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The regulation of constructive learning processes

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Background. Classical instructional design theories and constructivist theories disagree on the issue of how high-quality learning can be realised. Research on student learning has identified a large number of learning components, but the problems of overlap among conceptualisations and the direction of interrelations among constructs have received little attention.

Aims. The main aims of this study were: increasing integration of existing models of student learning; gaining understanding of the regulation of constructive learning processes; and investigating the degree to which these phenomena generalise across contexts.

Samples. A total of 717 students from an open university (OU) and 795 students from a regular university (RU), from various academic disciplines, participated in the studies. The mean age of the OU students was 36.2 years and of the RU students 22.5 years.

Methods. Based on phenomenographic studies, a diagnostic instrument was constructed that covered four learning components: cognitive processing, metacognitive regulation, mental learning models, and learning orientations. It was administered to all students from the samples. Factor analyses on the data were conducted to achieve a more integrated model of student learning. Regression analyses were performed to study the directionality in the regulation of learning processes.

Results. Four learning dimensions were consistently found: an undirected, reproduction-directed, meaning-directed and application-directed style. These styles consisted of typical combinations of learning components. Moreover, students' use of constructive processing strategies was explained much better by self-regulation of learning than by external regulation. These findings were almost identical at both educational institutions, indicating a high degree of generalisability.

Conclusions. The integrated model of student learning developed in this study can reduce the overlap among learning component conceptualisations considerably. The results stress the importance of process-oriented teaching models for improving the quality of student learning.

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In recent years the quality of the learning processes that students realise has received increased attention in both educational practice, research and theory. For example, an explosive growth of the number of participants could be observed in higher education. Lecturers were challenged to give more students a fully-fledged academic education, often in less time. This has given rise to worries among policy-makers, teachers and students about the quality of learning processes in these environments. Among researchers the attention for the quality of learning has grown as well (e.g., Wagner & McCombs, 1995). For example, Entwistle's (1995) studies are concerned with exploring influences on the quality of learning in higher education. Volet (1995) emphasises the importance of research aimed at improving the quality of students' cognitive and metacognitive processes for constructing and using knowledge. Lonka's (1997) studies are aimed at exploring constructive processes in student learning. In educational theory, a dispute has been going on between classical objectivist theorists and advocates of the more recent constructivist theories of learning and teaching (Duffy & Jonassen, 1992; Prawatt & Floden, 1994; Simons, 1993).

An issue of disagreement among theorists is the way in which high-quality learning can be achieved. Until recently, theories on instructional design took little account of the results of cognitive-psychological research on learning processes (see, e.g., Elen & Lowyck, 1995; Vermunt, 1992). In classical instructional design theories the designer of instruction is the directing agency, who prescribes to a high degree how learners should behave to realise the objectives presented by the designer. This view on the design of instruction is founded on the idea that teaching in essence comes down to transfer of knowledge from an external source to the learner. Ever more, however, this view has come under pressure (see, e.g., Biggs, 1996; Shuell, 1996). A lively discussion has recently arisen about the presuppositions of these design theories. For instance, Duffy & Jonassen (1992) state that 'learning' is not a passive, knowledge-consuming and externally directed process, but an active, constructive and self-directed process in which the learner builds up internal knowledge representations that form a personal interpretation of his or her learning experiences. These representations constantly change on the basis of the meanings people attach to their experiences. Duffy & Jonassen argue for founding instructional design consistently on a theory of learning. In short, the students' learning activities are under external control in traditional instructional design theories, while in constructivist theories these learning activities are under control of the learner.

A fundamental issue, then, regarding the promotion of high-quality learning is whether this may be accomplished by direct external instructions, for example learning objectives, questions, or study tasks. A study by Marton & Säljö (1984) indicated, for example, that questions intended to induce a deep approach to learning resulted in a 'technification' of the learning processes of students. Students shifted their attention to being able to answer the questions that were posed, but did not engage in a deep approach to learning. This suggests that inducing a deep approach to learning may not be realised by direct instructions. Yet, as mentioned above, in many instructional design theories and practices didactic aids are the most common means to try to influence the students' way of processing. For example, in distance education these adjunct aids are often interwoven in the learning materials (e.g., objectives, questions, directions for studying), and in regular education students are often confronted with both adjunct aids in textbooks as well as tasks, questions, or assignments given by the lecturer.

To gain some initial understanding of this phenomenon of 'regulation of high-quality learning', Vermunt (1996) extensively interviewed regular and distance university students about various aspects of their learning. More specifically, they answered questions about their learning activities and strategies, conceptions of learning and teaching, learning orientations, and interpretations and appreciations of instructional measures. In short, the results indicated that four qualitatively different ways of learning could be discerned, and that these differences in quality were manifested in several learning components, such as the cognitive processing strategies and metacognitive regulation strategies students employed to learn, their mental models of learning, and their learning orientations.

