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ABSTRACT

The effectiveness of cooperative learning arrangements is often attributed to the fact that the learners are not only "passive" recipients but also "active" explainers. To test this assumption experimentally explaining and listening were compared with respect to motivation and learning results. Forty first-year college students, grouped in pairs, learned probability calculations from worked-out examples. After an individual phase of learning, each member of a dyad took the role of explainer or listener. The role of the listener was more favorable with respect to both motivation and learning results. A second experiment tested whether learning by explaining was a poor result in the first experiment because the conditions favored listening, and not because explaining was so ineffective. An additional group of 10 dyads (20 learners) learned in unstructured cooperation. Both listening and unstructured cooperation were preferable to explaining. Findings suggest that the positive effects of explaining are overestimated in present research on cooperative learning. Future studies should attempt to determine the precise conditions under which explaining in cooperative arrangements leads to favorable outcomes. (Contains 5 tables, 2 figures, and 15 references.) (SLD)

Learning by explaining - or better by listening?

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Abstract

The effectiveness of cooperative learning arrangements is often attributed to the fact that the learners are not only "passive" recipients, as is typical of traditional forms of learning, but also "active" explainers. In order to experimentally test this assmuption explaining vs. listening was compared with respect to motivation and to learning results in an experiment 1. Forty first-year university students of education learned probability calculation from worked-out examples. They were grouped together in pairs (20 dyads). After an individual phase of learning, the two learners of each dyad were brought together and took over the role of the explainer or the listener, respectively. It turned out that the role of the listener was more favorable with respect to both motivation and learning results. Experiment 2 tested whether learning by explaining came off badly in experiment 1 because listening was a very favorable mode of learning in this context and not because learning by explaining was so ineffective. For this purpose, an additional group of 10 dyads (20 learners) was studied. These subjects learned in unstructured cooperation. It turned out that not only listening, but also unstructured cooperation was preferable to explaining. These findings indicate that the (positive) effects of explaining are presently overestimated in research on cooperative learning. Future studies should aim to determine the precise boundary conditions under which explaining in cooperative arrangements leads to favorable outcomes.

LEARNING BY EXPLAINING - OR BETTER BY LISTENING?

The effectiveness of cooperative learning arrangements is often attributed to the fact that the learners are not only "passive" recipients, as is typical of traditional forms of learning, but also "active" explainers. It is supposed that the demand to explain to somebody else "urges" the explainer to clarify, to organize, and, in some cases, even to reorganize the material. In clarifying and (re-)organizing the material, the explainer may discover gaps or inconsistencies in his or her understanding. That means that explaining can foster elaborative and metacognitive mental activities that usually enhance learning.

One type of evidence for these assumptions is provided by the research program of Webb and colleagues (cf. Webb, 1991). In a series of studies on relevant processes during cooperative learning, it has been shown that students who give many (elaborated) explanations obtain the highest learning gains. However, this evidence is equivocal. It cannot be ruled out that the ability to give explanations is an indicator of effective and efficient learning. For this reason, it is important to have a look at the experimental studies on the effects of giving explanations.

In several experiments, explainers and listeners (or persons who studied merely individually) were compared with respect to the amount they learned from a text. It turned out that the explainers learned more, at least when "high-level" criteria (e.g., main ideas in contrast to details) were employed to assess the learning outcomes (e.g., Lambiotte et al., 1988; Ross & DiVesta, 1976). In contrast, in experiments in which subjects learned by problem solving, no evidence for the effectiveness of learning by explaining was found (Bargh & Schul, 1980; Neber, 1995). Possibly, the effects of explaining depend on context conditions (e.g., learning criteria, learning mode). Empirical evidence on the effects of explaining when employing learning modes other than learning by text or by problem solving is not available. An additional restriction of previous experiments is the neglect of motivational factors that can be affected by an explanation demand and that, in turn, can affect learning results (for an exception see Ross & DiVesta, 1976). Hence, little is known about the interplay between explanation demand, motivation, and learning results.

The goal of an *Experiment 1* was to compare the effects of explaining and of listening with respect to motivation and learning outcomes in the context of learning from worked-out examples (domain: probability calculation). This learning mode was chosen because recent research has underlined the prominent role of learning from worked-out examples in initial skill acquisition (cf. VanLehn, 1996). In *Experiment 2* the outcomes of "free" (i.e., unstructured) cooperation were compared with learning in the roles of explainers or listeners respectively.

