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Cooperative learning, motivational effects, and student characteristics: An experimental study comparing cooperative learning and direct instruction in 12th grade physics classes

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Abstract

One hundred thirty-seven students in 12th grade physics classes participated in a quasi-experimental study comparing the jigsaw classroom method of cooperative instruction with traditional direct instruction. While no differences were found between the two conditions for physics achievement gains, the results revealed differences in students' experience of the three basic needs (autonomy, competence, and social relatedness as posited by self-determination theory of learning), in self-reported cognitive activation, and in degree of intrinsic motivation. Path analyses showed that the basic needs partially mediated the effects of method of instruction on cognitive activation and intrinsic motivation. Increases in feelings of competence with cooperative learning were associated with better performance in physics. When controlling for competence, however, direct instruction had a facilitating effect on physics performance. Four aspects of students' personal learning characteristics (previous knowledge, academic self-concept in physics, academic goal orientation, uncertainty orientation) were assessed. Method of instruction was found to interact with self-concept: students with low academic self-concept profited more from cooperative instruction than from direct instruction because they experienced a feeling of greater competence.

Keywords: Cooperative learning; Jigsaw classroom; Direkt instruction; Basic needs; Intrinsic motivation

1. Introduction

The present study investigates a form of cooperative instruction—the jigsaw classroom—that has received a great deal of attention in recent years based on social psychological analyses by Aronson (1978, 2002). The jigsaw learning technique is a structured, cooperative strategy that avoids many of the problems of other forms of learning in a group. This technique and other innovative forms of teaching and learning have been used successfully to

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promote learning achievements across a range of curriculum areas including narrative writing in small groups (Zammuner, 1995), problem solving in mathematical tasks (Webb & Farivar, 1994), and conceptual understanding in physics (Howe, Tolmie, Greer, & Mackenzie, 1995). An overview of numerous findings that are favorable for cooperative learning and teaching methods overall, but are also heterogenous (Gillies, 2003a, 2003b), emphasized that it is structured forms of cooperative learning in particular that lead to better learning outcomes than traditional methods of direct instruction. The present study focuses on the ways in which a highly structured form of cooperative learning—the jigsaw classroom—may work. At the same time, the study examines whether there are personal variables that support the effectiveness of cooperative teaching as compared to the traditional whole-class lecture method.

The following paper looks first at the question of the effectiveness of the jigsaw classroom as compared to the traditional teaching method in science (physics) instruction. Second, focus is placed on the learning process in the jigsaw classroom, and hypotheses are formulated with the aim to understand learning outcomes in relation to mediating variables. Third, the effectiveness of the jigsaw method as compared to direct instruction is brought into connection with several variables at the level of students' personal learning characteristics (academic self-concept, motivational orientation, uncertainty orientation).

The jigsaw classroom, or jigsaw structure, belongs to a set of innovative cooperative forms of learning; it is set apart from loose, unstructured group work by the following features (see Johnson & Johnson, 1990)—(a) positive interdependence: each member has to contribute to the group task. As in a jigsaw puzzle, each piece—each student's part—is essential for completion of the task; (b) individual accountability: all group members understand they are required to make their own contribution to the group; (c) students actively promote each other's learning. The jigsaw learning technique was first developed and implemented by Elliot Aronson (1978). In the jigsaw classroom, the day's lesson is divided into several segments, and each student, who is in one of several jigsaw groups (of three to five students each), is assigned to learn about one segment of the written material. Before reporting on their topic to their jigsaw groups, students meet first with other students who have been assigned the same segment (one from each jigsaw group) in a temporary "expert" group. Together, the experts research their segment, discuss, and clear up questions with each other. Finally, the jigsaw groups reconvene, and each student in each group acts as a tutor to the group on his or her speciality topic. Aronson (2002) sums up the advantages of this specific cooperative learning technique: his research group found that students learn the material faster and perform significantly better on objective exams than a control condition of students learning the same material in classes conducted with traditional instruction. More importantly, however, as Aronson (2002) emphasized, the jigsaw structure encourages listening, engagement, and empathy by giving each member of the group an essential part to play in academic activity. Group members must work together as a team to accomplish a common goal; each person depends on all the others. Group goals and individual goals complement and bolster each other.

According to academic performance, the results of jigsaw studies are heterogenous and somewhat less enthusiastic. Lazarowitz, Hertz-Lazarowitz, and Baird (1994) showed that students in the jigsaw classroom scored significantly higher in academic outcomes, on self-esteem measures, and in involvement in the classroom. Yet there are also studies that show no advantages for the jigsaw procedure. Moskowitz, Malvin, Schaeffer, and Schaps (1985) found that participation in the jigsaw classes did not have any positive effect on students. Jigsaw methods failed to influence students' perceptions of classroom climate, attitudes towards peers or school, locus of control, school attendance, or reading and mathematics achievement. A positive effect was found on academic self-esteem, but only for female participants. Jürgen-Lohmann, Borsch, and Giesen (2001) also showed no differences for academic achievement between cooperative learning with jigsaw and traditionally structured classes in undergraduate teaching. However, the cooperative learning method did increase students' active involvement in classes.