Cognitive processing activities are those thinking activities students use to process learning contents and to attain their learning goals by doing so. They directly lead to learning results in terms of attributes such as knowledge, understanding, and skill. Examples are: looking for relations among the parts of the subject matter, memorising and rehearsing learning contents, thinking of examples, and selecting main points (Geisler-Brenstein, Schmeck & Hetherington, 1996; Janssen, 1996; Schellings, Van Hout-Wolters & Vermunt, 1996). Metacognitive regulation activities are directed at regulating the cognitive activities and therefore lead to learning results indirectly. Examples are: planning a learning process, monitoring learning progress, and diagnosing the cause of difficulties that arise during learning (Brown, 1987; Volet, 1991). Active, 'on-line' regulation of learning is one aspect of metacognition; it is the more dynamic aspect. Another aspect is more static in nature: the knowledge, views, conceptions and beliefs people have about learning processes, the functioning of one's own thinking and the variables that influence these processes. A mental model of learning is viewed here as a coherent whole of learning conceptions: conceptions and misconceptions about learning processes. This concerns conceptions of learning and thinking activities, conceptions about oneself as a learner, conceptions of learning objectives and learning tasks, conceptions of learning and studying in general and conceptions of the task division between oneself and others in learning processes (e.g., Flavell, 1987; Lonka, Joram & Bryson, 1996; Marton, Dall'Alba & Beaty, 1993; Prosser, Trigwell & Taylor, 1994). Learning orientations refer to the whole domain of personal goals, intentions, motives, expectations, attitudes, worries and doubts of students in doing courses or studies (Biggs, 1987; Entwistle, 1988; Gibbs, Morgan & Taylor, 1984). Learning styles are viewed here as consisting of these four elements: the cognitive processing activities students employ, the metacognitive regulation activities they use to direct their learning processes, their mental models of learning and teaching, and their learning orientations.

The majority of study strategies research thus far has focused on cognitive processing strategies and motivation. For example, Pask (1988) identified a serialist and holist strategy that students may employ in achieving understanding. Marton & Säljö (1984) interviewed students about their approaches to learning and identified a deep and a surface approach. Svensson (1984), in describing structural differences in student learning, proposes the distinction between an atomistic and a holistic approach. Geisler-Brenstein *et al.* (1996) discern five types of learning strategies: deep learning, elaborative processing, agentic learning, methodical learning, and literal memorisation. They developed an instrument, the Inventory of Learning Processes — Revised (ILP-R), to assess these learning strategies. Biggs (1987) makes a distinction between three types of learning strategies, deep, surface and achieving, each corresponding with a particular study motive: intrinsic, extrinsic and achievement motivation. He developed the Study Process Questionaire (SPQ), a self-report instrument, to measure these dimensions of student learning. Tait & Entwistle (1996) developed the Revised Approaches to Studying Inventory (RASI). The RASI contains scales in the domain of cognitive processing (e.g., deep approach, surface approach, strategic approach and apathetic approach) and study motivation and affection (e.g., active interest, fear of failure, intention to excel and lack of direction). Both the SPQ and RASI are widely used instruments to assess student learning (see for example Andrews, Violato, Rabb & Hollingsworth, 1994). Weinstein, Zimmermann & Palmer (1988) developed the Learning and Study Strategies Inventory (LASSI), that contains scales not only in the domains of cognitive processing (e.g., 'information processing') and motivation (e.g., 'motivation') but also on metacognitive regulation (e.g., 'self-testing').

The various conceptualisations of learning strategies in the domain of cognitive processing show considerable overlap, as is the case with the various conceptualisations of student motivation dimensions (see, for example, Janssen, 1996; Tait & Entwistle, 1996). In contrast, until now little is known about relations between regulation activities in the way students use them (Brown, 1987; Volet, 1991). Stylistic aspects of this regulation of learning phenomenon, and the way this regulation is associated with the use of processing strategies by students, remain obscure so far. One objective of the studies here reported upon is to investigate these overlaps and interrelations.

What also remains scarce in the literature on student learning are studies in which the relations between cognitive and regulative learning strategies, mental models of learning and learning orientations are investigated. Although there are some studies in which two existing instruments were administered (e.g., Murray-Harvey, 1994), some studies in which cognitive and motivational aspects of student learning are studied simultaneously (Andrews *et al.*, 1994; Biggs, 1987; Janssen, 1996), some studies which add regulative aspects to these variables (e.g., Pintrich, Smith, Garcia & McKeachie, 1993; Weinstein *et al.*, 1988), studies in which cognitive, regulative, metacognitive and motivational components of student learning are studied together in one study are scarce (see for an exception Lonka & Lindblom-Ylänne, 1996). Almost no models of student learning incorporate all these four components. For example, the relative importance of mental learning models and learning orientations in regulating learning behaviour needs clarification. Other issues under discussion are the bipolarity of learning strategies and style dimensions, and the stability of these phenomena (Messick, 1994; Riding & Cheema, 1991).

