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Computer-Assisted Instruction and Conceptual Change

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ABSTRACT

In this study, the question was addressed which instructional conditions are required to teach students how they themselves can initiate and perform learning activities aimed at conceptual change. The CONTACT-2 strategy (a computer-assisted instructional strategy for promoting conceptual change in the domain of basic physical geography) served as starting point for the design of several training procedures aimed at enhancing self-regulated learning. With the first experimental condition, strategic support was gradually withdrawn ('faded') within each instructional step, while, with the second experimental condition, the number of steps was reduced as the training continued. The original CONTACT-2 condition served as control condition. Subjects were 65 fifth- and sixth-graders (primary education). Dependent variables concerned students' abilities to initiate and perform learning activities aimed at conceptual change, the quality of their conceptions, and their learning performance. Results suggested that 'fading' can be a fruitful instructional approach to foster self-regulated learning aimed at conceptual change, provided that the 'fading' procedure is tuned to the students' actual level of self-regulated learning: external control should not be withdrawn until students are able (and prepared) to initiate and perform the learning activities being required. When these conditions are met, designing effective training procedures aimed at 'learning for conceptual change' seems possible.

INTRODUCTION

The idea that learning should be active is widespread among educational researchers already: an assumption of many recent theories of learning

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and instruction is that knowledge and skills cannot be transferred in a direct way but result from the learner's mental activities (e.g., De Jong, 1992; Duffy & Jonassen, 1991; Resnick, 1989; Vermunt, 1992). Therefore, the quality of the student's learning performance appears to depend on the quality of his or her learning activities. An essential aspect of active learning is searching for and using prior knowledge in understanding new information: many constructivist learning theories (e.g., Hegland & Andre, 1992) consider active use of prior knowledge to be a key strategy for constructing rich and useful mental representations. Prior knowledge can be described as all knowledge learners have when entering a learning environment, which is potentially relevant for acquiring new knowledge (see also Biemans & Simons, 1996).

In this article, the question is addressed which instructional conditions are required to teach students how they *themselves* can activate their prior knowledge and how they can initiate and perform learning activities aimed at conceptual change. In other words, how can instructional systems teach students how to use their correct or partially correct prior knowledge without creating interference and, simultaneously, how to deal with incorrect (i.e., not in accordance with generally accepted scientific views) or partially incorrect prior knowledge, which tends to resist change (see Eylon & Linn, 1988)? At this point, it should be noted that, in our view, generally accepted scientific views especially exist in well-structured knowledge domains, for example in the domain of basic physical geography, which has been treated in our studies: the distinction between incorrect and correct conceptions is far less clear when advanced knowledge acquisition in ill-structured domains is concerned (see also Spiro, Feltovich, Jacobson & Coulson, 1991).

Inspired by current conceptual change approaches (e.g., Ali, 1990; Duit, 1994; Hewson & Hewson, 1984; Nussbaum & Novick, 1982; Pintrich, Marx, & Boyle, 1993; Prawat, 1989; Strike & Posner, 1985, 1992), the CONTACT-2 strategy had been designed as part of our previous study (see for more details Biemans & Simons, 1996). The CONTACT-2 strategy was typified by continuous, computer-assisted activation of the conceptions of individual learners (fifth- and sixth-graders, primary education) in text processing (domain: basic physical geography). The strategy was based upon an instructional model consisting of 5 steps aimed at conceptual change: students should be activated to 1) search for their own relevant preconceptions; 2) compare and contrast their preconceptions with the new information; 3) formulate new conceptions, based upon the previous step; 4) apply the new conceptions; and 5) evaluate the new conceptions, based upon the previous step (see also Ali, 1990; Biemans &

Simons, 1995). Based upon the findings of this study (see for more details Biemans & Simons, 1996), one could conclude that the CONTACT-2 strategy was effective as instructional strategy aimed at conceptual change: additional empirical support for the underlying activation model was provided (see also Ali, 1990).

In the present study, we focused on another aspect of the CONTACT-2 strategy: the CONTACT-2 strategy is characterized by a high degree of external control. As had been shown in our previous study, a high degree of external control can result in conceptions of a higher quality and in better learning performance, but it may also lead to higher dependence on external support (see also Biemans & Simons, 1992). In our view, high dependence on external control can be an undesirable side-effect of an (any) instructional strategy in the longer term: without external help, students may not be able to initiate and perform the particular learning activities themselves and, thus, to achieve the learning goals (see also Vermunt, 1992). One could argue that the ultimate goal of instruction should be to teach students how to initiate and perform learning activities themselves (see also Jonassen, 1991): independence of external control is a core characteristic of self-regulated learning (see also Simons, 1991; Vermunt, 1992). Moreover, designing instructional programmes for all subject matter following the CONTACT-2 strategy would be impossible. Therefore, training procedures aimed at teaching students how to activate their own preconceptions and how to construct correct conceptions themselves took a central position in the present study.

Following Shuell (1988), 5 learning functions were distinguished, which have to be performed to ensure adequate learning (see also Simons, 1991): 1) preparing learning; 2) taking learning steps; 3) regulating learning; 4) providing feedback and judgment; and 5) maintaining concentration and motivation. Each learning function includes various activities, which can be undertaken either by the learner or by an external source (e.g., the teacher or C.A.I. program), depending on the way the learning situation is organized (see also Biemans & Simons, 1992).

In case of direct teaching, learning functions are mainly fulfilled by an external source. These learning situations are characterized by a high degree of external control: the external source initiates and fulfils the learning functions. A second option is activation of learning functions, which pertains to forcing the learner to perform the corresponding learning activities in a specified way. In this case, the degree of external control still is relatively high: the learning functions are initiated and structured by the external source through the presentation of assignments to be performed by the learner. Another way in which instructional systems can influence learning functions is by stimulation, which involves either providing general advice to execute certain learning activities or training the learner to fulfil the learning functions. Compared with the option of activation, stimulation is typified by less external control: the learner is stimulated to initiate and perform the corresponding learning activities. Finally, if the student is able to fulfil learning functions in an adequate way with a (very) low degree of external support, learning is self-regulated.

Many training programs have been developed to improve self-regulation knowledge and skills (see Nisbet, 1989; Van Hout-Wolters, 1994). These training programs considerably differ with respect to the degree of external control provided by the learning environment. Some programs are characterized by a high degree of external control, while, with other training procedures, learners have to rely on themselves to a higher extent (see also Wittrock, 1990). A gradual transfer of the responsibility for learning processes from an external source in the learning environment (e.g. the teacher or C.A.I. program) to the learner ('fading' of external control) seems to be another, promising option to enhance the quality of the student's self-regulated learning. Training programs based upon 'fading' principles are characterized by a gradual withdrawal of external regulation control as the training proceeds (see also Brown, Collins, & Duguid, 1989; De Jong, 1992; Reeve, Palincsar, & Brown, 1987; Simons & Kluvers, 1994).

RESEARCH QUESTIONS AND GENERAL HYPOTHESIS

In the present study, the question was addressed which instructional conditions are required to teach students how they themselves can activate their prior knowledge and how they can initiate and perform learning activities aimed at conceptual change. As mentioned above, gradually transferring the responsibility for learning processes from the learning environment to the learner ('fading') seems to be an adequate approach to promote self-regulated learning. Therefore, in this study, the following general hypothesis with respect to training procedures aimed at promoting self-regulated learning was examined (see also Biemans & Simons, 1992, p. 335): fading (of external control) seems to be a promising approach to reach this goal (enhancing self-regulated learning), provided that the fading procedure is based upon the student's actual level of self-regulated learning. If external support is withdrawn without the student being able and prepared to perform the corresponding regulation activities, poorer learning performance is inevitable; if the fading procedure is tuned to the student's knowledge and skills, however, the quality of self-regulated learning and learning performance can be improved.