This heterogenous pattern of results for the jigsaw technique somewhat contrasts the literature regarding cooperative learning in general. Slavin, Hurley, and Chamberlain (2003) state that research on cooperative learning is one of the greatest success stories in the history of educational research. The benefits of cooperative learning include academic gains across different curriculum domains (for a review see Slavin et al., 2003) as well as positive effects of cooperative learning on interpersonal attitudes, behaviors, values and skills (for a review see Solomon, Watson, & Battistich, 2002). The present study focuses on some mediating variables which might be responsible for effectiveness of cooperative learning with the jigsaw classroom.

1.1. Basic needs and jigsaw classroom

If the jigsaw classroom is an effective teaching method, the question arises as to what mediating variables are responsible for this effectiveness. Our study proposes that the jigsaw technique has the potential to satisfy the basic needs in the theory of self-determination (Deci & Ryan, 1985, 2000), and thus to enhance the probability of intrinsically motivated, deep-level learning. As a cooperative learning environment, the jigsaw classroom should support the need to experience social relatedness. In comparison with direct instruction, there will also be a better chance to feel autonomous because students have more leeway in structuring the learning process. Beyond that, the jigsaw classroom is hypothesized to have particular advantages as to the need for competence: the student's experience of responsibility for a segment of the material, and of acting as an expert source for other students, is posited to give the student an experience of feelings of competence that is rare in traditional forms of instruction. In summary, the present study proposes to show positive effects of the jigsaw method on the experience of autonomy, competence, and social relatedness (hypothesis 1), which in turn should determine to what extent one exhibits self-determined (intrinsic) motivation (hypothesis 2). Furthermore, because intrinsic motivation is connected with the application of more effective deep level processing strategies (e.g. Schiefele, 1991), we postulate more application of deep level processing strategies (hypothesis 3) and better performance (hypothesis 4) in jigsaw groups compared to direct instruction. Lastly, the perceptions of competence, autonomy, and social relatedness are mediators of the effects of method of instruction on the learning outcome variables (intrinsic motivation, deep-level strategies, and performance) (hypothesis 5).

1.2. Personality variables as learning prerequisites

Various theories and empirical findings indicate that there are differences among students in how well they manage with cooperative forms of instruction. The present study considers several more or less enduring personality variables that have been proposed to have a connection with self-directed or cooperative forms of learning: academic self-concept, academic goal orientation, and uncertainty orientation.

1.2.1. Academic self-concept

The academic self-concept represents a generalized, domain-specific feeling of competence that is determined by the student's experience of competence in specific domains of the curriculum, or school subjects. The theoretical and practical significance of the academic self-concept has been demonstrated in a multitude of investigations that found that this individual characteristic explained and predicted academic performance-related behavior. There is a wide consensus that the academic self-concept, mediated by motivational variables, facilitates learning processes at school (see, for example, Helmke & van Aken, 1995). The academic self-concept is formed through experiences with the school environment and is influenced especially by environmental reinforcements and significant others. Contemporary academic self-concept researchers assert that students' perceptions of their competence in given areas provide key ingredients to their self-concepts (e.g., Bong & Skaalvik, 2003; Harter, 1982; Marsh, 1990; Skaalvik, 1997). The clear assignment of roles and tasks in the jigsaw classroom (each student is the expert on a segment of material) gives students opportunities to feel competent that they do not have in traditional, teacher-guided instruction. The students shown to profit the most from cooperative learning in jigsaw are those who do not have favorable academic self-concepts in the sciences and are thus not likely to have positive experiences of competence in that domain. Therefore, we predict an interaction between method of instruction and academic self-concept on feelings of competence (hypothesis 6). Since there is a close connection between domain-specific academic self-concept in physics and gender, in that girls generally have a worse self-concept in physics, the present study expects to find results when comparing girls and boys that correspond to these gender differences. Due to worse academic self-concepts in physics, girls should profit more from jigsaw learning than boys with respect to their perception of competence (hypothesis 7).

1.2.2. Academic goal orientation

Even though the jigsaw classroom is a relatively highly structured form of cooperative learning, it still demands a greater ability on the part of the student to learn independently than does direct lecturing by the teacher. Since the jigsaw classroom requires self-regulated learning, a key component to success will be motivation to learn. Therefore, it is reasonable to test the relationship between this form of instruction and academic goal orientation. Current theorizing on achievement goals (Harackiewicz, Barron, Tauer, & Elliot, 2002) distinguishes pursuit of mastery (or task) goals and performance (or ego) goals. When pursuing mastery goals in a learning situation, a student's purpose is to develop competence by acquiring new knowledge and skills. In contrast, when pursuing (approach) performance goals, a student's purpose is to demonstrate competence relative to others. Harackiewicz and colleagues examined independent and interactive effects of these goals (Barron & Harackiewicz, 2000; Hidi & Harackiewicz, 2000). They showed that mastery goals predicted continued academic interest, whereas performance goals predicted performance (Harackiewicz et al., 2002). The present study seeks to demonstrate that mastery and (approach) performance goals have different effects in different instruction settings. Mastery orientation should strengthen the perception of competence and autonomy, especially in the cooperative learning condition. In other words, we postulate a main effect (hypothesis 8) and an interaction effect (with method of instruction; hypothesis 9) for the connection between mastery orientation and the perception of competence and autonomy. Approach performance goals should predict performance, independent of method of instruction (hypothesis 10).