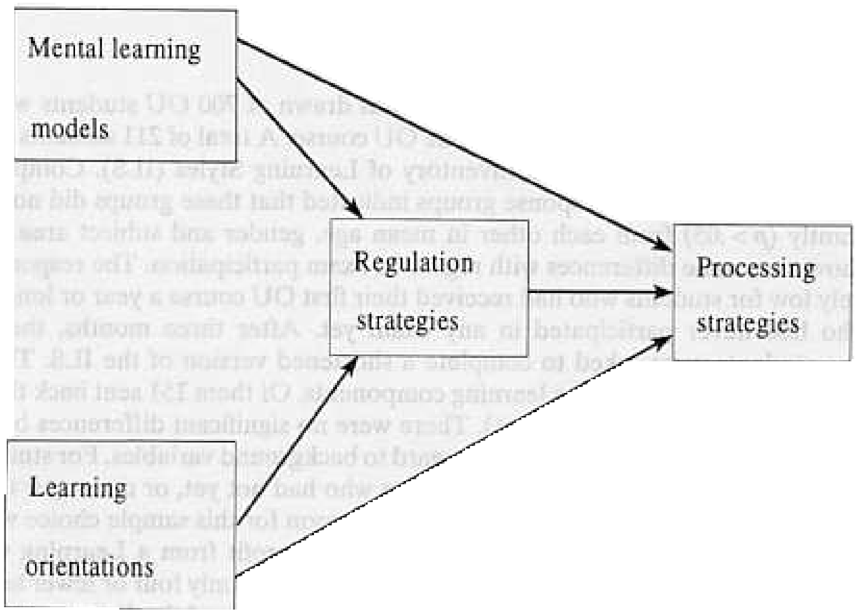
Typically, research with instruments such as the ILP-R, SPQ, RASI and LASSI use factor analysis to identify associations among the student learning dimensions (items and scales) they measure. From a regulation-of-learning perspective, however, one might argue that regression analysis is a more appropriate statistical technique. Regulation of learning implies directionality: students employ regulation strategies to direct their processing of subject matter, and this regulation is influenced by conceptions of learning and learning orientations.

Finally, most studies on student learning are conducted within the context of one particular educational institute. The issue of the extent to which the findings can be generalised to other student populations often is not addressed.

The present studies

The objectives of the studies reported in this article were fourfold. First, the studies were aimed at increasing the integration of existing conceptualisations of student learning components and at linking metacognitive aspects of student learning to students' cognitive processing strategies and study motivation. In this sense the studies were meant to verify the results of Vermunt's (1996) phenomenographic studies on a larger scale. Secondly, the studies were aimed at gaining understanding of the 'regulation of learning' phenomenon. Here, the point of departure was the model depicted in Figure 1. According to this model, the way in which students process the subject matter is most directly determined by the regulation strategies they employ. Mental learning models and learning orientations also influence the processing strategies that students use, but their influence is supposed to be mostly indirect, via regulation strategies. The way in which students regulate their learning processes is, to an important extent, determined by their mental models of learning and their learning orientations. Thirdly, the degree to which these phenomena generalise across contexts was investigated by studying two different types of learning environments: distance education (an open university) and regular education (a regular university). Fourthly, the stability over time of learning styles was studied.

Figure 1. A model of the regulation of constructive learning processes



Research contexts. Studying at the open university (OU) means that students work much with self-instructional materials. Beside their actual learning content, these materials contain many in-text teaching devices meant to support and direct the learning processes of students. Examples are: introductions, highlighted central concepts, summaries, overviews, rehearsal units, assignments, learning objectives, questions, tasks, directions for studying, and self-tests with feedback. Students can also attend a limited number of meetings guided by a tutor. In contrast, studying at the regular university (RU) is characterised by a combination of independent study, lectures, and tutorials. Students independently study the materials chosen or compiled by their teachers. These study materials may also contain regulation devices like objectives, questions, and the like, but most of them do not. There are relatively many contact periods with teachers that students may attend. In these lectures and tutorials teachers clarify the subject matter and provide students with directions for their independent study.

Four studies will be reported upon: three done at an open university and one study done at a regular university. In each study partly similar and partly unique data were gathered. The similar aspects are reported upon here. *Study OU-1* was primarily aimed at the construction of a reliable diagnostic instrument, at studying relationships among processing and regulation strategies, mental learning models, and learning orientations, and at investigating the stability of learning style components. One of the aims of *Study OU-2* was to study the learning effects of a Learning Guide composed around the Inventory of Learning Styles. An important aim of *Study OU-3* was to study relationships between students' learning strategies and all kinds of exam results. The main goal of *Study RU-1* was to investigate the degree to which the results found in the OU studies were generalisable to the context and population of a regular university.

Method

Studies OU-1, OU-2 and OU-3

Samples. For study OU-1, a random sample was drawn of 700 OU students who had received the course materials of at least one OU course. A total of 211 students (30 per cent) sent back a fully completed Inventory of Learning Styles (ILS). Comparisons between response and non-response groups indicated that these groups did not differ significantly ($p > .05$) from each other in mean age, gender and subject area. There were, however, some differences with regard to exam participation. The response was relatively low for students who had received their first OU course a year or longer ago and who had never participated in any exam yet. After three months, these 211 response students were asked to complete a shortened version of the ILS. This was done to study the stability of the learning components. Of them 151 sent back the fully completed ILS (72 per cent response). There were no significant differences between response and non-response groups with regard to background variables. For study OU-2, a random sample of 500 students was drawn who had not yet, or no longer than 10 months ago, received their first OU course. The reason for this sample choice was the idea that these 'beginning students' especially could profit from a Learning Guide, which formed a part of this study. Students who had studied only four or fewer learning units of OU course materials were instructed to skip part A of the ILS, as they were

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Inventory of Learning Styles (ILS). Based on the categories of description that resulted from phenomenographic analyses of extensive interviews with 35 students (see Vermunt, 1996), a diagnostic instrument was composed in the form of an inventory. From the interviews, statements were selected that were considered to be characteristic for the various processing, regulation, conception and orientation categories, and that covered as many different aspects of them as possible. If necessary, the formulations were slightly adapted. This first version of the ILS was administered in study OU-1. It consisted of 241 statements, covering four domains. In part A, entitled 'Study activities', 50 processing and 50 regulation items were included. Students were asked to indicate on a five-point scale the degree to which they used the described activity in their studying. The scale varied from (1) I seldom or never do this, to (5) I (almost) always do this. For part B on 'Study motives and study views' another 50 items were selected about learning orientations and 91 items were included about mental models of learning. In the latter part students were asked to indicate on a five-point scale the degree to which the phrased motive or the described view corresponded to their own motives or views. In this part the scale varied from (1) totally disagree, to (5) totally agree. In studies OU-2, OU-3 and the stability study a revised version of the ILS was used with 144 items: 60 statements on processing and regulation activities, 30 items about learning orientations and 54 items about mental models of learning.