Therefore, in this study, the CONTACT-2 strategy (see for more details Biemans & Simons, 1996) served as starting point for computer-assisted 'learning-to-learn' training procedures aimed at teaching students how to perform the various CONTACT-2 activities themselves or, in other words, at teaching students how to activate their own preconceptions and how to construct correct conceptions themselves. To achieve these learning goals, external control was gradually withdrawn as the training went on ('fading'). With the first instructional condition, strategic support was gradually withdrawn within each instructional step while, with the second instructional condition, the number of steps was reduced as the training continued. Moreover, students from both experimental 'fading' conditions were informed of the learning goals: learning how to activate their own preconceptions and how to construct correct conceptions themselves. Paris, Newman, and McVey (1982) had shown that 'informed training' leads to more adequate strategy use and to higher learning performance than 'blind training' (see also De Jong, 1992). Thus, with respect to learning-to-learn training procedures, informing students of the learning goals seems a necessary condition.

In the present study, the CONTACT-2 strategy, which had been designed as part of the previous study, served as control condition (see for more details Biemans & Simons, 1996). To be able to compare the empirical results across studies, the CONTACT-2 conditions from both studies were identical: external control was not withdrawn as the training continued and students were not informed of learning-to-learn training goals (the CONTACT-2 strategy was aimed at promoting conceptual change at content level and not at enhancing the quality of students' self-regulated learning, as opposed to the two experimental conditions).

The main goal of the present study was to examine to what extent the learning activities corresponding to the various instructional steps can be learned. Again, dependent variables concerned quality of students' conceptions, their ability to apply these conceptions, and their learning performance (see for more details Biemans & Simons, 1995, 1996). After the training, students' abilities to initiate and perform learning activities aimed at conceptual change were measured in 2 testing sessions. The specific hypotheses will be described in the section of the same name.

METHOD

Subjects

Subjects were 65 students, being 10 to 13 years old and attending three different classes of two primary schools (30 fifth- and 35 sixth-graders). After being matched based upon their reading comprehension level as judged by their teacher (high, average, or low) and their grade (5 or 6), Ss were assigned to the three instructional conditions at random.

Training and Instructional Conditions

Subjects were assigned to three instructional conditions: the experimental condition 'fading within each instructional step' (N=21), the experimental condition 'fading of the number of steps' (N=22) and the CONTACT-2 control condition (N=22). The CONTACT-2 condition was identical to the condition of the same name used in the previous study (see for more details Biemans & Simons, 1996).

The CONTACT-2 strategy is typified by *cont*inuous, computer-assisted *act*ivation of the conceptions of individual learners in text-processing. The strategy is based upon a process-oriented, heuristic activation model consisting of 5 steps aimed at conceptual change (see also Ali, 1990; Nussbaum & Novick, 1982; Prawat, 1989; Strike & Posner, 1985):

1) searching for own preconceptions;
2) comparing and contrasting these preconceptions with the new information;
3) formulating new conceptions, based upon the previous step;
4) applying the new conceptions;
5) evaluating the new conceptions, based upon the previous step.

The CONTACT-2 steps can also be depicted as a flowchart (see Figure 1) (see for more details about the instructional environment Biemans & Simons, 1995, 1996).

At the beginning of each of the seven training sessions, students have to search for their preconception by answering the particular idea question. An idea question can be described as a concrete problem, which has to be solved by relating the central concepts from the corresponding training text. For example, the idea question from the fourth training session ran as follows:

Suppose it is a hot, sunshiny day and you are on the beach. When you hold your hand close to the sand, you can feel the heat on your skin. What do you experience when you hold your hand higher above the sand?

Students have to choose from six answer alternatives corresponding to different ideas of the relations between the central concepts from the text:

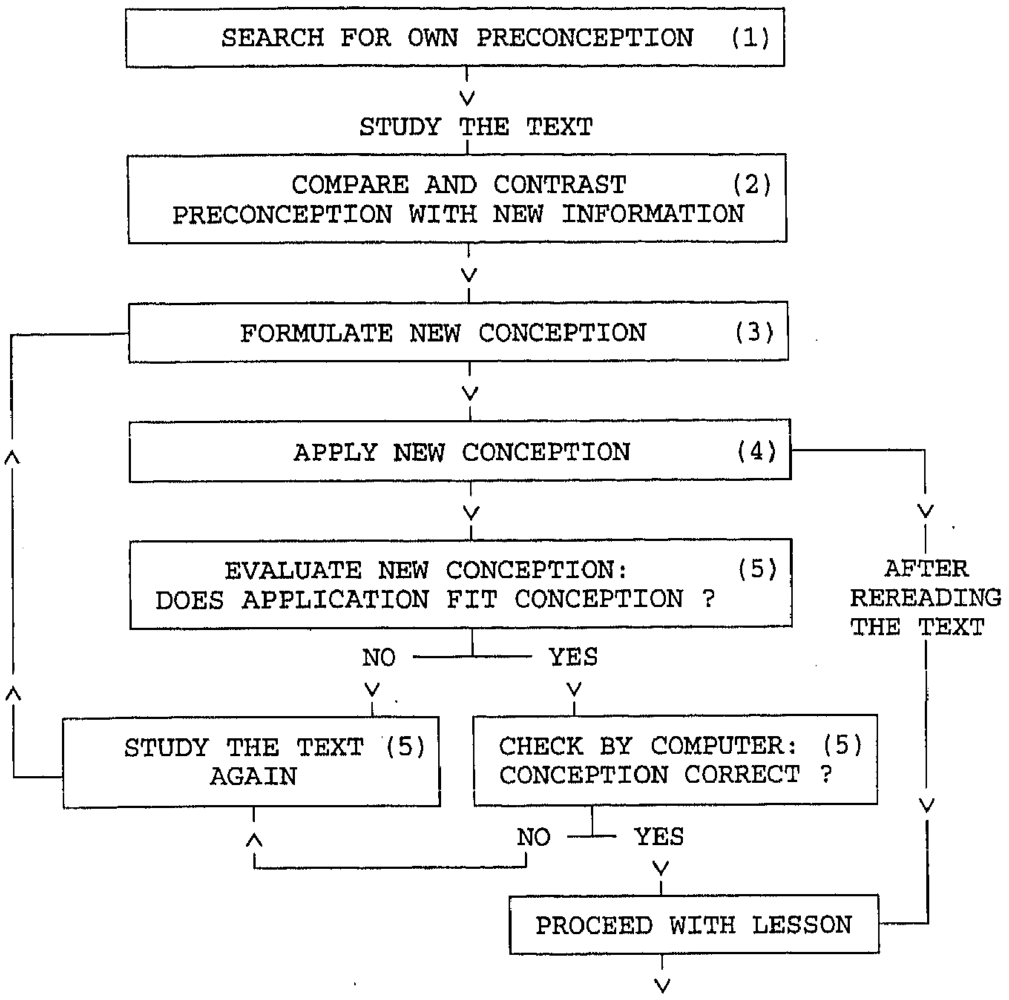

Fig. 1. The steps of the CONTACT-2 strategy.

1. *Higher above the sand it is warmer because it is closer to the sun.*
2. *Higher above the sand it is warmer because hot air goes up.*
3. *Higher above the sand it is warmer because the clouds block the sunbeams.*
4. *Higher above the sand it is colder because sand is always hot.*
5. *Higher above the sand it is colder because the air gets heated from below.*
6. *Higher above the sand it is as warm as it is close to the sand because the sun is everywhere.*

The answer alternatives are based upon various conceptions, which had been determined as frequently held by students in the domain of basic physical geography (see Ali, 1990). One of these answer alternatives corresponds to the generally accepted scientific notion as explained in the text. The answer given by the particular student is regarded as his or her initial idea or preconception.

