Experts' Explanations Engage Novices in Deep-Processing

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Abstract

Experts and intermediates fundamentally differ in the ways they explain subject matter to novices. Experts provide less details but in a highly coherent format, whereas intermediates provide many additional details but in a format with low coherency. In a recent study, we found that experts' explanations enabled novices to acquire more transferable and flexible knowledge as opposed to explanations by intermediates mainly due to the higher coherence of experts' explanations. In order to investigate more directly how experts' and intermediates' explanations differently triggered novices' processing of the explanations, we conducted a think-aloud study. Results indicated that novices learning with an expert's explanation processed the explanations deeper than novices with intermediates' explanations. In line with this, deep processing was significantly related to novices' transfer. Thus, expertise can be regarded as an essential prerequisite for generating effective instructional explanations that engage novices to process the subject matter deeply and to generate transferable knowledge.

Keywords: expertise; processing; instructional explanations; transfer.

Introduction

Experts and intermediate students fundamentally differ in the ways they explain subject matter to novices. Figure 1 shows two propositional representations, one intermediate student's explanation and one expert's explanation, taken from a study by Lachner, Gurlitt and Nückles (2012). These propositional representations about bacterial endocarditis, an inflammation of the heart valves, structurally differ in several important respects.

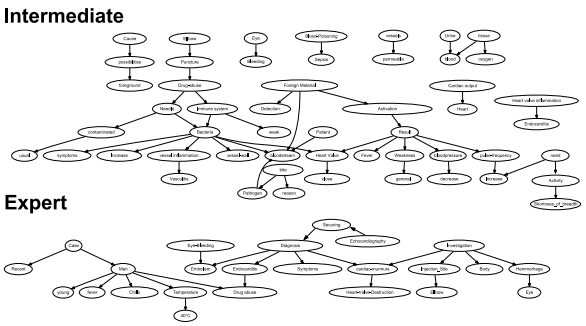

Figure 1: Graphical representation of an intermediate's explanation and an expert's explanation.

The typical expert's explanation consisted of only a few, mainly advanced, clinical concepts (N = 24). Beyond that, the expert's explanation was very coherent, as she related all explanatory concepts to each other, resulting in a single very coherent chunk of knowledge. In marked contrast, the typical intermediate's explanation provided many concepts (N = 52). Although there was one interrelated chunk about pathophysiological processes of bacterial endocarditis, the intermediate was less likely to relate basic pathophysiological concepts with advanced concepts, which resulted in many fragmented knowledge blocks (N = 8).

These two explanations nicely illustrate well-known differences between experts and intermediates. For instance, research on categorization shows that experts tend to organize their knowledge around abstract principles, which allows them to integrate their knowledge in a more coherent manner, whereas novices organize their knowledge around superficial features, which results in less coherent knowledge structures (Chi, Feltovich, & Glaser, 1981; Rottman, Gentner, & Goldwater, 2012).

In the same vein, in the medical domain, it has been shown that experts subsume basic medical concepts under advanced concepts, which results in very condensed schemata, whereas intermediates rather rely on detailed knowledge, as they have not yet acquired these advanced clinical principles. This subsumption process is also known as knowledge encapsulation (Boshuizen & Schmidt, 1992, Rikers, Schmidt, & Boshuizen, 2000; 2002).

Lachner et al. (2012) found that these effects for coherence and knowledge encapsulation also hold true for instructional explanations, specifically explanations written for novice medical students. Compared to intermediates, medical experts wrote more coherent and equally more encapsulated explanations, meaning that they omitted more details in their explanations. However, both intermediate students and experts used the same amount of advanced concepts. Apparently, experts adapted their choice of words, but not the way they would structure an explanation.

Learning from Instructional Explanations

As explanations by experts and intermediates fundamentally differed on the level of coherence and encapsulation, explanations by experts and intermediates might also affect student learning differently. For instance, Hinds, Patterson and Pfeffer (2001) investigated how the instructor's domain expertise affected novices' learning in the domain of electrical engineering. More specifically, they examined how novices studying an intermediate's explanation differed from novices studying an expert's explanation with regard to their performance on near transfer and far transfer tasks. Results indicated an interaction effect. Although novices

with an intermediate's explanations outperformed novices with an expert's explanation on near transfer tasks, there was a clear benefit for novices with experts' explanations on far transfer tasks. In a related study, Boekhout, van Gog, van de Wiel, Gerards-Last, and Geraets (2010) showed that worked examples constructed by experts led to larger benefits for novices in transfer tasks than worked examples constructed by intermediates. However, with regard to the acquisition of factual knowledge, novices with experts' worked examples did not differ from novices learning from intermediates' worked examples.