Procedures. In all OU studies the ILS was sent to the students from the sample, together with a covering letter and a post-paid return envelope. Two or three weeks later a reminding letter was sent to all students who had not reacted until then. Participation in the studies was voluntary and the students were not rewarded for their participation. For the stability study the ILS was sent to the students three months (13½ weeks) after the first administration of the ILS. In study OU-2 the concept version of the Learning Guide and an evaluation form for that packet were also sent to the students. In study OU-3 the ILS was sent to the students on the day the exam took place.

RU-study

Sample. A sample of 1279 students was drawn from the population of 2530 students of a regular university who had not yet passed the first year propaedeutic exam of their current subject area. In six of the eight subject areas of this university the whole population was included in the sample. Because of the large numbers of first-year students of Economy and Law, a random sample of 200 students was drawn for these subject areas. A fully completed ILS (see below) was received from 795 students (62 per cent response). This response group consisted of 56 per cent male and 44 per cent female students. The mean age was 22.5 years. Of the students in this response group 13 per cent studied Law, 17 per cent Economy, 14 per cent Econometry, 10 per cent Management Information Sciences, 13 per cent Sociology, 24 per cent Psychology, 9 per cent Language and Literature, and 0.4 per cent Philosophy. There were no data available about the non-response group.

Inventory of Learning Styles. In this study the final version of the ILS, which contains 120 items (see Results section), was used. If necessary these items were slightly reformulated to make them also applicable for the study situation of a regular university.

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Data analyses of all four studies

In the studies OU-1, OU-2 and OU-3 the ILS was completed by 717 students in total. The analyses with regard to the Inventory of Learning Styles were done on the basis of the data of this whole group, with the exception of 63 students of study OU-2 who were asked to complete only part B of the ILS. Their data are left out here, for reasons of comparability of the various analyses. Data were analysed with the SPSS-X statistical package. On the four separate parts of the ILS (processing activities, regulation activities, learning orientations and mental models of learning) principal components analyses were conducted with oblique rotation on item level. For the scale construction process item and reliability analyses were used. Then, principal components analyses with oblique rotation were done on the scales of the ILS. To analyse the direct contributions of mental models of learning and learning orientations to the variance in learning strategies, regression analyses were performed. For the stability study, test-retest reliabilities of the ILS were computed by correlating (Pearson r) the ILS scale scores of students of the first and second ILS-administration.

Results

The data of the OU studies were used to reduce the number of items in the Inventory of Learning Styles (ILS) from 241 to 120 items, a more usable size. The first step was done on the basis of study OU-1. A number of criteria was used in the process of eliminating items. For example, items with an extreme high or low mean, or a small standard deviation, were removed. On the basis of the principal component analyses on item level, items were removed that had a low loading on all factors, or about equal loadings on more than one factor. On the basis of reliability analyses items were removed from scales when their corrected item-scale total correlation was so low that elimination of the item made the Cronbach alpha rise. Finally, items were removed from scales that contained a lot of items and already had very high reliabilities. In this way the best 144 items were selected for inclusion in the first revised version of the ILS.

This version was administered in studies OU-2, OU-3 and the stability study. Then, on the basis of similar criteria as in the first construction step, this ILS version was further reduced in size. In this phase the test-retest correlations of items, based on the stability study, were considered as selection criteria, too. This second construction step resulted in the final version of the Inventory of Learning Styles of 120 items. It contains 27 items on processing activities, 28 on regulation activities, 25 on learning orientations and 40 on mental models of learning. Table 1 presents the scales and sample items.

Processing and regulation strategies

Principal components analyses (oblique rotation) on the 27 items about processing activities of OU students revealed five clear dimensions that represent distinctive processing strategies: combinations of processing activities that students often use in coherence. The first factor groups statements referring to relating and structuring the subject matter. Characteristic of these items is that students try to relate elements of the subject matter to each other and try to structure these elements into a whole. On the second factor items that have to do with memorising and rehearsing the subject matter have high loadings. Students try to learn facts, definitions, lists of characteristics and the like by heart by rehearsing them. The items with high loadings on the third factor have in common that they refer to concretising and applying the subject matter. When studying the subject matter students think of examples they know from their own experience, and they use what they learn in a course in their activities outside their studies. The fourth factor groups items that refer to a thorough and analytic way of studying. In this way, the subject matter is gone through in a stepwise fashion and the separate elements are studied in detail and one by one. A common element of the activities that load highly on the last factor is the critical way in which the subject matter is processed. Students form their own view on the subjects that are dealt with, draw their own conclusions and are critical of the conclusions drawn by the authors of the study materials. The Cronbach alpha of the ILS processing scales constructed in correspondence with the factor solution varies between .67 and .80. In a three-factor solution, the items of the scales 'relating and structuring' and 'critical processing' define one factor and the items of the scales 'memorising and rehearsing' and 'analytic processing' another one. The former factor may be interpreted as 'deep processing', the latter as 'stepwise processing'. The items of the scale 'concrete processing' stay on a separate factor in this solution.

