also influence their teaching (Borko & Putnam, 1996). These beliefs can be roughly divided into two different views of learning: a transmission view of learning and a constructivist view of learning. A transmission view of learning focuses on the contents to-be-learned and emphasizes the role of transmitting knowledge to the learner. In contrast, a constructivist view of learning places a learner's own knowledge-construction activities at the center of instruction and emphasizes the role of supporting a learner's learning.

Research has provided evidence that such beliefs have an impact on teaching and learning. For example, Staub and Stern (2002) found that teachers with a constructivist view of learning were more successful in enhancing a learner's problem solving. In addition, Dubberke et al. (2008) showed that the teachers' beliefs strongly guided their teaching practices. For example, teachers with a transmission view of learning less often engaged in activities to support the learners' knowledge acquisition than teachers with a constructivist view of learning.

Despite these findings, there is also research showing that the teachers' beliefs are not necessarily associated with their pedagogical activities observed in classroom (e.g., Leuchter et al., 2006). It can be assumed that this is because teachers might not be completely accurate in self-assessing their beliefs about learning. Another explanation is that the teachers' beliefs might be too distal to strongly shape their teaching practices.

In the context of tutoring, it is a completely open question as to how the tutors' beliefs about learning influence their assessment of tutees. In line with the findings obtained in research on classroom teaching, it can be assumed that a constructivist view of learning supports the accuracy with which tutors assess a tutee's understanding. This is because tutors with a constructivist view of learning as opposed to tutors with a transmission view of learning see tutees as being actively involved in learning. Thus, it is supposed that tutors with a constructivist view of learning provide tutees with opportunities to be active and constructive on their own. As a result, the tutors should get insights into the tutees' understanding and learning progress during the course of tutoring.

Research Questions

We present an empirical study in which we examined human tutoring in biology to shed light on the role of the tutors' content knowledge and beliefs about learning in assessing a tutee's conceptual understanding. We addressed the following research questions:

1) How accurately do tutors assess a tutee's correct understanding and a tutee's incorrect understanding?
2) Is the tutors' assessment accuracy positively associated with the tutees' learning?
3) Does the tutors' content knowledge positively influence their assessment accuracy?
4) Does the tutors' orientation towards a constructivist view of learning positively influence their assessment accuracy?

Method

Sample and Design

A total of $N = 22$ dyads of tutors and tutees participated in the empirical study. Tutors were university students of biology. Of the tutors, 18 were female and 4 were male. Their mean age was 22.64 years ($SD = 2.79$). Tutees were K-7 students from Realschulen (i.e., schools from the middle track of the German school system). Of the tutees, 9 were female and 13 were male. Their mean age was 12.64 years ($SD = 0.49$). The tutors and the tutees did not know each other before tutoring.

We examined the accuracy with which the tutors assessed a tutee's individual understanding. We also analyzed the impact of their assessment accuracy on tutees' learning. Finally, we investigated the influence of the tutors' content knowledge and beliefs about learning on their accuracy at assessing a tutee's individual understanding.

Materials

Textbook (Tutee and Tutor) In the tutoring session, the tutor and the tutee engaged in a dialogue on the basis of a passage about the human circulatory system, which was previously used by Chi et al. (2001). We adapted this passage for the present study by deleting and reformulating some sentences. Each of the remaining 59 sentences of the passage was printed on a separate sheet of paper. The sentences were presented to the tutor and the tutee in a ring binder.

Content Knowledge Test (Tutor) The test consisted of 18 multiple-choice items. Each correct answer was assigned 1 point. The test measured not only the tutors' knowledge about basic concepts to be discussed in tutoring, but also their knowledge about advanced concepts of the human circulatory system, about the relationships among these concepts, and about the relevance of these concepts for life processes. Hence, answering the test required different levels of knowledge. Accordingly, item difficulty ranged from .41 to .95 (M = .64, SD = .16).

Beliefs About Learning Questionnaire (Tutor) The questionnaire was adapted from Staub and Stern (2002). On a 4-point Likert scale ranging from 1 (= *strongly disagree*) to 4 (= *strongly agree*), the tutors indicated their agreement with 19 statements. Agreement with 9 out of the 19 statements indicated a constructivist view of learning. The agreement with the remaining 10 statements indicated a transmission view of learning. The statements indicating a transmission view of learning were reversed so that the mean agreement with a constructivist view of learning could be computed, with higher scores showing a more constructivist view of learning.