1.2.3. Uncertainty orientation

The personality trait of uncertainty orientation (Sorrentino & Roney, 1999) has been found to be associated with a preference for cooperative forms of learning. The construct of uncertainty orientation describes a person's typical ways of dealing with complexity, uncertainty, and abundant information. Whereas uncertainty-oriented persons are particularly interested in the ambiguity and ambivalence of a situation and have a desire to attain new knowledge, certainty-oriented persons are more inclined to orient towards what is already known and familiar. It was found that uncertainty-oriented students, not only feel more comfortable in the classroom with cooperative forms of learning than certainty-oriented students, but they also learn more than in traditional instruction, whereas certainty-oriented students are less comfortable in social interaction learning groups and performed poorly (Huber, Sorrentino, Davidson, Eppler, & Roth, 1992). We therefore propose that there is an interaction of uncertainty orientation and method of instruction: In cooperative learning, uncertainty-oriented students should perform better than certainty-oriented persons, whereas with direct instruction there is no connection between uncertainty orientation and performance (hypothesis 11).

2. Method

2.1. The learning unit

Two learning units covering motion of electrons in electric and magnetic fields and electromagnetic oscillations and waves were implemented in eight 12th grade physics classes. The following criteria were used in the selection of the topics: the topics had to be meaningful, that is, important for the 12th grade level, as well as interesting; and it had to be possible to divide the material into independent segments, so as to be suited to the jigsaw technique. A detailed description of the two learning units, which focused on either the study topic ‘‘scanning electron microscope’’ or ‘‘microwave oven’’, is reported elsewhere (Berger, 2002, 2003).

2.2. Participants and experimental design

Eight 12th grade physics classes, with a total of 137 students, participated in the study in the 2002–2003 school year. Originally, the study was to be conducted as a cross-over design that investigated the method of instruction as both between-subject factor and within-subject factor (although with different study topics). Some students studied the topic of ‘‘scanning electron microscope’’ in the jigsaw classroom and then received direct instruction for the second study topic, ‘‘microwave oven.’’ Other students learned about the first study topic through direct instruction and then studied the second study topic through the jigsaw classroom. However, for the second study topic (microwave oven), some classes and several students were not available for our study. To compensate for this, new classes of 12th graders were included for the second study topic. The design was evaluated as a between-subjects design for the method of instruction with the study topic as a control factor.[1] Classes were assigned randomly to the direct instruction or the cooperative learning condition.

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[1] Due to the fact that some students participated in both study topics the actual sample size was larger. As a result of different missing values for the dependent measures in different lessons it varied between 166 and 189 for the statistical analyses.

2.3. Procedure

First, students were given a test of academic performance (pretest) and a questionnaire assessing personality variables (self-concept, goal orientation, and uncertainty orientation). The actual learning unit was made up of 4 school hours (scanning electron microscope) or 3 school hours (microwave oven). First, basic information on motion of electrons and electromagnetic oscillations and waves, respectively, was introduced in one or two physics hours through direct instruction (same for both conditions). At the end of this lesson, the learning experience questionnaire was given as a pretest measurement. In the next two physics hours (in a double period), students in the experimental groups worked in the jigsaw classroom, while the control groups studied the same learning material through traditional classroom instruction. In the jigsaw classroom, the learning experience questionnaire was administered after the work in the expert groups and again when students had finished with the jigsaw groups. In the traditional classroom condition, the learning experience questionnaire was given once at the end of the lesson. The posttest on academic performance was given in an extra lesson some days after the learning unit.

2.4. Independent variables

2.4.1. Method of instruction

After all students had been given a general introduction to the topic in a direct instruction setting, the classes were divided randomly for the two conditions of method of instruction. In the jigsaw classroom condition, the study topic (scanning electron microscope or microwave oven) was divided into four, self-contained and comprehensible segments. Temporary groups of experts were formed. The groups were made up of 3–5 students that were assigned the same segment of the material. They learned about their segments using prepared lesson materials and by conducting some experiments. They were asked to learn the material and to prepare it for presentation to their jigsaw group, in which each member had been assigned a different segment of the material. The students were allowed to form the jigsaw groups themselves (of the required size)[2]; the assignment to the expert groups was random (students drew cards with their segment assignments). For the direct instruction condition, the teachers were asked to prepare a conventional lesson based on the material used in the jigsaw classroom. Teachers were encouraged to follow standards of effective direct instruction: small and carefully sequenced steps, fast pacing, and a great deal of teacher–student interaction (see Rosenshine & Stevens, 1986).