A similar analysis was conducted for the 28 ILS-items referring to the way students regulate their learning processes. Here, too, five dimensions could be discerned which, in this case, represent five different regulation strategies. The first factor can be interpreted as self-regulation of learning processes and results. Students plan their processing activities, diagnose the cause of problems that occur during learning, invent questions to test their learning progress, and also direct themselves towards learning objectives that are not presented to them, but that they pose themselves. The second factor groups items characterised because students, in regulating their learning processes, let themselves be led to a high degree by the didactic aids woven into the course materials or provided by the lectures, such as introductions, learning objectives, directions, questions, or assignments: external regulation of learning processes. The third factor groups activities having to do with monitoring difficulties with regulating

Table 1. Scales of the Inventory of Learning Styles (ILS) (OU-version) and sample items

ILS-scales	Sample scale-items
Processing strategies	
Deep processing	
Relating & structuring	try to combine the subjects that are dealt with separately in a course into one whole.
Critical processing	compare my view of a course topic with the views of the authors of the textbook used in that course.
Stepwise processing	
Memorising & rehearsing	I memorise lists of characteristics of a certain phenomenon.
Analysing	I analyse the separate components of a theory step by step.
Concrete processing	I pay particular attention to those parts of a course that have practical utility.
Regulation strategies	
Self-regulation	
Learning process & results	To test my learning progress, I try to answer questions about the subject matter which I make up myself.
Learning content	In addition to the syllabus, I study other literature related to the content of the course.
External regulation	
Learning process	study according to the instructions given in the course materials.
Learning results	test my learning progress solely by completing the questions, tasks and self-tests in the course materials.
Lack of regulation	notice that it is difficult for me to determine whether I have mastered the subject matter sufficiently.
Mental models of learning	
Construction of knowledge	If I have difficulty understanding a particular topic, I should consult other books of my own accord.
Intake of knowledge	To me, learning means trying to remember the subject matter I am given.
Use of knowledge	The things I learn have to be useful for solving practical problems.
Stimulating education	The course team should encourage me to compare the various theories that are dealt with in a course.
Co-operative learning	I have a need to work together with other students in my studies.
Learning orientations	
Personally interested	I do these studies out of sheer interest in the topics that are dealt with.
Certificate-oriented	I study above all to pass the exam.
Self-test-oriented	I want to test myself to see whether I am capable of doing studies in higher education.
Vocation-oriented	I have chosen this subject area, because I am highly interested in the type of work for which it prepares.
Ambivalent	I am afraid these studies are too demanding for me.

one's own learning processes: lack of regulation. Students find it difficult to assess whether they master the subject matter sufficiently, do not find it clear what they have to remember, and experience insufficient hold on the regulating elements like learning objectives and directions for studying given in the study materials or by the lecturers. The items with high loadings on the fourth factor have in common that they refer to consulting literature and sources outside the syllabus. This regulation strategy can be interpreted as self-regulation directed at learning contents. A common characteristic of the items that load highly on the fifth factor is that students, in monitoring and testing their learning results, let themselves be directed to a large extent by the didactic adjunct aids given in the study materials or by the lecturers, such as self-tests, assignments and questions: external regulation of learning results. The Cronbach alpha of the five ILS regulation scales that were composed in correspondence with this factor solution varies between .67 and .78. In a three-factor solution, the items of both self-regulation scales define one common factor, as well as the items of both external regulation scales. Lack of regulation remains a distinct dimension in this solution.

Mental learning models and learning orientations

The 40 items on mental models of learning and the 25 items on learning orientations were analysed in the same way as the items referring to processing and regulation activities. The five factors referring to mental models of learning can be interpreted as follows: a mental model of learning in which a lot of value is attached to studying in co-operation with fellow students and sharing the tasks of studying with them; a model in which studying is viewed as constructing one's own knowledge and insights; a view in which studying is seen as the intake of knowledge provided by education; a mental learning model in which stimulating education is considered important; and a view in which students attach much value to learning to use the knowledge they acquire. The five learning orientation factors can be interpreted as: a vocational learning orientation; an orientation directed at testing one's own capabilities; an ambivalent learning orientation; an orientation in which one is mainly directed at gaining certificates; and an orientation in which students mainly do their studies out of personal interest. The Cronbach alpha of the ILS-scales constructed in correspondence with these factor solutions varies between .74 and .93.

Internal consistencies and test-retest correlations

For the regular university study, this ILS version was kept intact as much as possible. Only words in items that have little meaning in the context of regular education were adapted. For example, concepts like 'learning unit' were replaced by 'article' or 'chapter in a textbook', 'course team' and 'study counsellor' by 'teacher', 'self-test' by 'questions in the book' or 'questions asked by the teacher', etc. In Table 2 the number of items per scale and subscale, the reliabilities (internal consistencies) of these scales, the mean item means and the mean standard deviation of the items are shown, both for the OU and RU studies. As can be seen in this table, the main scales deep processing, stepwise processing, self-regulation and external regulation each consist of two sub-scales. Dependent on the aim of the ILS administration, the main scales or the subscales may be used. In the table the psychometric properties of both main scales and subscales are presented. In the OU population the Cronbach alpha varies for the main scales from .68 to .93, while two subscales have an alpha of .67. For the RU students this alpha varies from .57 to .89 for the main scales, while one subscale has a lower value. Of all 24 main scales and subscales 21 have an alpha of .70 or higher in the OU population. For RU students there are 19 scales achieving this level. In Table 2 the correlations between the first and second administration of the ILS are shown as well. The correlations vary between .58 to .80 for the main scales, while the lowest correlation for the subscales is .55. It is noteworthy that, in general, the correlations appear lower for learning strategies than for learning orientations and mental models of learning.