Beneficial Features of Instructional Explanations

Bridging findings from expertise research and tutoring research, Lachner and Nückles (2013) investigated which expertise-related textual features of explanations accounted for the better transfer of novices learning with experts' explanations. Specifically, they examined how coherence and encapsulation of the instructors' explanations, as coherence and encapsulation were selective indicators for expertise (Lachner et al., 2012; Rikers et al., 2002; Rottman et al., 2012), affected novices' learning outcomes. Similarly to Hinds et al. and Boekhout et al., Lachner and Nückles found that novices studying with experts' explanations significantly outperformed novices with intermediates' explanations on transfer tasks. At the same time, in line with Boekhout et al., they did not find a significant difference between experts' and intermediates' explanations regarding novices' factual knowledge.

More importantly, Lachner and Nückles (2013) conducted a mediation analysis to investigate whether encapsulation, as measured by the omission of detailed knowledge, or coherence, as measured by the number of isolated fragments (see Figure 1), accounted for novices' transfer. Results indicated that the degree of encapsulation had no effect on novices' transfer, whereas explanatory coherence clearly mediated the effect of instructors' expertise on novices' transfer. Therefore, the authors could show that it was the coherence of experts' explanations that enabled novices to transfer their acquired knowledge to other medical tasks.

Nevertheless, although the Lachner et al. study suggests that explanatory coherence fostered novices' transfer, they did not examine which learning processes were provoked by experts' versus intermediates' explanations that could explain the transfer effect.

Processing of Instructional Explanations

Bransford and Schwarz (1999) proclaimed that for flexible transfer, learning with "understanding" is necessary. Studies by Gilabert, Martinez and Vidal-Abarca (2005) and Linderholm et al. (2001) support this view, as they found that the high coherence of texts fostered students' active processing of the text material. As coherent explanations highlighted important causal relations between concepts, the coherence of explanations probably served as a valuable scaffold to engage students' processing.

Text processing can be regarded as the construction and integration of multiple independent representations of a text (Kintsch, 1988; Kintsch, 2004). First, learners construct a text base which contains the essential meaning of the text, mainly by translating the text into propositions, or in other words, by paraphrasing the text and by bridging inferences to connect information within the text (Kintsch, 1988). Second, learners construct a situation model by doing self-explanations to fill coherence gaps with their prior knowledge. Kintsch (2004) argued especially processing activities, that aim to enrich the situation model, are needed to develop a deep understanding.

In the study by Lachner and Nückles (2013), the mediating variable between instructors' expertise and novices' transfer was explanatory coherence. In the study described here, we examined whether the effect of expertise on novices' learning can be explained by novices' processing activities. In line with text comprehension research, (Gilabert et al., 2005; Linderholm et al., 2001), we assumed that experts' coherent explanations may better promote novices' deep processing and novices' acquisition of flexible knowledge compared to intermediates' less coherent explanations.

Research Questions and Hypotheses

To investigate novices' processing activities while learning with experts' and intermediates' explanations, we conducted a think-aloud study. The aims of our study were twofold. First, we wanted to replicate the findings by Lachner and Nückles (2013) that experts' explanations were better suited to foster novices' transfer compared to intermediates' explanations. Second, as we were interested in novices' processing activities, we examined how novices processed explanations by intermediates and experts using a think-aloud procedure.

Learning Hypotheses

In line with previous research (Boekhout et al., 2010; Hinds et al., 2001; Lachner & Nückles, 2013), we hypothesized that novices would benefit more from experts' explanations as opposed to intermediates' explanations in transfer tasks. Experts' coherent explanations would better enable novices to construct an appropriate situation model of bacterial endocarditis and thus enable them to transfer their knowledge of bacterial endocarditis to other tasks (Kintsch, 2004).

For novices' factual knowledge gain, we refrained from making clear predictions, as Boekhout et al. (2010) and Lachner and Nückles (2013) did not find any significant differences between explanations by experts and intermediates. As coherence mainly accounted for the construction of a rich situation model and not for the generation of an adequate text base (Gilabert et al., 2005; Kintsch, 2004), novices with intermediates' explanations could perform just as well in a factual knowledge test as those with experts' explanations.