2.4.2. Study topic

Two learning units on different study topics in physics were designed and implemented. The first study topic was the functioning of the scanning electron microscope, and the second was the functioning of the microwave oven. The variable study topic was taken as a control factor.

2.5. Dependent variables and scale analyses

2.5.1. Personality questionnaire

All scales were 5-point scales. A scale consisting of three items measured *academic self-concept* (Hoffmann, Häußler, & Peters-Haft, 1997; e.g. "I comprehend physics very well … very poorly"). The Cronbach's alpha internal consistency reliability was .89. Students' *academic goal orientations* were measured using items based on data in Köller (1998). Three content and test-statistical characteristics items were selected for mastery goals (e.g. "I feel happy at school when what we are learning makes sense to me".) and (approach) performance goals (e.g. "I feel happy at school when I get better grades than my schoolmates"). The Cronbach's alpha internal consistency reliability coefficients for the subscales mastery goals and performance goals were .62 and .88, respectively. Students' *uncertainty orientation* was assessed using the uncertainty tolerance scale by Dalbert (1996) (e.g. "I like unexpected surprises" or "I like to let things happen".). Cronbach's alpha coefficient was .69.

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[2] Note that choosing their own jigsaw groups could have affected performance in the cooperative learning condition. Studies on cooperative learning favor heterogenous ability grouping (Lou et al., 1996; Saleh, Lazonder, & de Jong, 2005).

2.5.2. Learning experience questionnaire

Scales measuring students' learning experience—*basic needs, intrinsic motivation, and activation of deeper level processing strategies*—were administered at several points in time. So as not to overtax the students, the questionnaire needed to be short. The items also had to be constructed so that they were applicable for different learning situations (direct instruction and cooperative learning). Due to these constraints, a new questionnaire was constructed, tested, and revised psychometrically in a sample of 163 students. Some of the items were based on a questionnaire by Prenzel and colleagues (Prenzel & Drechsel, 1996; Prenzel, Eitel, Holzbach, Schoenheinz, & Schweiberer, 1993; Prenzel, Kristen, Dengler, Ettle, & Beer, 1996) and some were newly developed (see the items in Appendix A). The Cronbach's alpha internal consistency reliability for each of the subscales was as follows (measured in the physics hour after the experimental variation, jigsaw classroom condition or direct instruction condition): Cronbach's alpha coefficients for experience of autonomy, experience of competence, and experience of social relatedness were .62, .82, and .73, respectively. Cronbach's alpha for intrinsic motivation was .70. Cronbach's alpha coefficient for activation of deeper level processing strategies was .75.

2.5.3. Academic performance

Students took pre- and posttests in physics. The two achievement tests differed and were constructed according to different criteria. The first test assessed students' knowledge of the general concepts, which were covered again in the learning unit, whereas the second exam tested students on the specific knowledge contained in the four experts' segments acquired during the learning unit. The questions were designed to cover the different learning skills of reproduction and reorganization, transfer, and problem-solving thinking. The pre- and posttests contained four sections. The Cronbach's alpha coefficient was .51 for the pretest and .56 for the posttest.[3]

3. Results

3.1. Effects of the experimental variation

A multivariate analysis of variance (MANOVA) was performed with method of instruction and study topic as independent variables and with the learning experience variables[4] (the three basic needs, intrinsic motivation, activation of deeper level processing) and the results of the physics achievement tests as dependent measures. For all variables, corresponding pretest measures were used as covariates. The multivariate analysis of variance showed a significant main effect for method of instruction (Wilks $F(6,153) = 10.09$, $p < .001$).[5] At the level of the univariate F tests, there were main effects for method of instruction on all of the learning experience variables ($p < .05$), but not on academic performance ($p = .12$). The multivariate tests for the factor study topic ($F(6,153) = 0.51$, $p > .50$) and for the two-way interaction of method of instruction × study topic ($F(6,153) = 1.78$, $p = .11$) were not statistically significant. Table 1 shows the adjusted means for the comparison of the two methods of instruction, aggregated across the study topics for all dependent variables. Hypotheses 1, 2 and 3 were supported; but there was no main effect of method of instruction on performance (as postulated in hypothesis 4).

Additionally, for the jigsaw classroom condition, academic performance was divided into expert performance (student's score on that part of the test that covered the segment of the learning material assigned to the student) and tutored performance (the student's score on that part of the test that tested segments a student had learned about from fellow group members). Students' academic performance on their own expert segments ($M = 72\%$) was better than their performance on tutored segments ($M = 54\%$; $t(87) = 4.96$, $p < .001$). Moreover, the experts in the jigsaw classroom performed better on the part of the test covering their assigned segments than students who were taught by the teacher in frontal instruction (adjusted means $M = 70\%$ vs. $M = 61\%$, $F(1,165) = 3.66$, $p < .06$). However, jigsaw classroom students performed worse on the segments of the learning materials that they had learned about from fellow

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[3] For the evaluation of these internal consistencies, one has to take into account that the four tasks measured different knowledge components.