Table 2. Number of items (*N*), internal consistency (Cronbach alpha), mean item means (*M* items), mean item standard deviation (SD items) of ILS scales for open university (OU) students ($N = 654$) and regular university (RU) students ($N = 795$), and test-retest correlations ($r_{t\text{-}rt}$) of ILS scales with an interval of 13½ weeks for open university students ($N = 151$)[1]

ILS-scales	*N*	α scales		*M* items		SD items		$r_{t\text{-}rt}$
		OU	RU	OU	RU	OU		
Processing strategies								
Deep processing	11	.83	.85	3.42	3.16	1.22	1.21	.63
Relating & structuring	7	.80	.83	3.56	3.36	1.20	1.18	.58
Critical processing	4	.72	.72	3.16	2.81	1.27	1.25	.55
Stepwise processing	11	.79	.78	2.78	2.78	1.32	1.29	.73
Memorising & rehearsing	5	.79	.79	2.63	2.83	1.36	1.30	.71
Analysing	6	.67	.63	2.92	2.73	1.29	1.16	.67
Concrete processing	5	.74	.71	3.03	2.81	1.25	1.17	.58
Regulation strategies								
Self-regulation	11	.81	.79	2.47	2.30	1.30	1.19	.70
Learning process & results	7	.75	.73	2.45	2.54	1.29	1.28	.66
Learning content	4	.78	.73	2.50	1.87	1.33	1.03	.69
External regulation	11	.78	.68	3.49	3.22	1.30	1.22	.75
Learning process	6	.67	.48	3.45	3.08	1.32	1.21	.79
Learning results	5	.71	.65	3.51	3.38	1.28	1.23	.61
Lack of regulation	6	.68	.72	2.15	2.40	1.16	1.17	.68
Mental models of learning								
Construction of knowledge	9	.77	.78	3.69	3.52	1.01	0.99	.72
Intake of knowledge	9	.78	.77	3.47	3.53	1.20	1.10	.79
Use of knowledge	6	.76	.70	3.75	3.91	1.07	0.91	.70
Stimulating education	8	.90	.88	2.85	3.13	1.32	1.13	.76
Co-operative learning	8	.93	.89	2.25	3.01	1.23	1.20	.79
Learning orientations								
Personally interested	5	.74	.57	3.69	3.17	1.17	1.04	.74
Certificate-oriented	5	.81	.76	3.09	3.28	1.38	1.18	.72
Self-test-oriented	5	.86	.84	2.59	2.83	1.41	1.28	.78
Vocation-oriented	5	.85	.69	3.11	3.79	1.46	1.07	.80
Ambivalent	5	.75	.82	1.75	2.07	1.01	1.12	.74

Significance level all correlations: $p < .001$ (one-tailed testing)

Interrelations among learning components

In Table 3 the relations among the ILS scales for both populations are shown in a four-factor principal component analysis solution with oblique rotation. In both studies clearly the same dimensions appear. The first factor can be interpreted as a meaning-directed learning style, with high loadings of relating and structuring, critical processing, self-regulation of learning processes and learning contents, construction of knowledge as mental model of learning, and personal interest as learning orientation. Also concrete processing loads rather high on this factor. It is noteworthy, though, that in the OU population personal interest shows a lower association with this dimension than for RU students. The second factor can be viewed as a reproduction-directed learning style, with high loadings of the ILS scales memorising and rehearsing, analysing, external regulation of learning processes and learning results, intake of knowledge as mental model of learning, and certificate and self-test-directed learning orientations. The third factor can be viewed as an undirected learning style, with high loadings of lack of regulation, an ambivalent learning orientation, and co-operation and stimulating education as mental models of learning. Finally, the fourth factor can be interpreted as an application-directed learning style, with high loadings of concrete processing, use of knowledge as mental model of learning, and vocational and certificate-oriented learning orientations.

Regulation of learning processes

To get a better view of these interrelations from a regulation-of-learning perspective, for OU and RU students separately five multiple regression analyses were conducted with the ILS processing strategies as dependent variables and the regulation strategies, mental models of learning and learning orientations from the ILS as independent variables (see Figure 1). The results are shown in Table 4. The patterns of relationships are highly comparable for both groups of students. The degree to which students use the two deep processing strategies in both groups is mostly dependent on the degree to which they use a self-regulated strategy in the regulation of their learning processes. As students make more use of these processing strategies, they also more often have a mental model of learning in which the construction of own knowledge is central and, especially RU students, less often have a mental model of learning based on the intake of knowledge. In both groups self-regulation of learning contents also contributes positively to the degree students process the subject matter critically, and, for RU students only, to the use of a relating and structuring processing strategy. Learning orientations, with one exception, show no relationship at all with the use of deep processing strategies. The only exception concerns the contribution of personal interest to critical processing of subject matter, only for OU students.