Experiment 1

The following specific research questions were addressed:

(1) Do explainers and listeners differ with respect to their learning results? Does this effect depend on the type of learning criterion (self-transfer, near transfer, far transfer)?

(2) Do explainers and listeners differ with respect to their motivation during learning (anxiety and intrinsic motivation)?

(3) To what extent are learning results associated with anxiety and intrinsic motivation?

Method

Sample, design, and procedure

Forty first-year university students of education voluntarily participated in this experiment. The subjects were grouped together in pairs (yoking procedure) and were randomly assigned to the role of an explainer or a listener respectively. The explainers had to explain the solutions of worked-out examples from the domain of probability calculation to the listeners.

Except for the phase of explaining and listening, the learners worked in individual sessions. First, the subjects had to work on a pretest on probability calculation. Then, in order to provide or re-activate basic knowledge that allowed the subjects to understand the worked-out examples, an instructional text on basic principles of probability calculation was given to the subjects. The comprehension of these basic concepts was assessed by a criterion-referenced test that was evaluated immediately. If there was a wrong answer, the experimenter gave a semi-standardized explanation and had the subject re-read the corresponding text passage. After an individual phase of learning from

worked-out examples, one learner of the experimental group and one of the control group were brought together and they learned by explaining or listening respectively. After this social learning phase, they individually filled in questionnaires on intrinsic motivation and anxiety. Finally, the individual learning outcomes were assessed by a post-test.

Instruments und Materials

The following description of the instruments and the materials is ordered according to the chronological sequence of the experimental sessions.

Pretest. Nine relatively simple probability calculation problems were employed as a test of prior knowledge in probability calculation (e.g., "If you play the dice twice, what is the probability of two sixes?"). A reliability of .86. (Cronbach's Alpha) was determined for this test.

Instructional text and criterion-oriented test. The instructional text, which provided basic knowledge for the study of the worked-out examples, contained about 700 words (including formulas) and a diagram to illustrate the addition principle in probability calculation. The following principles were explained in a rather abstract manner: definition of probability, multiplication principle, addition principle, and principle of complementarity. The worked-out examples and the test items were based on these principles of probability calculation.

Worked-out examples: Individual learning phase. A computer monitor was used to display the worked-out examples. First, the problem givens were presented. Then the solution was displayed in a step-by-step manner (learner-paced procedure). The study time was fixed to 25 min. for all learners. In order to preclude the pitfall that the faster subjects acquired a *broader* knowledge base through the inspection of further examples with different underlying structures (i.e., solution principles), only four types of structures were used. Within the available time spans, which was fixed according to the results of previous studies (e.g., Renkl, in press), every subject processed the first four problems and thereby encountered each type of problem structure. Hence, the faster subjects were confronted with examples containing new surface features (i.e., new numbers, new objects), but not new structures.

Worked-out examples: Social learning phase. For the social learning phase, there were eleven worked-out examples, each on separate sheet of paper. The examples were given to the learners one after another. Learning time was fixed to 20 min. for all dyads. On the average, the pairs studied eight worked-out examples (*M*: 8.00; *SD*: 2.47). The underlying structures of the worked-out examples were identical for both learning phases.

Questionnaire on motivation. The questionnaire measured intrinsic motivation and anxiety during the social learning phase. The state scale of the STAI (*S*tate-*T*rait-*A*nxiety-*I*nventory; German version of Laux, Glanzmann, Schaffner & Spielberger, 1981) was employed to assess the learners' emotional tension. Seven other items tapped on content-related worry (e.g., "I worried whether I could understand the examples"). In addition, anxiety elicited by the social situation was assessed (partner-related worry) (e.g., "I worried whether the other will confuse me"). Intrinsic motivation was measured by a five item scale (e.g., "Studying the examples was fun"). All self-report scales were sufficiently reliable: emotional tension (STAI): .90 (Cronbachs Alpha); content-related worry: .65; partner-related worry: .75; intrinsic motivation: .69.

Post-test. The post-test that measured the learning results included 15 items. Three items were relatively simple problems similar to those in the pretest. The remaining 12 items, which addressed "understanding", were constructed according to the following categories (see Figure 1): known problems with irrelevant information inserted (self-transfer); isomorphic problems (near transfer); different underlying structure, similar surface features (far transfer).