[4] For comparison with the control condition, the chosen point in time of measurement of the learning experience variables under the jigsaw condition was after working in the expert group. The results at this measurement point (except for experience of autonomy) were the same as the results of the measurement after working in the jigsaw group.

[5] This analysis is without the control factor of learning group. Including learning group as a nested factor within the factor of method of instruction yielded the same results.

Table 1
Adjusted means and standard deviations for all dependent variables as a function of method of instruction

Dependent variable	Method of instruction			
	Direct instruction by the teacher		Jigsaw classroom	
	M	(SD)	*M*	(SD)
Experience of autonomy	2.5	(0.84)	3.4	(0.97)
Experience of competence	4.0	(0.84)	4.4	(0.68)
Experience of social relatedness	3.6	(0.83)	4.3	(0.76)
Intrinsic motivation	3.2	(0.94)	3.5	(0.73)
Activation of deeper level processing strategies	3.2	(0.74)	3.5	(0.67)
Academic performance [% of max. score]	61.5%	(24.8)	56.2%	(19.7)

group members than students who had been taught the material through the traditional method of instruction (adjusted means $M = 52\%$ vs. $M = 62\%$; $F(1,165) = 9.25$, $p < .05$).

3.2. Path analysis

In hypothesis 5, it was postulated that the perceptions of competence, autonomy, and social relatedness were mediators of the effect of method of instruction on the outcome variables of intrinsic motivation, deep-level strategies, and performance. In order to test these mediational hypotheses, for each of the three outcome variables a path analysis was performed (see Figs. 1–3, correlation matrix see Table 1). For all three path analyses, the fit indices were acceptable (all RMSEA < .10). The direct effects of method of instruction on the outcome variables can be found in Table 2. For intrinsic motivation, the direct effect of method of instruction was $r = .25$ ($p < .05$; see Table 2); with the mediator variables experience of competence and experience of autonomy the direct path from method of instruction to intrinsic motivation disappeared ($\beta = -.09$, ns; see Fig. 1). For activation of deeper level processing, there was an analogous pattern of results. The correlation with method of instruction was significant, $r = .39$ ($p < .05$), yet with the basic needs as mediator variables the path from method of instruction to activation of deeper level of processing was $\beta = .01$, ns (see Fig. 2). For the outcome variable of academic performance, the situation was somewhat different. Without mediators there was no direct effect from method of instruction to academic performance (see Table 2; correlation between method of instruction and performance was $r = .00$). When controlling for the basic needs, method of instruction had a *negative* effect on academic performance (see Fig. 3). At the same time, the possible mediator variable of competence had a positive effect on academic performance ($\beta = .32$, see Fig. 3). Thus, controlling for

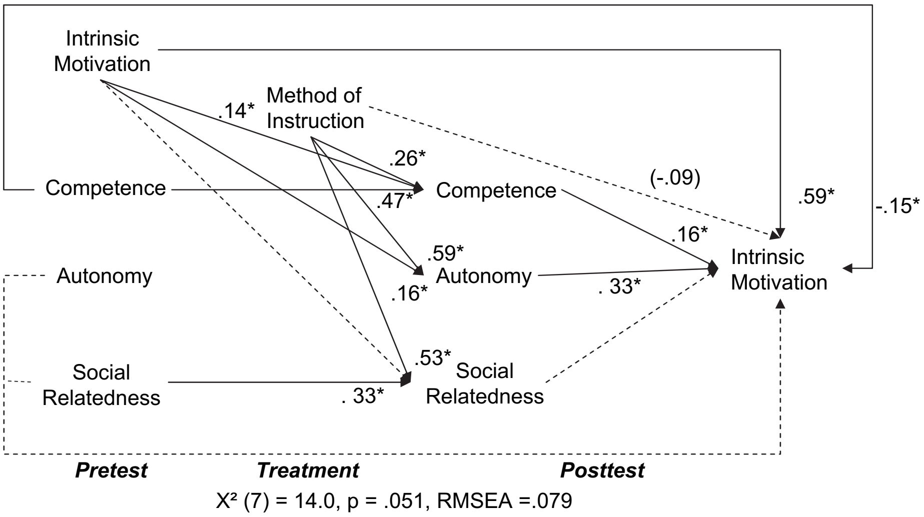

Fig. 1. Path analysis for the prediction of intrinsic motivation. Path coefficients with solid lines are significant (${}^{*}T > 2$, $p < .05$). Admitted but not significant paths are shown as dotted lines. *Note*. Method of instruction is coded as follows: 0 = direct, 1 = cooperative.