Both stepwise processing strategies are, however, regulated in a different way from both deep strategies. The strategy based on external regulation and the strategy based on self-regulation of learning processes contribute to the degree to which students employ a detailed, analytic strategy, to roughly the same extent. Students also use this processing strategy more often to the extent that their mental model of learning is more reproductive in nature. The use of the memorising and rehearsing processing strategy is, for both groups of students, mainly related to a reproductive mental model of learning, followed by the degree to which a self-regulated strategy is used in regulating

Table 3. Factor loadings (pattern matrices) of ILS scales in a four-factor oblique solution for open university (N = 654) and regular university (N = 795) students

ILS-scale	F1		F2		F3		F4	
	OU	RU	OU	RU	OU	RU	OU	RU
Processing strategies								
Deep processing								
Relating & structuring	.71	.72						
Critical processing	.75	.70						
Stepwise processing								
Memorising & rehearsing			.65	.73				
Analysing	.27		.69	.76				
Concrete processing	.58	.65					.43	−.39
Regulation strategies								
Self-regulation								
Learning process & results	.78	.74						
Learning content	.69	.72						
External regulation								
Learning process			.82	.73				
Learning results			.67	.54				
Lack of regulation					.75	.74		
Mental models of learning								
Construction of knowledge	.72	.75						
Intake of knowledge		−.36	.67	.54	.35	.33		
Use of knowledge							.67	−.74
Stimulating education					.59	.73		
Co-operative learning					.67	.61		
Learning orientations								
Personally interested	(.24)	.54					−.70	.25
Certificate-oriented		−.41	.40	.40			.59	−.33
Self-test-oriented			.34		.32	.29		
Vocation-oriented							.84	−.80
Ambivalent					.73	.65		
Eigen value	3.6	4.3	3.0	3.0	2.4	1.9	2.0	1.3
% explained variance	17.9	21.3	14.9	15.2	11.9	9.6	9.8	6.4
Cumulative %	17.9	21.3	32.8	36.5	44.7	46.1	54.6	52.5

Principal component analysis; loadings $> -.25$ and $< .25$ omitted

one's own learning processes. For RU students only an externally regulated strategy also contributes to about the same degree as the self-regulated one to the use of this memorising strategy. Learning orientations show almost no association with the employment of the stepwise processing strategies.

For both OU and RU students the use of a concrete processing strategy is mainly related to a mental model of learning in which the use of knowledge is stressed. Besides, both self-regulated strategies contribute to the use of the concrete processing strategy. Especially for RU students, a frequent use of the concrete strategy is also associated negatively with a mental model of learning based on intake of knowledge. The only direct association of concrete processing with a learning orientation is, for RU students only, with personal interest.

Table 4 also shows that, for both groups of students, the degree of self-regulation of learning processes shows a positive relation to the employment of *all* five processing strategies, mostly, however, with the two deep strategies. External regulation strategies are not associated with the use of relating, critical and concrete processing strategies. It is also interesting that the reproductive mental model of learning contributes negatively to the use of relating, critical and concrete processing strategies, and that these relations are stronger for RU students than for OU students. The externally regulated strategy aimed at monitoring learning results, the mental models of learning in which much value is attached to stimulating education and to co-operation with fellow students, and the vocation-oriented, self-test-oriented and ambivalent learning orientations show little to no relation to the strategies that students use to process the subject matter.

For both groups of students five multiple regression analyses were conducted as well with the ILS regulation strategies as dependent variables and the mental models of learning and learning orientations from the ILS as independent variables. As can be seen in Table 5, here the patterns of relationships for both types of universities are highly comparable, too. For both groups the use of self-regulated strategies shows the largest association with the mental model of learning in which one's own responsibility for the construction of knowledge is stressed. The reproductive mental learning model also contributes to the use of these strategies, but to a smaller degree and negatively. Learning orientations play a less important role in self-regulation. For both groups, however, there are positive contributions from vocational learning orientations to self-regulation of the learning process and from personal interest to self-regulation of learning contents, although these effects seem bigger for RU students than for OU students.

The degree to which both OU students and RU students employ externally regulated learning strategies is mainly associated with the degree to which they view learning to be in essence equivalent to the intake of provided knowledge. In the use of external regulation strategies, learning orientations also play a minor role in comparison with mental models of learning. For both groups, however, it holds that when the certificate orientedness of students increases the use of externally regulated learning strategies increases as well. An increase in ambivalence goes together with a decrease in the use of an external regulation strategy aimed at learning processes. These motivational effects seem stronger for OU students than for RU students.

Lack of regulation is mostly associated with the ambivalent learning orientation, in both populations of students. Furthermore, an increase in the degree to which students show this lack of regulation in their learning behaviour is associated with an increase of the value they attach to co-operation with fellow-students and also with an increase in reproductive elements in their mental model of learning. Besides, for RU students it holds that the more their learning behaviour is typified by lack of regulation the more value they attach to stimulating education. For both groups of students the mental model 'use of knowledge' and the self-test-oriented learning orientation are hardly or not at all associated with the way students regulate their learning processes.