When students have answered the idea question, they have to study the first part of the (new) information from the text. The seven training texts are all relatively short (7-8 text screens plus 2-3 pictures; 400-550 words). The texts deal with basic physical geography, treating weather concepts like equator, earth rotation, rain, wind, atmospheric pressure, etc. Each student is allowed the time he or she needs to study the text screens and to perform the learning activities corresponding to the steps of the instructional strategy.

After studying the first part of the text, students have to compare and contrast their preconception with the essential information from the text. They have to state whether their initial idea (see step 1) is in accordance with the textual information or not.

Next, students have to review their preconception and construct a new conception (formulate a new idea), based upon their conclusions from the previous step: the same idea question (see step 1) is presented again. Their answer is regarded as their new conception.

With the fourth instructional step, students have to apply their new conception by answering a so-called practice question (a concrete problem treating the same concepts and relations between concepts as the particular idea question - see also step 1): based upon their new idea, they have to choose from four answer alternatives. For example, the first practice question from the fourth training session ran as follows:

The sunbeams go down to the earth. Which statement is correct?

1. *The sunbeams lose a large portion of their heat in the atmosphere of the earth. Because of this, it is hotter higher in the atmosphere.*
2. *The sunbeams are only converted into heat at the surface of the earth. Because of this, it is hotter closer to the surface of the earth.*
3. *The sunbeams give their heat directly to the atmosphere of the earth. Because of this, temperatures are the same everywhere in the atmosphere.*
4. *The sunbeams give their heat to the clouds. Because of this, it is hotter higher in the atmosphere.*

Students have to evaluate their new conception by comparing and contrasting their new idea with their answer to the practice question from the previous step: they have to state whether both answers are in accordance with one another or not.

If they state that both answers are not in accordance with one another, students have to study the most important part of the text again to discover the mistakes they have made (the so-called feedback loop). After re-reading the text, they have to construct a new conception (formulate a new idea) and apply this conception again. The same procedure has to be followed if the students' new conception is not correct (yet). Therefore, their idea is checked by the computer.

If students have not constructed a correct conception at the end of the first sequence of steps, a second sequence is presented. On the other hand, if students hold a correct conception at the end of the first sequence, they only have to study the second part of the text. At the end of each training session, students have to state their final conception by answering the particular idea question. Their answer is regarded as their final idea or conception.

With all CONTACT-2 steps, strategic support in 'How' and 'Why' parts is provided. These 'How' and 'Why' parts include regulation questions (to be answered by the students to regulate their own learning activities aimed at conceptual change) and regulation hints (see also Biemans, 1989; Biemans & Simons, 1992; De Jong, 1992): the 'How' parts contain information about how that particular step can be realized and, in the 'Why' parts, the relevance of the particular step is explained. When students are executing a particular step, the corresponding 'How' and 'Why' parts are optional. During the first sequence of steps, however, the so-called monitoring question 'Do you understand what to do with this step?' is always posed before the students can execute the particular step. In case of a negative answer, students have to study the corresponding 'How' parts before executing the step. In case of an affirmative answer, students can execute the step immediately.

In the CONTACT-2 control condition, external control through regulation questions, regulation hints, and monitoring questions was not 'faded' throughout the training. In the two experimental conditions, however, external control was gradually withdrawn as the training went on (see also section 'Research questions and general hypothesis'). These 'fading' procedures consisted of four stages.

The 'fading' procedure for the first experimental condition 'fading within each instructional step' ran as follows:

- at the beginning of the training, students were supported by the complete CONTACT-2 strategy (stage 1: introduction session and first training session);
- during the next two sessions, students were only supported by regulation questions and regulation hints (the 'How' and 'Why' parts): monitoring questions ('Do you understand what to do with this step?') were omitted (stage 2: second and third training session);

- during the next two sessions, students were only supported by regulation questions: regulation hints were omitted as well (stage 3: fourth and fifth training session);
- during the last two training sessions, regulation questions were 'faded' as well: students had to perform the various CONTACT-2 steps without strategic support (stage 4: sixth and seventh training session).

For the second experimental condition 'fading of the number of steps', the following 'fading' procedure was used:

- at the beginning of the training, students were supported by the complete CONTACT-2 strategy (stage 1: introduction session and first training session);
- during the next two sessions, students were supported by the five CONTACT-2 steps without the feedback loop (stage 2: second and third training session);
- during the next two sessions, students were supported by the first three CONTACT-2 steps: the steps 'apply the new conception' and 'evaluate the new conception' were omitted as well (stage 3: fourth and fifth training session);
- during the last two training sessions, only the first CONTACT-2 step 'search for own preconception' was presented: the steps 'compare and contrast the preconception with the new information' and 'formulate a new conception' were omitted as well (stage 4: sixth and seventh training session).

Design and Testing Materials

In the experimental design, the factor Instruction was used as between-subjects factor. The factor Instruction had three levels: the experimental condition 'fading within each instructional step' (condition 1), the experimental condition 'fading of the number of steps' (condition 2), and the CONTACT-2 control condition (condition 3) (see also section 'Training and instructional conditions').

As mentioned in the section 'Research questions and general hypothesis', students' abilities to initiate and perform learning activities aimed at conceptual change were measured in two testing sessions after the training. During the first testing session, students had to perform the various CONTACT-2 activities without the support of regulation questions, regulation hints, and monitoring questions: in this case, the CONTACT-2 steps were presented without additional help (see also section 'Training and instructional conditions'). During the second testing session, students' conceptions were only activated before and after studying the text through the idea question (see the example in the section 'Training and instructional conditions'): in this case, students had to initiate the various CONTACT-2 activities themselves (the CONTACT-2 steps were not presented).

The first two hypotheses concerning the intervention effects (see also section 'Specific hypotheses') pertained to the variables registered as part of these testing sessions. For both testing sessions, these dependent variables concerned: 1) quality of students' conceptions at the beginning and at the end of each session: 2) quality of students' conceptions after the session and their ability to apply these conceptions, and 3) students' learning performance (see for more details about the dependent variables and the corresponding testing materials Biemans & Simons, 1995, 1996).

The effects of the training on the quality of students' conceptions were measured through the idea question from the particular session (see the example in the section 'Training and instructional conditions'): students had to state their conception both at the beginning and at the end of each testing session.

The quality of students' conceptions and their ability to apply these conceptions were also measured after each testing session. Immediately after each session, students answered the particular idea question. Moreover, they answered the two practice questions from the particular session (see the example in the section 'Training and instructional conditions'). The same questions were posed after two weeks.

The training effects on students' learning performance were measured through a computer-based posttest which was administered after each testing session. Each posttest consisted of nine questions (with four answer alternatives) dealing with concepts and relations between concepts from the particular text. For example, one of the posttest questions from the fourth training session ran as follows:

Suppose, there is a very tall tree in the forest.
Which statement is correct?

1. *It is hotter close to the top of the tree than it is close to the surface of the earth.*
2. *It is colder close to the top of the tree than it is close to the surface of the earth.*
3. *Close to the top of the tree it is as hot or as cold as it is close to the surface of the earth.*
4. *Close to the top of the tree it is always hotter than it is close to the surface of the earth because the heat stays there.*

The third hypothesis concerning the intervention effects pertained to the data registered as part of the various training sessions: with respect to the training sessions data, the stages of the 'fading' procedures were assumed to affect the quality of the students' conceptions, their ability to apply these conceptions, and their learning performance (see also section 'Specific hypotheses'). These variables were measured in a similar way as the dependent variables registered as part of the two testing sessions (see for more details about the dependent variables and the corresponding testing materials Biemans & Simons, 1995, 1996). Students' learning performance, however, was measured both through a posttest, which was administered immediately after the corresponding training session, and through a retention test, which was delivered two weeks after the last training session.