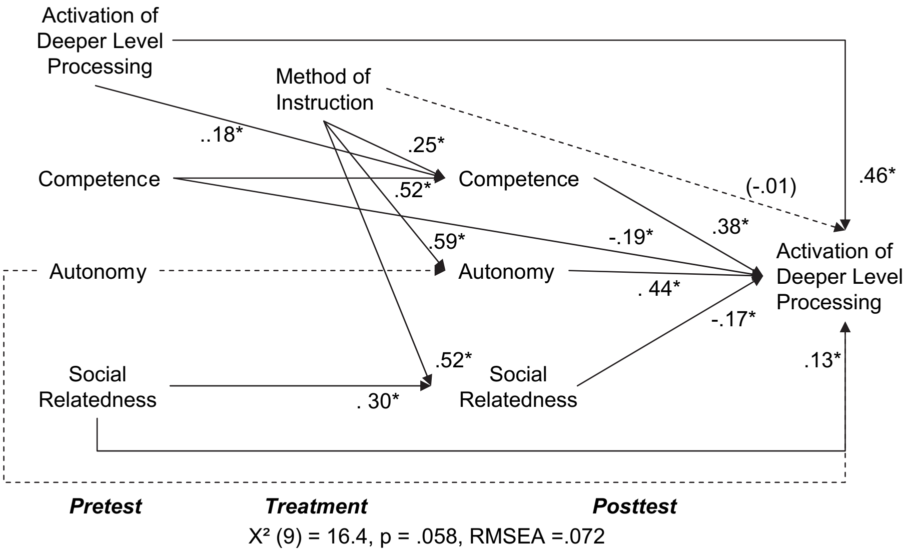

Fig. 2. Path analysis for the prediction of activation deeper level processing. Path coefficients with solid lines are significant ($^{*}T > 2$, $p < .05$). Admitted but not significant paths are shown as dotted lines. *Note*. Method of instruction is coded as follows: 0 = direct, 1 = cooperative.

competence uncovered a positive effect of traditional instruction on performance (see Section 4). In this case, the mediator variable experience of competence acts like a suppressor variable for the path from method of instruction to academic performance (see Kenny, Kashy, & Bolger, 1998). Taken together, the mediating role of basic needs (hypothesis 5) was confirmed for intrinsic motivation and activation of deeper level processing strategies, and it was at least partly confirmed for academic performance.

3.3. The role of student characteristics in relation to learning

The hypotheses concerning personality variables were mainly associated with interaction effects. We tested these effects using the product term approach within multiple regressions (Jaccard, Turrisi, & Wan, 1990). The interaction term method of instruction × self-concept was significant for the prediction of competence (see Table 3) hence supporting hypothesis 6. To demonstrate the effect more clearly, the students were divided into post hoc groups of

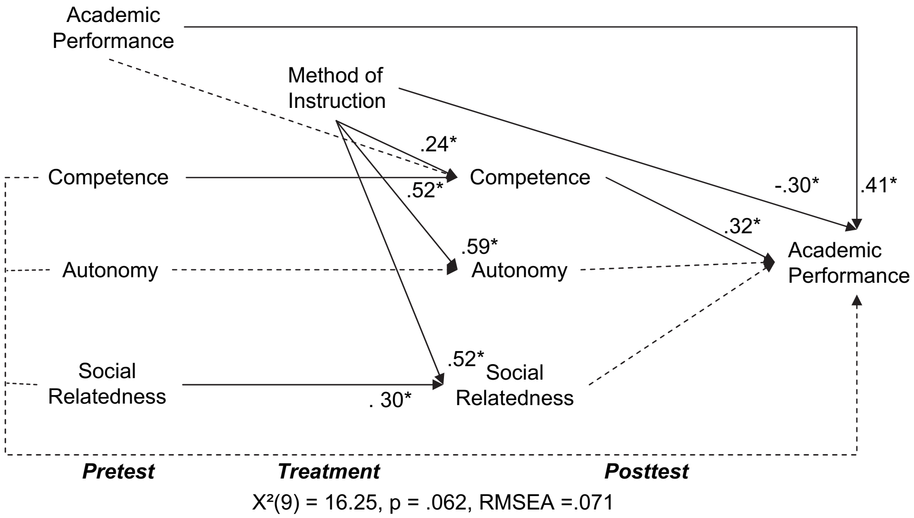

Fig. 3. Path analysis for the prediction of academic performance. Path coefficients with solid lines are significant ($^{*}T > 2$, $p < .05$). Admitted but not significant paths are shown as dotted lines. *Note*. Method of instruction is coded as follows: 0 = direct, 1 = cooperative.

Table 2
Correlation matrix for path analyses

	2	3	4	5	6	7	8	9	10	11	12	13
1. Performance (pretest)	.25*	.30*	.20*	.13	.12	.36*	.28*	.16*	.12	.40*	.18*	.21*
2. Intr. mot. (pretest)		.67*	.30*	.30*	.29*	.16*	.32*	.26*	.10	.30*	.69*	.57*
3. Activation (pretest)			.33*	.36*	.28*	.21*	.35*	.25*	.17*	.21*	.47*	.65*
4. Competence (pretest)				.13	.40*	.15	.58*	.06	.18*	.16*	.16*	.23*
5. Autonomy (pretest)					.35*	.36*	.16*	.30*	.30*	−.03	.27*	.33*
6. Social rel. (pretest)						.10	.22*	.21*	.36*	.18*	.29*	.30*
7. Method of instruction							.36*	.62*	.55*	.00	.25*	.39*
8. Competence (posttest)								.08	.41*	.28*	.28*	.42*
9. Autonomy (posttest)									.49*	.04	.45*	.52*
10. Social rel. (posttest)										.06	.24*	.29*
11. Performance (posttest)											.21*	.13
12. Intr. Mot. (posttest)												.65*
13. Activation (posttest)												