Givens of a worked-out example In an aptitude test for aircraft pilots, 40% of the applicants do not pass the physical examination and 60% do not pass the psychological tests. 20% of the applicants fail because of the physical and the psychological examination. What is the probability that two randomly selected applicants fit the job?
Self-transfer: Same deep structure - similar surface structure - irrelevant information In an aptitude test for aircraft pilots, 40% of the applicants do not pass the physical examination and 60% do not pass the psychological tests. 20% of the applicants fail because of the physical and the psychological examination. 40% merely failed to pass the psychological tests. What is the probability that two randomly selected applicants fit the job?
Near transfer Same deep structure - different surface structure Production errors cause 15% of pencils to be of an incorrect length and 10% of the incorrect diameter. In 5% of the cases, both faults are present. If two pencils are randomly selected, what is the probability that neither has an error?
Far transfer: Different deep structure - similar surface structure In an aptitude test for aircraft pilots, 40% of the applicants do not pass the physical examination and 60% do not pass the psychological tests. 20% of the applicants fail because of the physical and the psychological examination. What is the probability that at least one out of two randomly selected applicants fits the job?

Figure 1
Example presented for learning and post-test variants

Results

Table 1
Explainers and Listeners: Means of the post-test scores (in brackets standard deviations)

Variable (theoretical max.)	Listening	Explaining	*t*-value[a] (*df*=19)	Correlation between partners	Effect size
Post-test total (30)	20.25 (6.58)	16.60 (5.88)	2.51 *	.46 *	0.56
Self-transfer (8)	5.90 (2.17)	5.55 (1.96)	0.66 *n.s.*	.35 *n.s.*	0.15
Near transfer (8)	4.85 (2.46)	3.25 (1.92)	2.63 *	.24 *n.s.*	0.59
Far transfer (8)	4.30 (2.13)	2.60 (2.04)	2.78 *	.14 *n.s.*	0.62

Note. * $p < .05$; [a] two-tailed *t*-test for dependent samples.

(1) *Do explainers and listeners differ with respect to their learning results?*

The listeners outperformed the explainers with respect to all post-test measures (Table 1). The statistically significant group differences had substantial effect sizes of about 0.6. The pattern of results remained unchanged, when adjusted post-test scores were used (residual scores controlling for prior knowledge: post-test as a whole: $t(19) = 2.97$, $p < .05$; self-transfer: $t(19) = 0.74$, *n.s.*; near transfer: $t(19) = 3.13, p < .05$; far transfer: $t(19) = 2.65, p < .05$).

(2) *Do explainers and listeners differ with respect to their motivation during learning?*

In comparison to the explainers, the listeners' motivation was more favorable with respect to all variables (Table 2). Whereas the corresponding differences for intrinsic motivation and for emotional tension did not reach the level of significance, this was true for content-related worry and for partner-related worry. The effect sizes of the statistically significant group differences equaled about 0.5.

Table 2
Explainers and listeners: Means of the motivational variables (in brackets standard deviations)

Variable	Listening	Explaining	*t*-value[a] (*df*=19)	Correlation between partners	Effect-size
Intrinsic motivation	3.04 (0.89)	2.75 (0.77)	1.03 *n.s.*	-.13 *n.s.*	0.23
Emotional tension	1.86 (0.65)	2.08 (0.60)	1.25 *n.s.*	.25 *n.s.*	0.28
Content-related worry	1.64 (0.56)	2.03 (0.74)	2.19 *	.26 *n.s.*	0.49
Partner-related worry	1.45 (0.42)	1.85 (0.75)	2.46 *	.33 *n.s.*	0.55

Note. * $p < .05$; [a] two-tailed *t*-test for dependent samples.

Table 3
Relations of the motivational variables to post-test performance: Partial correlations in the groups of the listeners (first line) and of the explainers (second line)

	Post-test total	Self-transfer	Near transfer	Far transfer
Intrinsic motivation	.01 .19	-.03 .30	-.05 .16	.14 .00
Emotional tension	.34 -.25	.40# -.28	.37 -.42#	.04 -.13
Content-related worry	.20 -.28	.17 -.36	.18 -.33	.19 -.04
Partner-related worry	.45# -.32	.32 -.42#	.55* -.37	.28 -.03

Note. # $p < .10$; * $p < .05$ (two-tailed tests).

(3) *To what extent are learning results associated with anxiety and intrinsic motivation?*

In the group of the explainers, the (adjusted) learning results (controlling for prior knowledge) correlated negatively with the anxiety scores und positively with intrinsic motivation. In most cases, these correlations were not, however, significant. The pattern of associations in the listeners' group was different; some astonishing significantly positive correlations between anxiety and learning were obtained (Table 3).