Processing Hypotheses

As suggested by research on text comprehension (Gilabert et al., 2005; Linderholm et al., 2001), we assumed that experts' coherent explanations would encourage novices' deep processing compared to intermediates' explanations. Therefore, we expected that novices with experts' explanations would outperform novices with intermediates' explanations with regard to the proportion of bridging inferences and self-explanations, whereas intermediates' explanations would trigger novices' paraphrasing. For negative monitoring, we refrained from making clear predictions, as the fewer details in experts' explanations could trigger novices' monitoring, as well as the lack of coherence of intermediates' explanations.

Beyond that, as Kintsch (2004) suggested, we assumed that novices' transfer was significantly related to novices' deep processing.

Method

Participants

Sixty-eight novices from the University of Freiburg, Germany participated in the study. They were recruited from medicine (45 students) and biology programs (23 students). 70.60 % were female; their mean age was 20.25 (*SD* = 1.87). Participants were on average in their first semester (*SD* = 1.24) and had not yet attended any courses in cardiology. Participants were financially compensated with 10 Euro for their participation.

Design

Novices were randomly assigned to one of four explanations about bacterial endocarditis, an infection of the heart valves (two experts' explanations and two intermediates' explanations). We used a pretest-posttest design with type of explanations, that is, experts' explanations or intermediates' explanations, as independent variables. There were two classes of dependent variables: We analyzed novices' learning outcomes with both a factual knowledge test that measured novices' knowledge about central concepts and interdependencies of bacterial endocarditis, and with a transfer test that required the participants to apply their acquired knowledge of bacterial endocarditis to other medical phenomena. Additionally, we collected novices' processing activities by means of think-aloud-protocols (i.e. paraphrasing, bridging inferences, self-explanations, and negative monitoring) while studying the explanations.

Materials

Case description

We provided the participants with a general case description of a fictitious patient suffering from bacterial endocarditis. It included central findings of laboratory data, and descriptions of symptoms. The case description had been used in previous classical studies on the nature of expertise, as bacterial endocarditis can be regarded as a prototypical heart disease that requires deep-level knowledge about embolisms, the structure of the heart, and the circulatory system (Boshuizen & Schmidt, 1992).

Explanations

We selected two experts' explanations and two intermediates' explanations from a recent study by Lachner et al. (2012). We selected the explanations according to their degree of coherence, which can be regarded as the number of fragments in the explanation (see Figure 1). We chose the explanations of the two experts with the smallest number of fragments (Expert A: 1 fragment; Expert B: 3 fragments) and those of the two intermediates with the highest number of fragments (Intermediate A: 8 fragments; Intermediate B: 8 fragments).

In the Lachner et al. study, this structural feature of explanations mediated the effect of the instructors' expertise with regard to novices' transfer. The experts in that study were cardiologists who had at least 15 years of working experience. Intermediates were medical students in their fifth year of studying. The explanations were 157 words (*SD* = 36.03) long on average. The explanations pointed out the biomedical processes and causes of bacterial endocarditis, and how the symptoms mentioned in the case description could be related to the underlying biomedical processes.

Factual knowledge test

A factual knowledge test was used as pre- and posttest and measured novices' conceptual understanding of bacterial endocarditis. It consisted of nine multiple choice items with four answer possibilities and one correct solution (e.g. "What is the reason for the diastolic in cases of endocarditis?"). Participants received one point for each correct answer, yielding a total possible score of nine points.

Transfer test

To measure novices' transfer, we constructed two complex questions that required novices to transfer their acquired knowledge of bacterial endocarditis to other complex medical phenomena ("Why can endocarditis result in a cardiogenic shock?", "Can endocarditis be the cause of a stroke?"). First, participants' written answers to these questions were segmented into individual statements and then compared to reference answers constructed by a medical expert. A scorer who was blind to the participants' treatment condition used a strict manual in which participants received 0.5 points for each unit of the reference answer. For each task, participants could obtain 4.5 points, which resulted in a maximum score of 9 points for both answers.

Procedure

Participants were tested individually in a quiet room. They were randomly assigned to one of the four explanations. An experimental session lasted 60 minutes. During the experimental session, participants were not allowed to proceed before being signaled by the experimenter (exact time on task). First, participants answered the pretest (10 minutes). Then, in the learning phase, they received the case description and one of the randomly assigned explanations

(25 minutes). Participants were instructed to think aloud while they studied the explanation. If participants did not think aloud for more than 5 seconds, the experimenter prompted them to continue talking. In the post-test phase, participants answered the factual knowledge test (10 minutes) and accomplished the two transfer tasks (15 minutes).