Procedure

The procedure of this experiment was comparable to the procedure of the previous studies (see for more details Biemans & Simons, 1995, 1996). The procedure is depicted in Figure 2.

Specific Hypotheses

The main goal of the present study was to examine to what extent the learning activities corresponding to the various instructional steps can be learned. Again, dependent variables concerned quality of students' conceptions, their ability to apply these conceptions, and their learning performance (see for more details Biemans & Simons, 1995, 1996). After the training, students' abilities to initiate and perform learning activities aimed at conceptual change were measured in two testing sessions.

The hypotheses concerning the intervention effects mainly pertained to the variables registered during these two testing sessions. Both 'fading' conditions were hypothesized to be more effective than the CONTACT-2 control condition, which was characterized by a constant, high degree of external control: because of the gradual withdrawal of external support, the 'fading' conditions were assumed to prepare students to a higher

Session 1	Introduction session
Session 2 - 8	Training session + posttest + idea question and practice questions
Session 9	Testing session A + posttest + idea question and practice questions
Session 10	Testing session B + posttest + idea question and practice questions
Session 11	Retention test + idea questions and practice questions

Fig. 2. Procedure of the present study.

extent to perform the various learning activities themselves. Moreover, during the training, these students were informed that they had to learn to activate their own prior knowledge and to construct correct conceptions without external support. Therefore, both experimental 'fading' conditions were expected to lead to conceptions of a higher quality and to higher learning performance than the CONTACT-2 control condition (hypothesis 1).

With respect to the two experimental conditions, the first condition ('fading within each instructional step') was hypothesized to be more effective than the second condition ('fading of the number of steps'): reducing the number of instructional steps (as in the second condition) was assumed to be too drastic in the time-span of the training. If external support is withdrawn without the student being able (and prepared) to perform the corresponding learning activities, 'destructive frictions' and poorer learning performance are likely to be the result (see also Lohman, 1986; Vermunt, 1992). The first experimental condition ('fading within each instructional step'), in which the number of instructional steps stays constant but external control is reduced within each step, was expected to be better tuned to the student's actual level of self-regulated learning (see also Biemans & Simons, 1992). Therefore, this 'fading' condition was assumed to result in 'constructive frictions' and higher learning performance (hypothesis 2) (see also Lohman, 1986; Vermunt, 1992).

In both experimental conditions, external control was gradually withdrawn as the training went on. These 'fading' procedures consisted of four stages. During the first stage of the training, maximum support was provided by the instructional strategy, while, during the fourth training stage, external control was minimal. With respect to the training sessions data, the stages of the 'fading' procedures were assumed to affect the quality of the students' conceptions, their ability to apply these conceptions, and their learning performance. In other words, differences between the various instructional conditions were hypothesized to depend on the stages of the training. Again, the first experimental condition 'fading within each instructional step' was expected to be more effective and efficient than the other experimental condition 'fading of the number of steps' and the CONTACT-2 control condition. As reducing the number of instructional steps (as in the second condition) was assumed to be too drastic in the time-span of the training, differences between both experimental conditions were hypothesized to increase during the training (hypothesis 3) (see also Lohman, 1986; Vermunt, 1992).

Data analysis

To test the first two hypotheses (see also section 'Specific hypotheses'), three ANOVA's with the between-subjects factor Instruction were carried out for each of the two testing sessions (testing session A and testing session B). Before carrying out the analyses, mean scores were calculated by dividing the sum scores by the number of questions. The first ANOVA concerned the quality of students' conceptions at the beginning and at the end of each session. Here, the factor Session Time was introduced as within-subjects factor (see Table 1). The second ANOVA concerned the quality of students' conceptions after the session and their ability to apply these conceptions. In this analysis, the factor Testing Time was used as within-subjects factor (see Table 1). Finally, in the third ANOVA, students' learning performance was used as dependent variable (see Table 1) (see for more details about the dependent variables and the corresponding testing materials Biemans & Simons, 1995, 1996).

To test the third hypothesis (see also section 'Specific hypotheses'), three repeated measurement ANOVA's were carried out on the training sessions data (see also Table 2). Before carrying out the analyses, mean scores were calculated for each of the four 'fading' stages of the training by dividing the sum scores by the number of questions.

To explore the training effects on the quality of the students' conceptions during the seven training sessions, a repeated measurement ANOVA with the between-subjects factor Instruction and the two within-subjects factors Training Time and Training Stage was carried out (see Table 2). To examine whether the training affected the quality of the students' conceptions after the seven training sessions and their ability to apply

Table 1. Dependent Variables, Within-subjects Factors, and their Levels with respect to the Testing Sessions Data.

Dependent variable	Within-subjects factor	Levels
Conceptions during session	Session Time	Preconception Final conception
Conceptions after session + ability to apply	Testing Time	Immediately after session After two weeks
Learning performance	—	—

these conceptions, a repeated measurement ANOVA with the between-subjects factor Instruction and the two within-subjects factors Training Stage and Testing Time was carried out (see Table 2). Finally, to determine the training effects on the students' learning performance after the seven training sessions, a repeated measurement ANOVA with the between-subjects factor Instruction and the two within-subjects factors Training Stage and Testing Time was carried out (see Table 2) (see for more details about the dependent variables and the corresponding testing materials Biemans & Simons, 1995, 1996).

RESULTS

To be able to test the first two hypotheses (see also section 'Specific hypotheses'), two testing sessions were included in the present study. In both testing sessions, the following dependent variables were measured: quality of the students' conceptions during the session, quality of the

Table 2. Dependent Variables, Within-subjects Factors, and their Levels with respect to the Training Sessions Data.

Dependent variable	Within-subjects factors	Levels
Conceptions during training	Training Time	Preconception
		Final conception
	Training Stage	Stage 1
		Stage 2
		Stage 3
		Stage 4
Conceptions after training + ability to apply	Training Stage	Stage 1
		Stage 2
		Stage 3
		Stage 4
	Testing Time	Immediately after training
		After two weeks
Learning performance	Training Stage	Stage 1
		Stage 2
		Stage 3
		Stage 4
	Testing Time	Posttest
		Retention test

students' conceptions after the session and their ability to apply these conceptions, and their learning performance (see for more details about the dependent variables and the corresponding testing materials Biemans & Simons, 1995, 1996). First, the results of testing session A will be reported, followed by the results of session B.

Testing Session A

During the first testing session (testing session A), students had to perform the various CONTACT-2 activities without the support of regulation questions, regulation hints, and monitoring questions.

Conceptions during the Session

In this ANOVA, the main effect of the factor Instruction ($F(2,62)=.30$; $p=.74$) was not significant. The interaction effect between Instruction and Session Time ($F(2,62)=3.14$; $p\leq.05$), however, turned out to be significant. This interaction effect was not significant for the conditions 1 and 3 ($t=1.35$; $p=.18$) and the conditions 2 and 3 ($t=1.17$; $p=.25$) (see hypothesis 1). With respect to the conditions 1 and 2, however, the interaction effect between Instruction and Session Time was significant (see hypothesis 2): no differences were found between both conditions with respect to the quality of students' preconceptions; students from condition 1, however, had final conceptions of a higher quality than students from condition 2 ($t=2.50$; $p\leq.05$) (see Figure 3a).