Discussion

This is the first study that shows that explaining can also have negative effects on learning outcomes. In two respects, however, the results are consistent with previous research. First, learning roles such as explainer or listener affect only the attainment of "high-level" learning goals (in this case: near and far transfer). Second, the lacking superiority of learning by explaining is in accord with previous studies that did not investigate learning from text; they also failed to find superior learning under an explanation demand (see above). The learning mode and the learning criteria may be important factors that moderate the effectiveness of learning by explaining.

The negative motivational effects of explaining converge with similar results of Renkl (1995). He found that even the expectation of an explanation demand can elicit stress. The somewhat surprising positive correlations between anxiety and learning results in the listeners' group can be explained by the listeners' very low level of anxiety (group

means between 1.45 [partner-related anxiety] and 1.86 [emotional tension] on a 1-5 scale). Too low levels of activation are apparently not functional (cf. Yerkes-Dodson law).

It cannot be excluded that learning by explaining came off badly in experiment 1 just because listening was a very favorable mode of learning in this context and not because learning by explaining was so ineffective. In order to test this possibility, experiment 2 was performed.

Experiment 2

This experiment was designed to compared "free" (i.e., unstructured) cooperation with learning in the roles of explainers or listeners respectively. On the basis of different theoretical approaches in the field of cooperative learning, different predictions can be derived with respect to the effectiveness of unstructured cooperation. On the one hand, the Neo-Piagetian perspective (Doise & Mugny, 1984) stresses the importance of free exchange within cooperative dyads or groups for the acquisition of sophisticated knowledge structures (see also Damon, 1984; Rogoff; 1991). This would lead to the hypothesis that free cooperation is the most effective way of learning compared to learning by explaining or by listening. On the other hand, it was frequently found that the quality of unstructured cooperative exchanges is rather poor and that learners typically do not show those behaviors which make cooperation effective (e.g., Mandl, Gruber & Renkl, 1992; Ross & Cousins, 1995). Exactly for these reasons, cooperation scripts were developed in order to structure the exchange, for example, by assigning roles such as explainer or listener. In this perspective, learning by unstructured cooperation should result in low leaning gains. Taken together, the relative effectiveness of unstructured cooperation is an open question.

With respect to motivation, a study conducted by Spurlin, Dansereau, Larson, and Brooks (1984) suggests that free cooperation which allows for flexibly changing roles should be more favorable as compared to learning in fixed roles.

Specifically, the following research questions were addressed in Experiment 2:

(1) To what extent differs learning in unstructured cooperation from learning in fixed roles (explainer, listener) with respect to learning gains?

(2) To what extent differs learning in unstructured cooperation from learning in fixed roles with respect to motivational aspects?

Method

An additional group of 10 dyads (20 learners) was studied. These subjects cooperated without any role assignments. They were just instructed to explain the example solutions to each other. The experimental procedure, the instruments, and the materials were exactly the same as in Experiment 1. Note that the data of the explainers und the listeners of experiments 1 were re-used.

Results

(1) *To what extent differs learning in unstructured cooperation from learning in fixed roles with respect to learning gains?*

Table 4 shows the learning outcomes in the different groups of learners. A multivariate analysis of variance including the post-test subscales (self-transfer, near transfer, far transfer) revealed that the learners in unstructured cooperation outperformed the explainers ($F(3,26) = 3.47$, $p < .05$). This was also true, when prior knowledge was controlled (i.e., included as covariate; $F(3,25) = 3.91$, $p < .05$). Univariate analyses showed that this overall group difference was primarily due to the superior near transfer performance of the learners in unstructured cooperation ($t(28) = 2.07$, $p < .05$; analysis of covariance with prior knowledge as covariate: $F(1,27) = 8.19$, $p < .05$). The corresponding multivariate analysis of variance comparison between listeners und learners in unstructured cooperation yielded no significant difference ($F(3,26) = 1.99$, *n.s.*). Including prior knowledge as covariate did not change this finding ($F(3,25) = 2.00$, *n.s.*).