Misconceptions Test (Tutee and Tutor) The test consisted of 25 multiple-choice items that addressed concepts about the human circulatory system at the local level of propositions (cf. Chi et al., 2004). The items were adapted from tests originally developed by Sungur and Tekkaya (2003) and by Michael et al. (2002) or constructed on the basis of the literature on misconceptions of the human circulatory system (e.g., Pelaez et al., 2005). The items covered concepts about the human circulatory system that were explicitly or implicitly mentioned in the textbook. A correct answer indicated a scientifically correct understanding of the concept. Each of the incorrect answers indicated a specific type of incorrect understanding of the concept.

Drawings of the Human Circulatory System (Tutee and Tutor) On a sheet of paper, the outline of a human body was displayed. The tutees were asked to draw the blood path of the circulatory system into the human body and to explain the blood path. The explanations were audiotaped. By using this methodology, which was originally developed by Chi et al. (2004), we assessed a tutee's conceptual understanding at the global level of mental models.

To code the tutees' and the tutors' drawings and explanations of the human circulatory system, we adapted a classification scheme originally developed by Azevedo, Cromley, and Seibert (2004). On the basis of this classification scheme, the drawings were assigned to one of twelve categories. The categories reflect distinguishable types of correct and incorrect mental models with categories 0 to 9 indicating different types of incorrect mental models and with categories 10 to 11 indicating a correct mental model.

Procedure

Each tutoring session was divided into three phases: pre-test phase, tutoring phase, and post-test phase. It lasted about 3 hours.

Pre-Test Phase In the pre-test phase, the tutors completed the content knowledge test. The tutees completed the misconceptions test. In addition, the tutees were asked to draw the blood path of the human circulatory system in the outline of a human body and to explain the blood path as they knew it. Afterwards, both the tutors and the tutees individually read the passage about the human circulatory system.

Tutoring Phase The dyads of tutors and tutees read each sentence of the passage about the human circulatory system and engaged in a dialogue about each sentence. After the 33th sentence, tutoring was interrupted and the dyads were separated. The tutees were asked to draw and explain the blood path of the human circulatory system. To measure what the tutors thought that the tutees would know about the blood path, the tutors were required to draw and explain the tutees' mental model of the human circulatory system. After accomplishing this task, tutoring was continued.

Post-Test Phase After completing the tutorial dialogue, the dyads of tutors and tutees were separated again and asked to draw and explain the blood path of the human circulatory system. Afterwards, the tutees completed the misconceptions test. The tutors also received the 25 items of the misconceptions test and were asked to indicate how the tutee would answer each of the items. Finally, the tutors filled in the beliefs about learning questionnaire.

Results

The following results concerning the tutors' assessment accuracy and the tutees' learning are based on the data collected in the post-test phase.

Tutors' Assessment Accuracy

In a first step, we examined the accuracy with which the tutors assessed what the tutees did and did not know at the level of propositions (i.e., misconceptions test) and at the

level of mental models (i.e., drawings of the circulatory system).

Misconceptions Test On average, the tutees had a correct understanding of 49% (*SD* = 11%) of the concepts and an incorrect understanding of 43% (*SD* = 13%) of the concepts[1].

Generally, the tutors assumed tutees to have a correct understanding of 58% (*SD* = 12%) of the concepts and to have an incorrect understanding of 26% (*SD* = 5%) of the concepts. Hence, the tutors significantly overestimated the tutees' correct understanding of the concepts, $t(21) = -2.43$, $p = .02$, $\eta^2 = .22$ (strong effect), and significantly underestimated the tutees' incorrect understanding of the concepts, $t(21) = 6.10$, $p = .01$, $\eta^2 = .64$ (strong effect).

When we specifically looked at whether the tutors knew how the tutees would answer each of the items of the misconceptions test, we found that the tutors knew the tutees' precise answers for 43% (*SD* = 11%) of all items.

Drawings Of the tutees, 64% drew and explained an incorrect mental model, whereas 36% drew and explained a correct mental model.

The tutors assumed the tutees to have an incorrect mental model in 18% of all cases and assumed the tutees to have a correct mental model in 82% of all cases. Thus, the tutors tended to assume the tutees to have more often a correct mental model than the tutees actually had and to have less often an incorrect mental model than the tutees actually had, $\chi^2(1, N = 22) = 2.79$, $p = .09$, $\varphi = .36$ (medium effect).