Conceptions after the Session and Ability to Apply these Conceptions

In this analysis, the main effect of the factor Instruction ($F(2,62)=3.26$; $p\leq.05$) was significant. Differences between conditions 1 and 3 ($t=1.62$; $p=.11$) and conditions 2 and 3 ($t=.92$; $p=.36$) again were not significant (see hypothesis 1). Students from condition 1, however, had higher scores on the idea and practice questions than students from condition 2 ($t=2.53$; $p\leq.01$) (see hypothesis 2) (see Figure 3b). The interaction effect between Instruction and Testing Time ($F(2,62)=.40$; $p=.67$) was not significant.

Learning Performance

With respect to testing session A, the effect of the factor Instruction ($F(2,62)=.41$; $p=.67$) on students' learning performance was not significant: no differences were found between condition 1 ($M=.45$; $Sd=.22$), condition 2 ($M=.46$; $Sd=.16$), and condition 3 ($M=.41$; $Sd=.21$) (see hypotheses 1 and 2).

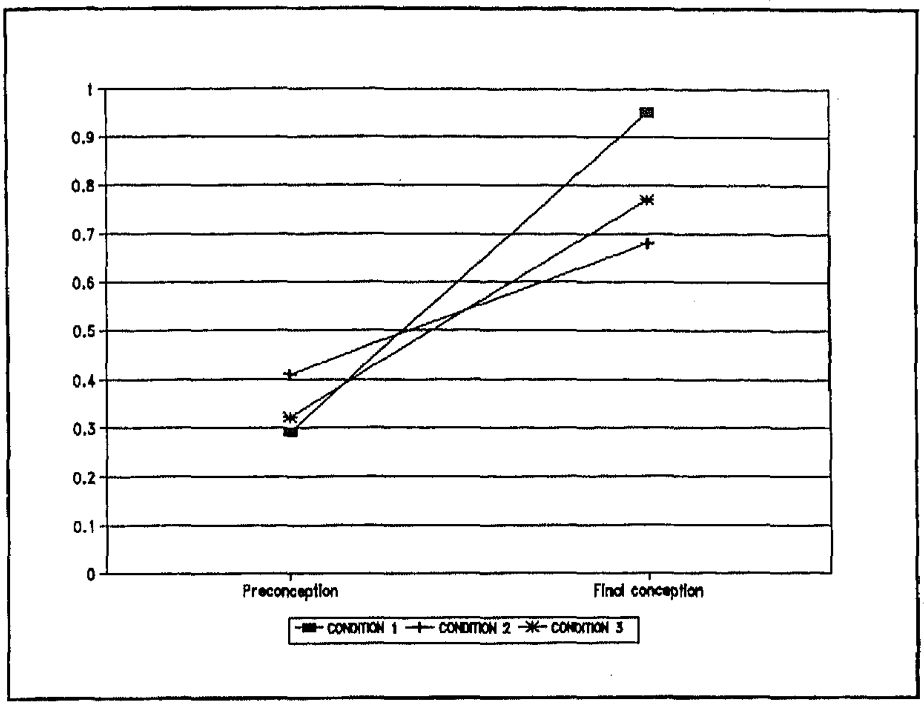

Fig. 3a. Mean scores for the 3 instructional conditions with respect to the quality of students' preconceptions and final conceptions (testing session A).

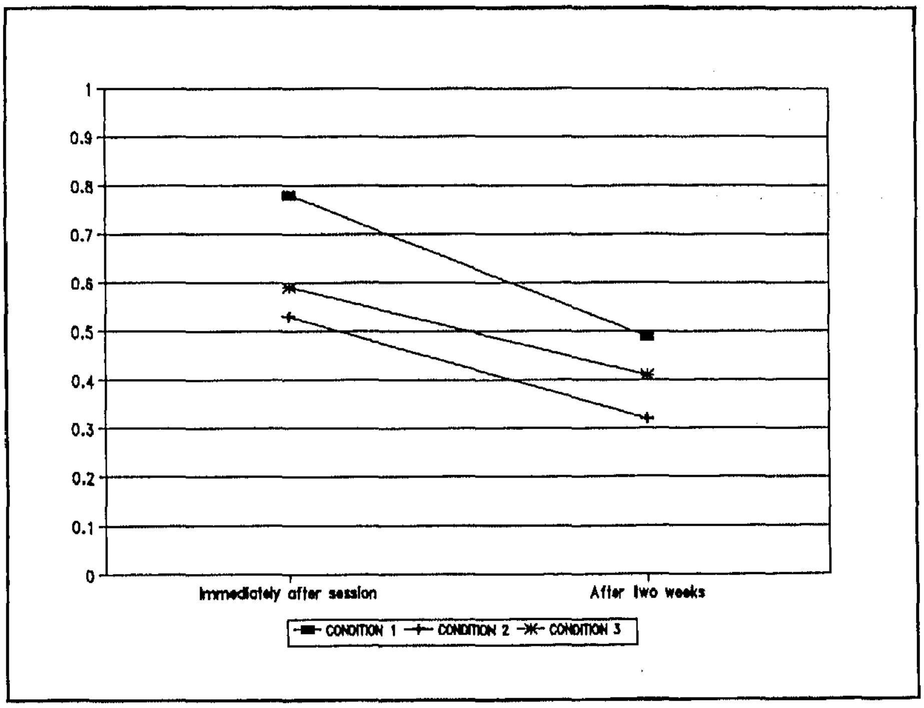

Fig. 3b. Mean scores for the 3 instructional conditions with respect to the quality of students' conceptions after the session and their ability to apply these conceptions (testing session A).

Testing Session B

During the second testing session (testing session B), students' conceptions were only activated before and after studying the text: in this case, students had to initiate the CONTACT-2 activities themselves.

Conceptions during the Session

With respect to testing session B, the main effect of the factor Instruction ($F(2,62)=4.74$; $p \leq .01$) was significant. Students from condition 1 had conceptions of a higher quality than students from condition 3 ($t=3.08$; $p \leq .005$) (see hypothesis 1) (see Figure 4a). Differences between conditions 1 and 2 ($t=1.59$; $p=.12$) (see hypothesis 2) and conditions 2 and 3 ($t=1.51$; $p=.14$) (see hypothesis 1) were not significant. The interaction effect between Instruction and Session Time ($F(2,62)=1.16$; $p=.32$) was not significant either.

Conceptions after the Session and Ability to Apply these Conceptions

The main effect of the factor Instruction ($F(2,62)=2.19$; $p=.12$) was not significant: no significant differences could be determined between the various instructional conditions (see Figure 4b) (see hypotheses 1 and 2). The interaction effect between Instruction and Testing Time ($F(2,62)=1.47$; $p=.24$) was not significant either.

Learning Performance

The effect of the factor Instruction ($F(2,62)=3.36$; $p \leq .05$) on learning performance was significant. Students from condition 1 ($M=.49$; $Sd=.23$) had higher learning performance scores than students from condition 3 ($M=.36$; $Sd=.15$) ($t=2.07$; $p \leq .05$) (see hypothesis 1). The same held for students from condition 2 ($M=.51$; $Sd=.25$) ($t=2.38$; $p \leq .05$) (see hypothesis 1). The difference between conditions 1 and 2 ($t=.28$; $p=.78$) was not significant (see hypothesis 2).

Training Sessions

To be able to test the third hypothesis (see also section 'Specific hypotheses'), the training sessions data were analysed. As part of the seven training sessions, the following dependent variables were measured: quality of the students' conceptions during the session, quality of the students' conceptions after the session and their ability to apply these conceptions, and their learning performance (see for more details about the dependent variables and the corresponding testing materials Biemans & Simons, 1995, 1996).