Note. $N = 166$; $^*p < .05$, performance = academic performance; activation = activation of deeper level processing; intr. mot. = intrinsic motivation; social rel. = social relatedness. Method of instruction is coded as follows: 0 = direct, 1 = cooperative.

students with a negative and students with a positive academic self-concept in physics. The students with a positive physics self-concept showed little difference in their experience of competence in the two instruction settings (adjusted means in the jigsaw classroom: $M = 4.6$; in direct instruction $M = 4.4$, Cohen's $d = 0.26$, $F(1,96) = 3.26$, $p > .05$), whereas students with a negative physics self-concept showed a considerable difference in the experience of competence in the two settings ($M = 4.2$ and $M = 3.7$; Cohen's $d = 0.47$; $F(1,82) = 9.51$, $p < .01$). A further analysis revealed that the relationship between domain-specific academic self-concept and situational experience of competence in the jigsaw classroom ($r = .24$) was weaker than the relationship between domain-specific academic self-concept and situational experience of competence in traditional direct instruction ($r = .48$). The difference between the correlations was statistically significant (Fisher Z-transformation, $z = 1.95$, $p = .05$).

The following results on interaction effects should be interpreted considering that academic self-concept in physics was strongly correlated with gender. For boys, learning in direct instruction ($M = 4.2$) or cooperatively ($M = 4.3$) makes little difference as to their experience of competence. However, the method of instruction makes a considerable difference for girls ($M = 3.9$ and $M = 4.5$). The interaction of method of instruction by gender with the dependent variable experience of competence was significant ($F(1,185) = 6.83$, $p < .01$), and hypothesis 7 was supported.

For mastery orientation, we postulated a main effect on the measures of competence and autonomy (hypothesis 8), which was hypothesized to be qualified by an interaction with method of instruction (hypothesis 9). While the main effect was found for the influence of mastery orientation on competence there was no significant interaction with method of instruction (see Table 4). For the experience of autonomy, the corresponding analyses were not significant (p values $> .05$). The data also did not support hypothesis 10; there was neither a substantial effect of performance goals on academic performance nor a significant interaction effect of performance goals × method of instruction on academic performance (p values $> .20$). The analyses for uncertainty orientation yielded no interaction effect with method of instruction, neither for academic performance (hypothesis 11), nor for intrinsic motivation or activation of deeper level processing (p values $> .50$).

Table 3
Summary of hierarchical regression analysis for predicting experience of competence from method of instruction and academic self-concept

Variable	*B*	SE *B*	β
Step 1			
Method of instruction	0.38	0.10	.25*
Academic self-concept	0.36	0.07	.35*
Step 2			
Method of instruction	1.39	0.46	.90*
Academic self-concept	0.81	0.21	.79*
Interaction method of instruction × academic self-concept	−0.30	0.13	−.83*

Note. $R^2 = .198$ for Step 1; $\Delta R^2 = .021$ for Step 2 (p values $< .05$); $N = 189$; $^*p < .05$.

Table 4
Summary of hierarchical regression analysis for predicting experience of competence from method of instruction and mastery orientation

Variable	*B*	SE *B*	*β*
Step 1			
Method of instruction	0.44	0.11	.28*
Mastery orientation	0.22	0.08	.19*
Step 2			
Method of instruction	0.32	0.67	.21
Mastery orientation	0.26	0.25	.23
Interaction method of instruction × mastery orientation	0.03	0.16	.09

Note. $R^2 = .113$ ($p < .05$) for Step 1; $\Delta R^2 = .000$ for Step 2 ($p > 0.50$); $N = 189$; $^*p < .05$.

4. Discussion

Comparison of the cooperative form of teaching/learning and the traditional method of direct instruction revealed clear differences in the learning experience, but no difference in academic performance as measured by a test of physics knowledge. Because of the way in which transmission of knowledge is structured in the jigsaw classroom, students learn more highly specialized knowledge: jigsaw participants showed higher achievement test scores in the areas that had been assigned to them as "experts" as compared to students that had been taught by the teacher in the traditional lecture form. At the same time, however, traditionally taught students performed better on areas of the material that jigsaw participants had been taught by fellow group members. As for perceptions of the learning experience, the jigsaw classroom rather than traditional direct instruction was seen in a more favorable light by students. The students reported more cognitive activation and involvement, they felt stronger intrinsic motivation, and they developed greater interest in the topic. In the overall view, a benefit of the jigsaw classroom becomes evident: when performance is the same, students are more involved and more interested in the material in the cooperative learning setting than in the traditional lecture form of instruction.