Analyses and coding

For the analyses of novices' learning processes, their think aloud protocols were transcribed and segmented into idea units. Based on Chi (2000), each idea unit was categorized as paraphrasing, bridging inferences, self-explanation, and negative monitoring (see Table 1). Thirty percent of the protocols were co-rated by a second rater. In assigning verbalizations to categories, inter-rater agreement was very good (κ = .88). Thus, only one rater coded the rest of the protocols.

Table 1: Categories to rate the think-aloud protocols.

Category	Description
Paraphrase	Novice simply restated or paraphrased a text segment from the explanation.
Bridging inferences	Novice relates different text passages of the explanation to better understand relations between sentences.
Self-Explanations	Novice connects new information with prior knowledge by self-explaining. Indicators are the generation of examples or making predictions.
Negative monitoring	Novice utters his /her non-comprehension

Results

We used an alpha level of .05 for all statistical analyses. As an effect size measure, we used partial η^2 qualifying values < .06 as small effect, values in the range between .06 and .14 as medium effect, and values > .14 as large effect (see Cohen, 1988).

A series of ANOVAs and χ^2 tests revealed no significant differences between the experimental conditions concerning age, $F(1, 66) = 1.22$, $p = .27$; gender, $\chi^2(1) = 2.50$, $p = .11$; study programs, $\chi^2(1) = .59$, $p = .44$; prior knowledge, $F(1, 66) = 1.16$, $p = .29$, and the number of processing activities, $F(1, 66) = .84$, $p = .36$.

Learning Hypotheses

Table 2 provides an overview of the means and standard deviations for the factual knowledge and the transfer test. To investigate differences in factual knowledge between novices who learned with an intermediate's explanation and novices learning with an expert's explanation, we performed an ANCOVA with type of explanation as a fixed factor, novices' posttest scores as dependent variable and novices' prior knowledge as a covariate. There was no significant difference for type of explanation regarding novices' factual knowledge, $F(1, 65) = 1.90$, $p = .17$, $\eta^2 = .03$. Thus, we could replicate the results from Lachner and Nückles (2013) that novices benefited from intermediates' and experts' explanations to a similar extent.

With regard to the transfer hypothesis, we found that novices learning with an expert's explanation significantly outperformed novices learning with an intermediate's explanation on the transfer tasks, $F(1, 65) = 15.56$, $p = .00$, $\eta^2 = .19$. Thus, as in the study by Lachner and Nückles, experts' explanations better supported novices in solving transfer tasks as opposed to intermediates' explanations.

Table 2: Means and standard deviations (in parentheses) for the learning outcome measures.

Dependent variable	Novices with Intermediates' Explanations	Novices with Experts' Explanations
Prior knowledge	3.29 (1.34)	3.71 (1.78)
Factual knowledge	4.18 (1.73)	4.76 (1.30)
Transfer	3.63 (1.78)	5.44 (1.84)

Processing Hypotheses

Table 3 shows the mean proportions and standard deviations of novices' processing activities. With regard to our processing hypothesis, we conducted a MANCOVA with type of processing activities (paraphrase, bridging inferences, self-explanations and negative monitoring) as dependent variables, type of explanation as independent variable and novices' prior knowledge as covariate. The MANCOVA revealed a significant effect for type of explanation, $F(3, 63) = 3.25$, $p = .03$, $\eta^2 = .13$. Separate ANCOVAS showed that this effect was specifically due to the differences in the proportions of paraphrasing and self-explanations (see Table 3).

Table 3: Mean proportions and standard deviations (in parentheses) of novices' processing activities

	Explanations by				
	Intermediate	Expert	F^a	p	η^2
Paraphrases	.51 (.24)	.33 (.22)	9.65	.00	.13
Bridging inferences	.22 (.12)	.24 (.17)	0.25	.62	.00
Self-Explanations	.11 (.11)	.20 (.22)	4.79	.03	.07
Negative monitoring	.16 (.15)	.22 (.21)	2.17	.15	.03

[a] $df = 1, 65$

As expected, novices learning with intermediates' explanations used more shallow processing strategies directed at the construction of the text base (i.e. paraphrasing a text segment) as compared with novices' learning with experts' explanations. In contrast, regarding the proportion of self-explanations, novices learning with experts' explanations used more deep-level processing strategies (i.e. self-explanations) as opposed to novices learning with intermediates' explanations.

However, there was no difference for type of explanation regarding the proportion of bridging inferences. Thus, novices used the same amount of bridging inferences to establish coherence within their text base regardless of which type of explanation they received. Additionally, we did not find any significant differences for type of explanation regarding negative monitoring, which suggests that intermediates' and experts' explanations entailed comprehension problems to a similar extent.