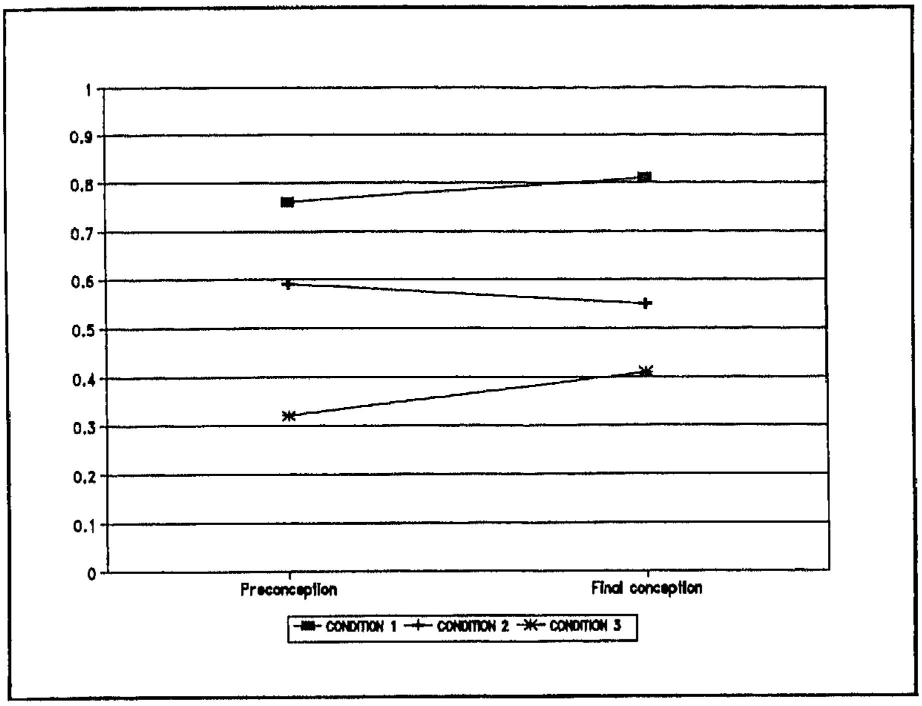

Fig. 4a. Mean scores for the 3 instructional conditions with respect to the quality of students' preconceptions and final conceptions (testing session B).

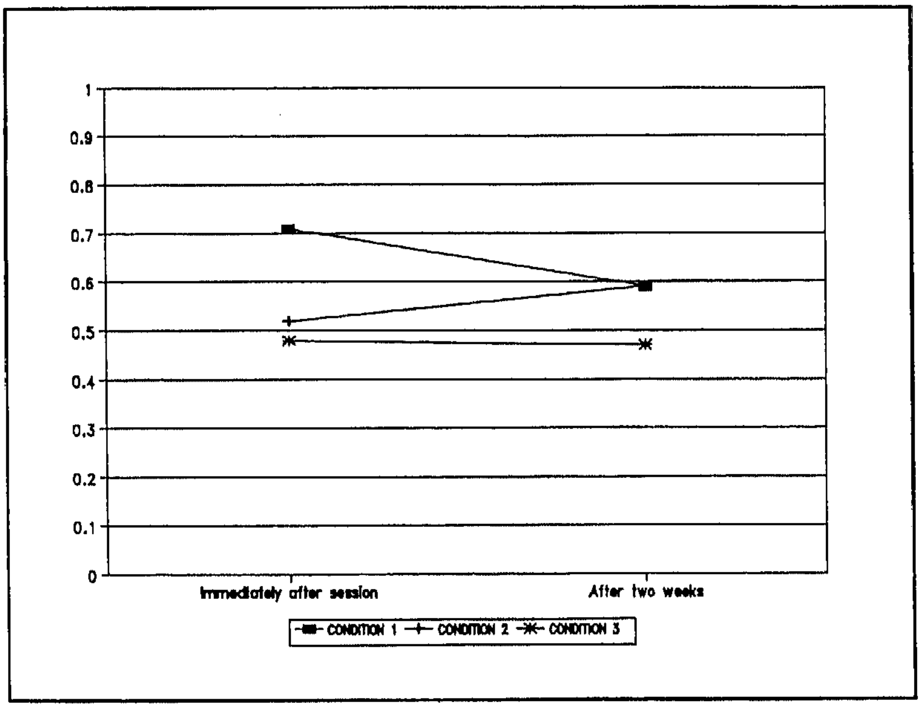

Fig. 4b. Mean scores for the 3 instructional conditions with respect to the quality of students' conceptions after the session and their ability to apply these conceptions (testing session B).

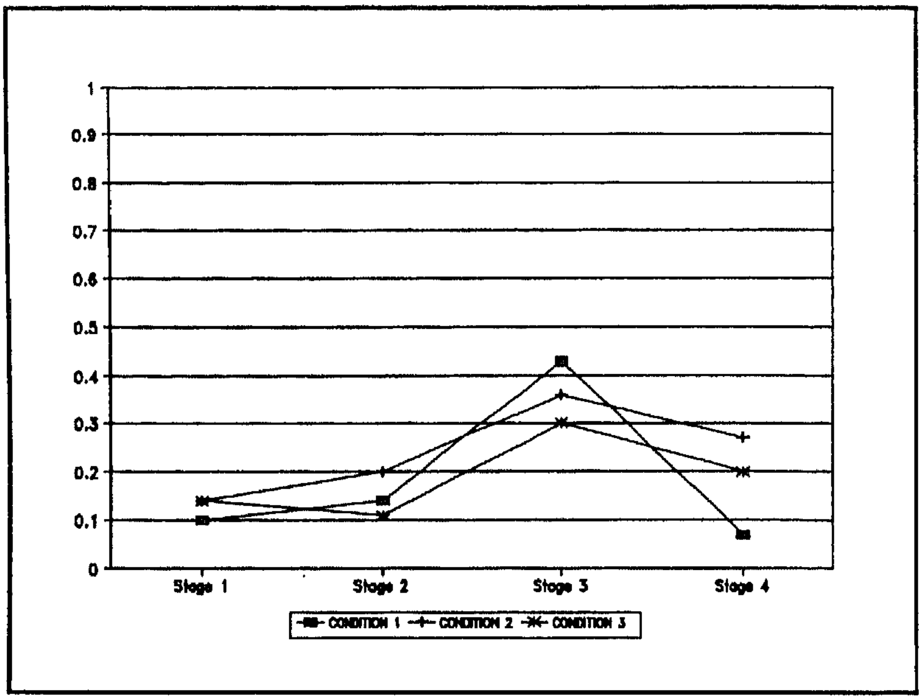

Fig. 5a. Mean scores for the 3 instructional conditions with respect to the quality of students' preconceptions (training sessions).