When we further looked at the categories into which the drawings of the tutees and the tutors fell, we found that, on average, the tutees' mental models were assigned to category 7 (*M* = 7.36, *SD* = 3.19). The tutors' drawings of the tutees' mental models were, on average, assigned to category 10 (*M* = 10.27, *SD* = 0.88). The difference between the average category of the tutees' mental models and the average category of the tutors' drawings of the tutees' mental models (*M* = -2.91, *SD* = 3.25) was significant, $t(21) = -4.20$, $p = .01$, $\eta^2 = .46$ (strong effect). Hence, the tutors largely overestimated the tutees' understanding at the level of mental models.

Tutors' Assessment Accuracy and Tutees' Learning

In a next step, we examined the importance of the tutors' assessment accuracy for the tutees' learning. To do so, we computed the correlation between the tutors' assessment accuracy at the level of propositions and the tutees' understanding at the level of mental models. The correlation was significant, $r = .59$, $p = .01$. Hence, the tutors' assessment accuracy was substantially associated with tutees' learning.

[1]To reduce the probability of guessing the correct answer in the misconceptions test, the tutees were asked to check the option "don't know" in case of uncertainty. Thus, correct and incorrect answers do not add up to 100%.

Tutors' Content Knowledge, Beliefs About Learning, and Assessment Accuracy

In a last step, we determined the relation between the tutors' content knowledge and beliefs about learning on the one hand and their assessment accuracy on the other hand. To measure the assessment accuracy at the level of propositions, we used the number of answers that the tutors correctly assumed the tutees to give to each of the items of the misconceptions test. To measure the assessment accuracy at the level of mental models, we used the difference between the category number of a tutee's mental model and the category number of a tutor's drawing of the tutee's mental model. Content knowledge and beliefs about learning were not significantly related with each other, $r = .25$, $p = .26$.

Content Knowledge In the content knowledge test, the tutors answered, on average, 64% (*SD* = 21%) of the items correctly. The number of correctly answered items was positively and significantly correlated with the accuracy with which the tutors assessed the tutees' understanding at the level of propositions, $r = .47$, $p = .03$. It was also positively and significantly correlated with the accuracy with which the tutors assessed the tutees' understanding at the level of mental models, $r = .48$, $p = .02$. Hence, the tutors with higher content knowledge were clearly more accurate in assessing the tutees' understanding.

Beliefs About Learning When answering the beliefs about learning questionnaire, the tutors achieved a mean score of 2.76 points (*SD* = 0.44). Hence, the tutors, on average, tended to show a constructivist view of learning. The correlation between the tutors' beliefs about learning and their accuracy at assessing what tutees knew at the level of propositions just failed to reach the 10%-level of statistical significance, $r = .35$, $p = .11$. The correlation between the tutors' beliefs about learning and their accuracy at assessing what tutees knew at the level of mental models was not significant, $r = .12$, $p = .59$. Obviously, the tutors' beliefs about learning were not generally associated with the accuracy with which the tutors assessed the tutees' understanding.

Discussion

The present study examined the accuracy with which tutors assessed a tutee's understanding of the human circulatory system. We found that the tutors significantly overestimated the tutees' correct understanding of important concepts related to the human circulatory system and significantly underestimated the tutees' incorrect understanding of these concepts. A similar pattern of results was obtained when we looked at the tutors' assessments of the tutees' mental models of the human circulatory system. Again, the tutors assumed the tutees to have a more complete understanding than they actually had. Overall, our findings replicate the results of Chi et al. (2004) and suggest that tutors seriously fail to take into account a tutee's alternative understanding.

As already discussed by Chi et al. (2004), tutors appear not to carefully assess what tutees do and do not know. Instead, they seem to exhibit a bias towards imputing their own normative perspective to the tutees (Hinds, 1999; Nickerson, 1999).

However, our results also show that the accuracy with which the tutors assessed a tutee's understanding largely depended on their content knowledge. In other words, tutors with more content knowledge were more accurate in assessing a tutee's conceptual understanding both at the level of propositions and at the level of mental models. It can be argued that this is likely to be because tutors with more content knowledge assess and categorize a tutee's understanding of concepts at a deeper level (Nickerson, 1999). This might allow the tutors to discriminate a tutee's understandings and misunderstandings more accurately (Chi et al., 1981).