To test whether novices' transfer was associated with the proportion of novices' deep processing of the explanations, we computed a Pearson's correlation. To obtain a single score for deep-processing of the explanations, we computed the proportion of deep processing learning activities (i.e. bridging inferences and self-explanations) that aimed at constructing a sufficient situation model for each participant. This was appropriate because the different values were significantly inter-correlated, $r(68) = .53$, $p = .00$. Novices' deep processing activities were significantly correlated with novices' performance on transfer tasks, $r(68) = .30$, $p = .01$. Evidently, novices' deep processing led novices to better transfer their knowledge to other tasks.

Discussion

The main goal of the present study was to investigate how experts' and intermediates' explanations differently affected novices' processing and novices' learning outcomes.

For novices' performance on transfer tasks, we could replicate findings of previous studies (Boekhout et al., 2010; Hinds et al., 2001; Lachner & Nückles, 2013) that experts' explanations more effectively enabled novices to transfer their knowledge acquired from the explanations to other related medical phenomena. Similar to findings by Boekhout et al. and Lachner and Nückles, we did not find any significant differences between experts' and intermediates' explanations regarding novices' factual knowledge gain. Apparently, intermediates' and experts' explanations were comparably appropriate to establish a solid text base. However, it must be noted that the average factual knowledge gain was rather low (see Table 2), which can be mainly attributed to the brief text length of our instructional explanations.

With regard to novices' processing of the explanations, we can conclude that experts' explanations engaged novices in a deeper processing of the explanations as opposed to explanations generated by intermediates. Novices with experts' explanations made significantly more self-explanations and less paraphrasing compared to novices with intermediates' explanations. However, in contrast to our assumptions, we did not find any differences for the proportions of bridging inferences and negative monitoring. Apparently, experts' omissions in their explanations and the lack of coherence in intermediates' explanations may have balanced each other out and therefore resulted in a trade-off in the novices' bridging inferences and negative monitoring.

Beyond that, we could show that novices' performance on transfer tasks was significantly related to novices' deep processing. Apparently, intermediates' less coherent explanations triggered shallow processing activities that solely aimed at the construction of a solid text base. In contrast, experts' explanations mainly triggered novices' deep processing, which resulted in the construction of a better situation model and a better performance on the transfer test. As intermediates primarily relied on shallow processing, they probably constructed a less coherent and therefore less effective situation model that resulted in a lower performance on the transfer tasks (Kintsch, 2004). However, there was only a moderate correlation between novices' transfer and deep-processing activities. However, think-aloud protocols are less reliable to measure unconscious comprehension processes (Graesser et al., 1997). Therefore, in subsequent studies, behavioral measures should be included as a complementary measure to tap implicit processes of comprehension more directly (Holmqvist et al., 2011; Kaakinen & Hyona, 2005).

What are the broader theoretical implications of our research? First, although research on the expert-blind spot (Hinds, 1999; Nathan & Koedinger, 2000) suggests that experts sometimes have difficulties in taking a novice's perspective, their instructional explanations nevertheless effectively support novice students in acquiring deep and flexible knowledge due to the superior coherence of their explanations. Compared to intermediates, experts produce explanations that highlight central principles of the subject matter in a very coherent manner. This supports novices in processing the explanations deeply in order to establish coherent and flexible representations of the subject domain.

Second, we could show that the effect of coherence on novices' deep-processing and on novices' transfer performance also holds true in more naturalistic settings, such as in giving explanations. In our study, we used real instructional explanations by experts and intermediates, instead of constructing highly coherent vs. low-coherent explanations (e.g. Ainsworth & Burcham, 2007; Gilabert et al., 2005; Linderholm et al., 2001). Despite the promising results of our study, there are also some limitations and open questions. One limitation of this experiment is the use of only one phenomenon of cardiology, namely bacterial endocarditis, which possibly restricts the generalizability of our experiment. However, bacterial endocarditis can be regarded as a classic disease, which requires fundamental knowledge about the circulatory system, the structure of the heart, and embolisms. In a similar vein, future studies should investigate whether the effect of the higher

coherence of experts' explanations on novices' processing and transfer also holds true for other subject-domains.

Overall, the present study shows that experts' explanations are an effective means to foster novices' deep processing of complex contents. Due to their high-coherence, experts' explanations prompt novices to process the explanations deeply by focusing on central principles, which results in more flexible knowledge structures and subsequently in a better transfer of knowledge to other tasks. In doing so, experts' explanations can be considered as a valuable scaffold for engaging novices in deep processing and in a meaningful construction of knowledge.

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