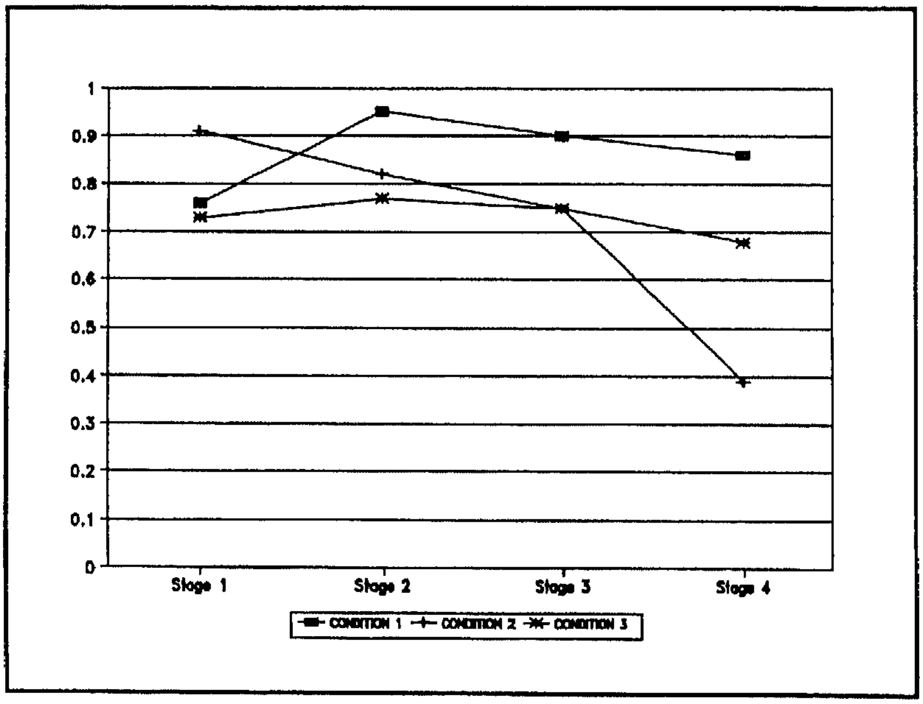

Fig. 5b. Mean scores for the 3 instructional conditions with respect to the quality of students' final conceptions (training sessions).

Conceptions during the training sessions

In this ANOVA, the main effect of the factor Instruction ($F(2,62)=1.02$; $p=.37$) and the interaction effect between Instruction and Training Stage ($F(6,118)=1.75$; $p=.12$) were not significant. The interaction effect between Instruction and Training Time ($F(2,62)=4.31$; $p\leq.05$), on the other hand, was significant. The interaction effect between Instruction, Training Time, and Training Stage ($F(6,118)=3.90$; $p\leq.001$), however, was significant as well. With respect to the quality of students' preconceptions, no differences between the various instructional conditions were found (see Figure 5a).

Concerning the quality of the students' final conceptions, however, such differences could be determined, depending on the training stage: the stage of the 'fading' procedures affected the quality of the students' final conceptions. During the first stage of the training, condition 2 led to final conceptions of a higher quality than the other 2 conditions. During the next stages, however, condition 1 led to the best final conceptions. The quality of the final conceptions of the students from condition 2 decreased dramatically as the training went on (see Figure 5b).

Conceptions after the Training Sessions and Ability to Apply these Conceptions

In this analysis, the main effect of the factor Instruction ($F(2,62)=1.81$; $p=.17$) was not significant. The interaction effect between Instruction and Training Stage ($F(6,118)=2.44$; $p\leq.05$), however, turned out to be significant. During the first half of the training, conditions 1 and 2 led to higher scores on the idea and practice questions than condition 3. During the second half of the training, however, scores of the students from the three conditions became ever more comparable (see Figure 6). Both the interaction effect between Instruction and Testing Time ($F(2,62)=.22$; $p=.80$) and the interaction effect between Instruction, Training Stage, and Testing Time ($F(6,118)=.98$; $p=.44$) were not significant. Thus, the relation between instructional condition and training stage was found both at posttest time and at retention time.

Learning Performance after the Training Sessions

In this ANOVA, the main effect of the factor Instruction ($F(2,62)=1.96$; $p=.15$) was not significant. The interaction effect between Instruction and Training Stage ($F(6,118)=3.89$; $p\leq.001$), however, turned out to be significant again. During the first half of the training, the conditions 1 and 2 led to higher learning performance scores than condition 3 while, during the second half of the training, scores of the students from the three

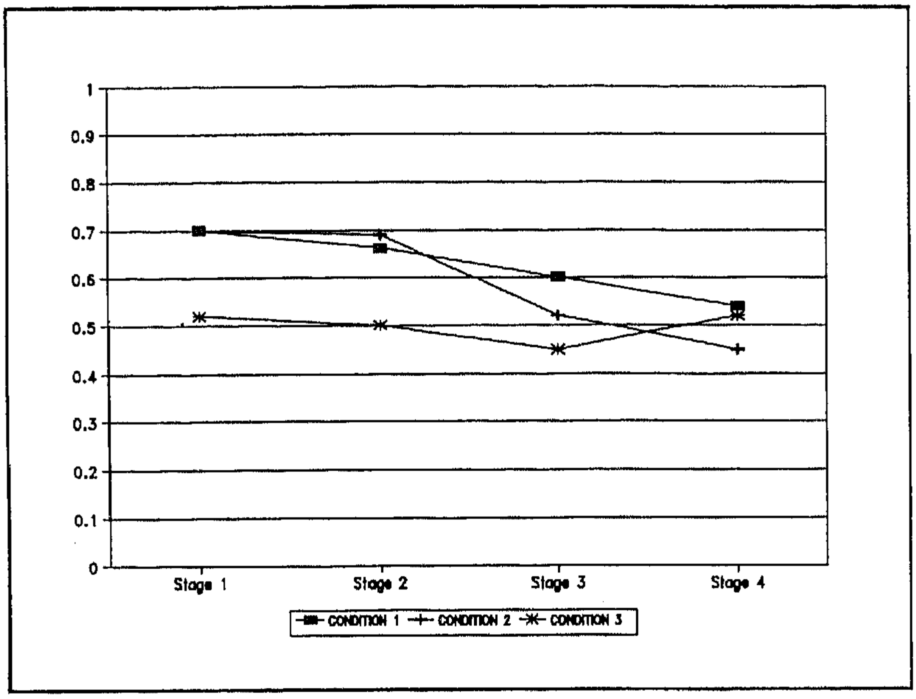

Fig. 6. Mean scores for the 3 instructional conditions with respect to the quality of students' conceptions after the sessions and their ability to apply these conceptions (training sessions).

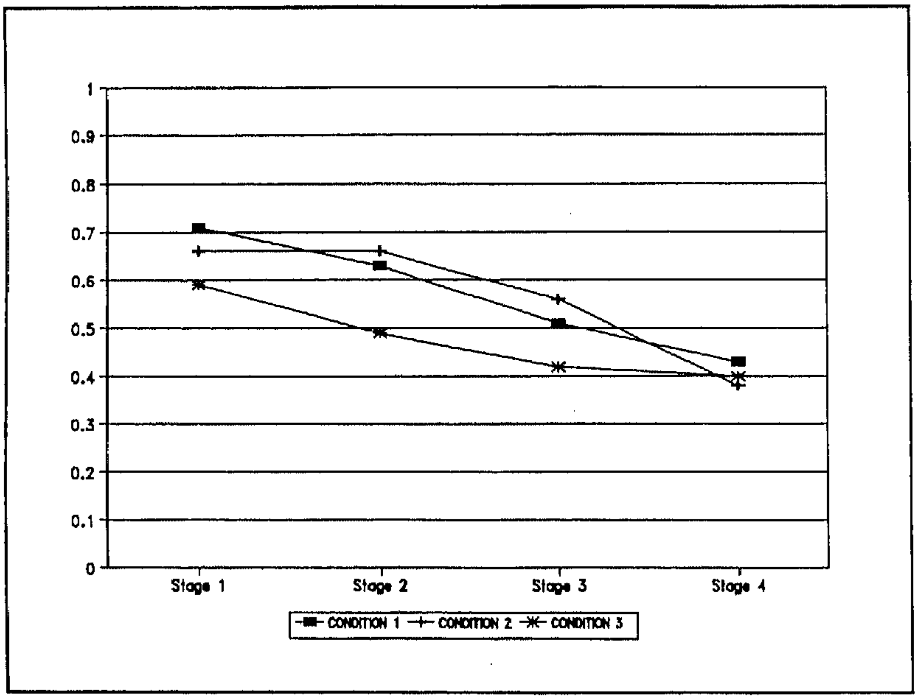

Fig. 7. Mean scores for the 3 instructional conditions with respect to students' learning performance (training sessions).

conditions became ever more comparable (see Figure 7). Both the interaction effect between Instruction and Testing Time ($F(2,62)=.40$; $p=.67$) and the interaction effect between Instruction, Training Stage, and Testing Time ($F(6,118)=1.01$; $p=.42$) were not significant. Thus, the relation between instructional condition and training stage again did not depend on the moment of testing.