In addition, we found that the tutors' beliefs about learning seemed to be less important for their assessment accuracy. This finding, however, has to be interpreted with caution. In our study, nearly all tutors showed an orientation towards a constructivist view of learning. Therefore, the variance of this tutor characteristic apparently was too small to yield any significant result.

Even though we observed differences in the accuracy with which the tutors assessed a tutee's understanding, we do not know yet which assessment strategies they used to collect diagnostically relevant information about a tutee. Prior research has already provided evidence for differences in tutorial actions between more experienced tutors and less experienced tutors. For example, Cromley and Azevedo (2005) found that more experienced tutors more often engaged in cognitive scaffolding. Less experienced tutors, in contrast, more often delivered information to the tutees. Following Chi et al. (2001), it is plausible to assume that these tutorial moves might help or hinder tutors in assessing what a tutee knows. For example, when asking questions (i.e., asking for information) instead of providing explanations (i.e., generating information on one's own), tutors might have more cognitive resources left for assessing a tutee's understanding (see also Wittwer, Nückles, & Renkl, 2010). Thus, to shed light on the question which moves of tutors positively and negatively influence their assessments of tutees, we are currently analyzing the tutoring protocols collected during the tutoring sessions.

Related to this is the question how the tutors in our study adjusted their tutorial moves on the basis of their assessments. Our results show that the tutors' assessment accuracy was positively associated with the tutees' learning. This suggests that the tutors might have used their assessments of what a tutee does and does not know in order to individualize instruction. It can be conjectured that the assessments, for example, influenced the tutors in deciding to move on to the next sentence of the textbook or to ask a question in order to elicit knowledge-construction activities from a tutee. Again, our content analysis of the tutoring protocols could clarify how the tutors adapted their moves to a tutee's specific understanding.

What are the implications of our study and what are the directions for future research? First, our findings suggest that it seems to matter who serves as tutor. Obviously, tutors with higher content knowledge can more accurately assess what a particular tutee does and does not know. As a result, these tutors acquire knowledge about a tutee's knowledge which they can use to support the tutee's learning[2]. Hence the concrete effectiveness of human tutoring might vary, amongst other things, as a function of tutor characteristics such as a tutor's content knowledge and tutoring experience (Cromley & Azevedo, 2005; though tutoring has generally been shown to be effective: Cohen, Kulik, & Kulik, 1982).

Second, our study seems to indicate that, in general, tutors with lower content knowledge have more difficulty with taking into account a tutee's particular understanding. At first glance, this finding might contradict the notion that peer tutors who normally do not possess considerably more knowledge than their tutees can also be responsive to their tutees' needs. However, such responsive behavior might not primarily result from the tutors' accurate assessments of the tutees' knowledge. Instead, it can be argued that tutors in peer tutoring share with their tutees a similar understanding of the learning task and, thus, might encounter the same comprehension difficulties. As a result of this common ground (Chi et al., 2004), the tutor and the tutee are more likely to "automatically" possess a mutual understanding. Hence, peer tutors might not be required to deliberately assess a tutee's understanding at all.

Third, our results show that, on average, the tutors largely overestimated a tutee's understanding. It was assumed that this finding can be attributed to the tutors' bias to impute their own normative perspective to the tutees. Although our study suggests that having more content knowledge reduces the risk of overestimating a tutee's understanding, there might be a trade-off between the tutors' content knowledge and their assessment accuracy under some circumstances. For example, Nathan and Petrosino (2003) found that pre-service teachers with higher content knowledge had problems with correctly estimating the difficulty of mathematical problems for learners. This was assumed to be a result of the pre-service teachers' discipline-specific perspective on the mathematical problems. Accordingly, it might well be that tutors who have, due to their high content knowledge, a more discipline-oriented view of the subject matter are particularly prone to an egocentric bias. In this case, it can be expected that tutors with such knowledge are less accurate instead of more accurate in assessing a tutee's understanding.

[2]In a mediation analysis, we found that the tutors' content knowledge influenced the tutees' learning. This effect was significantly mediated by the tutors' assessment accuracy.

Acknowledgments

We would like to thank our research assistants Julian Etzel, Tatjana Scharping, Anika Schoneville, and Raoul Zimmermann for their help with many practical aspects of the project. This research was supported by grants from the German Science Foundation DFG (WI 3348/2-1).

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