With respect to the performance in the post-test as a whole, the learners in unstructured cooperation differed significantly neither from the explainers ($t(28) = 0.69$, *n.s.*; analysis of covariance controlling for prior knowledge:

Table 4
Means (in brackets standard deviations) of the post-test scores as a function of learning condition

Variable (theoretical maximum)	Explaining	Listening	Unstructured cooperation
Post-test total (30)	16.60 (5.88)	20.25 (6.58)	18.10 (4.90)
Self-transfer (8)	5.55 (1.96)	5.90 (2.17)	5.05 (1.62)
Near transfer (8)	3.25 (1.92)	4.85 (2.46)	4.70 (1.57)
Far transfer (8)	2.60 (2.04)	4.30 (2.13)	2.90 (1.79)

$F(1,27) = 1.08$, *n.s.*) nor from the listeners ($t(28) = -0.91$, *n.s.*; analysis of covariance: $F(1,27) = 1.26$, *n.s.*).

(2) *To what extent differs learning in unstructured cooperation from learning in fixed roles with respect to motivational aspects?*

Table 5
Means (in brackets standard deviations) of the motivational variables as a function of learning conditions

Variable	Explaining	Listening	Unstructured cooperation
Intrinsic motivation	2.75 (0.77)	3.04 (0.89)	2.96 (0.55)
Emotional tension	2.08 (0.60)	1.86 (0.65)	2.13 (0.50)
Content-related worry	2.03 (0.74)	1.64 (0.56)	2.05 (0.52)
Partner-related worry	1.85 (0.75)	1.45 (0.42)	1.61 (0.66)

As Table 5 shows, there were just minor differences between the explainers and the learners in unstructured cooperation. Accordingly, a multivariate analysis of variance including intrinsic motivation, emotional tension, content-related worry, and partner-related worry did not yield a significant difference between these two groups ($F < 1$). The same was true for the comparison between learners in unstructured cooperation and listeners ($F < 1$).

Discussion

Figure 2 summarizes the findings. With respect to the learning outcomes, learning by explaining comes off badly in comparison not only to learning by listening, but also to learning in unstructured cooperation. Hence, in this context explaining is not at all a fruitful way of learning. Listening, instead, seems to be a quite favorable mode of learning, despite the possible incorrectness, incoherence, and incompleteness of the partners' explanations. Nevertheless, the listener can obviously use these explanations for own knowledge construction processes. With regard to motivation, the results of Spurlin et al. (1984) that the possibility to change roles enhance motivation could not be replicated.

Overall discussion

At first glance, the finding that the explainers were outperformed by the listeners and in part by the learners in unstructured cooperation seems somewhat astonishing, given the assumptions in the literature on cooperative learning with respect to the positive effects of explaining. A closer look at the situation of the explainer reveals, however, several plausible reasons for this result:

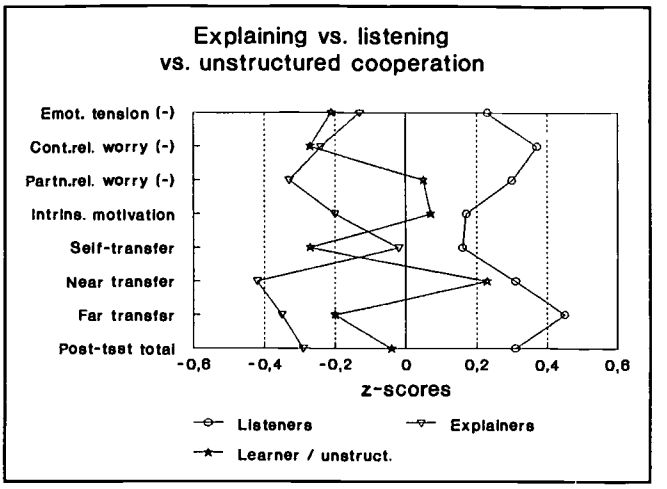

Figure 2
Summary of results

(a) There is (more or less) a "one-way flow" of information from the explainers to the listeners. In contrast to both the listeners und the learners in unstructured cooperation, there is little chance for the explainers to receive explanations that help them close their knowledge gaps.

(b) The explainer role induces stress. This is indicated by the explainers' unfavorable motivation during learning.

(c) The explainers have a dual task: to learn and to teach. They have to consider many aspects that are not directly related to the to-be-learned materials (e.g., planning and coordination of the explanations, management of the interaction). The explanation demand obviously overtaxes the explainers. The listeners and also the learners in unstructured cooperation, in contrast, can concentrate on learning.

The present findings indicate that the (positive) effects of explaining are presently overestimated in research on cooperative learning. Future studies should aim to determine the precise boundary conditions under which explaining in cooperative arrangements leads to favorable outcomes.

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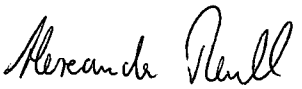

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