CONCLUSIONS AND DISCUSSION

In the present study, the question was addressed which instructional conditions are required to teach students how they themselves can activate their prior knowledge and how they can initiate and perform learning activities aimed at conceptual change. Previous studies (see Brown, Collins, & Duguid, 1989; De Jong, 1992; Reeve, Palincsar, & Brown, 1987; Simons & Kluvers, 1994) showed that gradual transfer of the responsibility for learning processes from the learning environment to the learner ('fading' of external control) can be an adequate approach to promote self-regulated learning.

Therefore, in this study, several hypotheses were tested (as mentioned in the section 'Specific hypotheses', the hypotheses concerning the effects of the training mainly pertained to the variables registered during the two testing sessions). First, both experimental 'fading' conditions were hypothesized to be more effective than the CONTACT-2 control condition. Second, concerning the two experimental conditions, the first condition ('fading within each instructional step') was assumed to be more effective than the second condition ('fading of the number of steps'). In other words, both 'fading' conditions were assumed to lead to conceptions of a higher quality and to higher learning performance than the CONTACT-2 control condition. Moreover, the condition 'fading within each instructional step' was hypothesized to be better tuned to the students' actual level of self-regulated learning than the condition 'fading of the number of steps': the condition 'fading of the number of steps' was expected to result in 'destructive frictions' and, thus, in conceptions of a lower quality and in lower learning performance (see also Lohman, 1986; Vermunt, 1992).

During the first testing session, students had to perform the various CONTACT-2 activities without the support of regulation questions, regulation hints, and monitoring questions. During the last two training sessions for students from the condition 'fading within each instructional step', regulation questions, regulation hints, and monitoring questions had been faded as well. Thus, for them, the degree (and kind) of external control in the last two training sessions and in the first testing session were comparable: students had to rely on themselves to the same extent.

During the last two training sessions for students from the condition 'fading of the number of steps', however, only the first step 'searching for preconceptions' was presented. Therefore, for these students, the degree (and kind) of external control in the first testing session did not match. Apparently, this resulted in 'destructive frictions' and, thus, in conceptions of a lower quality as compared with the condition 'fading within each instructional step'.

Students from the condition 'fading within each instructional step', on the other hand, seemed to be better prepared to perform learning activities aimed at conceptual change under these circumstances: they had final conceptions of a higher quality and were more successful in applying these conceptions. The test scores of the students from the CONTACT-2 control condition were also lower than the scores of the students from the experimental condition 'fading within each instructional step' but these differences were not significant.

With the second testing session, however, students from the condition 'fading within each instructional step' had conceptions of a significantly higher quality than students from the CONTACT-2 control condition and they had significantly higher learning performance scores. During this testing session, students' conceptions were only activated before and after studying the text: in this case, students had to initiate the CONTACT-2 activities themselves, without external support.

Students from the condition 'fading within each instructional step' seemed to be better prepared for this than students from the CONTACT-2 control condition. This could be explained by the fact that the CONTACT-2 condition had been characterized by a constant, high degree of external control. Because of this, these students did not seem able to initiate and perform the various CONTACT-2 activities themselves: they were not trained to do so. Students from the condition 'fading within each instructional step', on the other hand, seemed to be able to regulate their own learning aimed at conceptual change because external control had been gradually 'faded' during the training.

Students from the other experimental condition 'fading of the number of steps' also had higher learning performance scores than students from the CONTACT-2 control condition: for them, external control had been 'faded' during the training as well. So, because of these 'fading' procedures, both experimental conditions seemed to be more effective than the original CONTACT-2 strategy in enhancing students' ability to initiate and perform learning activities aimed at conceptual change.

Furthermore, with respect to the training itself, differences between the various instructional conditions were hypothesized to depend on the stages of the training. Again, the first experimental condition was expected to be more effective and efficient than the second experimental condition and the CONTACT-2 control condition. As reducing the number of instructional steps (as in the second condition) was assumed to be too drastic in the time-span of the training, differences between both experimental conditions were hypothesized to increase during the training (hypothesis 3).

This hypothesis was partly confirmed by the training sessions data. During the first stage of the training, the condition 'fading of the number of steps' led to final conceptions of a higher quality than the other two conditions. During the next training stages, however, the condition 'fading within each instructional step' led to the best final conceptions. The quality of the final conceptions of the students from the condition 'fading of the number of steps' decreased dramatically as the training continued. Thus, in this respect, the condition 'fading within each instructional step' was more effective than the CONTACT-2 control condition and the condition 'fading of the number of steps'.

Apparently, reducing the number of instructional steps (as in the condition 'fading of the number of steps') is indeed too drastic: this 'fading' procedure seems to result in 'destructive frictions' leading to conceptions of a lower quality (see also Lohman, 1986; Vermunt, 1992). Therefore, external support should not be withdrawn until the students are able (and prepared) to perform the corresponding learning activities themselves. In this respect, the other experimental condition 'fading within each instructional step', in which the number of instructional steps stays constant but external control is reduced within each step, appears to be better tuned to the students' actual level of self-regulated learning (see also Biemans & Simons, 1992): this 'fading' condition seems to result in 'constructive frictions' and, thus, in conceptions of a higher quality.

With respect to the quality of the students' conceptions after the seven training sessions and their ability to apply these conceptions, both 'fading' conditions led to higher scores than the CONTACT-2 control condition during the first half of the training. Probably, this was caused by motivational factors (see also Pintrich, Marx, & Boyle, 1993): students from both experimental conditions had been informed that they had to learn to activate their own prior knowledge and to construct correct conceptions without external support or, in other words, to learn in an active way. During the second half of the training, scores of the students from the three conditions became ever more comparable. The same pattern could be traced with respect to the students' learning performance. At this point, however, it should be noted that students from both 'fading' conditions received less external help than students from the CONTACT-2 control condition during the last stages of the training but were nevertheless able to achieve comparable learning results. This should be considered as a positive training effect as well. Moreover, students from both 'fading' conditions spent less time during the second half of the training than students from the CONTACT-2 condition.

To conclude, the results of the present study were in line with the general hypothesis concerning learning-to-learn training procedures formulated in the section 'Research questions and general hypothesis' (see also Biemans & Simons, 1992). 'Fading' of external control (see also Reeve, Palincsar, & Brown, 1987) seems to be a fruitful instructional approach to teach students how to initiate and perform learning activities aimed at conceptual change, provided that the 'fading' procedure is based upon the student's actual level of self-regulated learning. In this way, 'constructive frictions' (see Vermunt, 1992) can be created and the quality of self-regulated learning as well as learning performance can be improved. In the present study, the experimental condition 'fading within each instructional step' was most effective in most learning situations (varying with respect to the degree of external control being provided): this condition appeared to lead to the highest degree of cognitive flexibility.

In other words, with respect to learning-to-learn training procedures aimed at conceptual change, a learning environment characterized by a rather high degree of external control seems to be most appropriate to start with. External control should not be withdrawn until students are able (and prepared) to initiate and perform the learning activities being required: if the degree (or the kind) of external support is not adequate to serve the students needs, 'destructive frictions' and poorer learning performance are likely to be the result (see also Lohman, 1986). When these conditions are met, however, designing effective training procedures aimed at 'learning for conceptual change' seems possible.

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