Why is it that the motivational advantages of the jigsaw classroom do not also lead to improved academic performance? The path analysis based on our hypotheses regarding the mechanism of the effects of this form of cooperative learning provides an answer. Consistent with our assumptions, students in the jigsaw classroom indeed felt more competent, more autonomous, and more socially related to their classmates. Moreover, the path analysis revealed a positive and meaningful path from experience of competence to academic performance. As expected, the jigsaw classroom had an indirect effect on performance: students in the jigsaw classroom experienced themselves as more competent, and those feelings of competence improved subsequent physics performance. However, there was nevertheless no correlation between method of instruction and academic performance. It seems reasonable to assume two contradictory mechanisms that neutralized each other. The jigsaw method, via increased experience of competence, had a favorable effect on scores on the physics achievement test, while the traditional teaching method might have had benefits that were not captured by the variables in the self-report scales used in the study. When we control for varying experience of competence (see Fig. 3), we find a negative path from method of instruction to academic performance, that is, an advantage for traditional direct instruction. Some conceivable explanations for this effect are better structuring of the learning material by the teacher and better adaptation to the level of the students when comparing the quality of instruction of student "experts" and teachers.

Another aim of the study was to investigate whether the appropriateness and effectiveness of the cooperative form of learning depends on features of students' personalities. In particular, we were interested in the question of whether certain students are more likely to experience themselves as competent, autonomous, and more socially integrated in the cooperative learning environment. A corresponding interaction effect between personal characteristics and method of instruction was found only for academic self-concept and gender with respect to experience of competence. As mentioned at the outset, it can be assumed that the strength of the jigsaw classroom lies in the fact that each student has the role of an expert, and he or she can see himself or herself as a competent member of the class. In accordance with this, the study revealed precisely that this critical group of students with a low academic self-concept in physics felt clearly more competent than in the traditional teaching setting. This change took place without any detriment to the experience of competence by students with a high academic self-concept in physics. Corresponding results were found for gender differences, which is not surprising in view of the high correlation between self-concept and gender in physics. For boys, cooperative learning or direct instruction make no difference in their experience of feeling competent. However, the method of instruction makes a considerable difference for girls. In the jigsaw classroom, girls report a greater feeling of competence than in the traditional teaching setting.

The differential relationship between self-concept and experience of competence explains the advantages of the cooperative form of learning over direct instruction. More students can be guided towards greater feelings of competence, which increases motivation, and can lead to a better academic performance. In the long term, the jigsaw classroom can be a way to improve the academic self-concept of weaker students specifically. Unfortunately, these advantages, which show up in achievement gains on the students' assigned "expert" segments of knowledge, are made up for in overall academic performance by achievement losses in knowledge areas that they learned about from fellow group members. Thus there is a need for further development of the jigsaw technique as to the design of the procedure. Here, combining methods of peer tutoring (see King, 1999) with the jigsaw classroom might point research in the right direction.

Contrary to our expectations, for the other personal characteristics, there were no interactive effects with the method of instruction, or in other words, different values of these variables were not associated with the method of instruction with regard to either learning experience or academic performance. As could be expected, there were main effects for academic goal orientation, in particular for mastery goals. Students high in mastery goals tended to experience themselves as competent, autonomous, and socially integrated in the class, but this effect was independent of the method of instruction.

Earlier investigations found a relationship between uncertainty orientation and affinity to and effectiveness of cooperative forms of learning (Huber et al., 1992). This association could not be replicated in our study. However, according to the authors of that study, their findings should be interpreted cautiously; moreover, the relationship reported between method of instruction and uncertainty orientation did not reach statistical significance. In the present study, the fact that the material learned by the students was already quite structured may have better met the needs of certainty-oriented students, so that a differential effect of uncertainty orientation on academic performance in relations to method of instruction failed to appear.

5. Conclusion

This study failed to show positive effects of the jigsaw puzzle on academic performance. However, there were strong effects of cooperative learning on the experience of basic needs, intrinsic motivation, and activation of deeper level processing. In particular, the experience of competence seemed to be central as a psychological mechanism in explaining the benefits of cooperative learning in jigsaw groups.

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Appendix A. Items on the learning experience scales

Basic needs

I had the opportunity to learn about new things on my own (Experience of autonomy).
I had a feeling of freedom to make some of my own decisions (Experience of autonomy).
I noticed that I really understood things (Experience of competence).
I felt able to master the work (Experience of competence).
I was very comfortable with the atmosphere (Social relatedness).
I had a feeling of belonging to the others (Social relatedness).

Intrinsic motivation

My mind was elsewhere.[6]
I was eager to learn about the material.
The work was really fun.
If I wasn't told to, I wouldn't have done anything.[6]

Activation of deeper level processing

I felt focused.
I felt involved in learning the material.
I took a critical look at the new material.
I tried to distinguish between important and unimportant things.
I tried to connect what I was learning with things I already knew.

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[6] This is a reverse-scored item.

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