Table 4. Beta-weights of regulation strategies, mental learning models and learning orientations as predictors of processing strategies for open university students ($N=654$; d.f. = 15,637) and regular university students ($N=795$; d.f. = 15,774), based on the total regression model, and significance levels of the F-values

Processing strategies	Relating & structuring		Critical processing		Memorising & rehearsing		Analysing		Concrete processing	
	OU	RU	OU	RU	OU	RU	OU	RU	OU	RU
Regulation strategies										
Self-regulation										
Learning process & results	**.38**	**.41**	**.34**	**.25**	**.22**	**.18**	**.31**	**.20**	**.15**	**.22**
Learning content	.06	**.15**	**.13**	**.19**				**.12**	**.23**	**.24**
External regulation										
Learning process			−.08		.08	**.17**	**.38**	**.27**	.07	
Learning results				*−.07*	.06		*.09*	*.07*		
Lack of regulation	**−.12**	*−.07*			**−.13**			−.06		.06
Mental models of learning										
Construction of knowledge	**.15**	*.07*	**.15**	**.14**	.06					
Intake of knowledge	*−.08*	**−.19**		**−.14**	**.45**	**.50**	**.13**	**.19**	*−.09*	**−.17**
Use of knowledge	−.06						*.08*	*.07*	**.43**	**.30**
Stimulating education					*−.09*	**−.10**		*−.07*		
Co-operative learning				*−.07*						
Learning orientations										
Personally interested	.07		**.13**			*.07*	.06			**.13**
Certificate-oriented	.06							**.10**		−.06
Self-test-oriented								.06		
Vocation-oriented	.07									
Ambivalent	−.06									−.06
R^2										
F										

F-value: figures in italic, $p<.05$; figures in bold, $p<.01$. Weights ≥ −.05 and ≤ .05 omitted.

Conclusions and discussion

The purpose of the research reported in this article was not to add another new model of student learning to the existing field but to increase the integration of existing models and to embed the concept of metacognition firmly into them. The research showed that, in the learning component 'cognitive processing of subject matter', five strategies are sufficient to cover the variation found: a relating/structuring strategy, a critical strategy (together: deep processing), a memorising/rehearsing strategy, an analytical strategy (together: stepwise processing) and a concrete strategy. The distinctive feature of these strategies is that each one is characterised by the use of a particular combination of processing activities to learn. These results most closely parallel those of Geisler-Brenstein *et al.* (1996), whose analyses with the ILP-R resulted in a conceptualisation of processing strategies such as deep learning (semantic, critical), elaborative learning (episodic), agentic learning (serial, analytic) and literal memorisation. Their consistent

Table 5. Beta-weights of mental learning models and learning orientations as predictors of regulation strategies for open university students ($N = 654$; d.f. = 10,642) and regular university students ($N = 795$; d.f. = 10,779), based on the total regression model, and significance levels of the F-values

Regulation strategies	Self-regulation learning process & results		Self-regulation learning contents		External regulation learning process		External regulation learning results		Lack of regulation	
	OU	RU	OU	RU	OU	RU	OU	RU	OU	RU
Mental models of learning										
Construction of knowledge	**.50**	**.49**	**.45**	**.33**		.06	.08		−.06	
Intake of knowledge	**−.14**	**−.12**	**−.16**	**−.17**	**.41**	**.35**	**.29**	**.26**	**.12**	**.12**
Use of knowledge		−.06					*.09*	*.09*		
Stimulating education		**−.09**		*−.07*						**.16**
Co-operative learning	*.08*		.06		−.06	.06	*−.09*	**.10**	**.19**	**.12**
Learning orientations										
Personally interested			*.09*	**.16**	.06					
Certificate-oriented	**.15**			−.06	**.16**	*.10*	**.14**	*.10*		
Self-test-oriented	−.06				.07					
Vocation-oriented	*.09*	**.15**		**.11**					−.06	
Ambivalent		*−.07*			**−.15**	*−.09*		−.06	**.40**	**.42**
R^2	**.31**	**.34**	**.27**	**.27**	**.28**	**.18**	**.16**	**.17**	**.31**	**.35**
F	28.5	39.4	23.6	28.5	24.7	16.8	12.5	15.9	28.9	42.1

F-value: figures in italic, $p < .05$; figures in bold, $p < .01$. Weights $\geq -.05$ and $\leq .05$ omitted.

finding of a distinctive elaborative processing strategy and our similar finding of a concrete processing strategy show that processing strategies are much more varied than can be denoted with a deep-surface distinction. The five strategies we identified encompass Marton & Säljö's (1984) and Biggs' (1987) deep-surface approaches, Pask's (1988) holist and serialist strategies, Weinstein's (1994) information processing strategy, and Tait & Entwistle's (1996) 'relating ideas', 'unrelated memorising', and 'use of evidence'.

The analyses pointed to particular patterns in students' use of regulation activities as well. Five regulation strategies could be identified: two variants of a self-regulated strategy, two variants of an externally regulated strategy, and a strategy typified by lack of regulation. In contrast to what is the case with processing strategies, it is not so for regulation strategies that they form specific combinations of regulation activities. The defining criterion for the regulation strategies is much more the internal and external dimension than a combination of regulation activities that students utilise in coherence. The two self-regulation strategies encompass the scale 'metacognition' from the Motivated Strategies for Learning Questionnaire (Pintrich *et al.*, 1993) and the scale self-testing from the LASSI (Weinstein, 1994). The external regulation scale includes aspects of the LASSI-scale 'study aids'. Our 'lack of regulation' has, as far as we know, no parallel in the existing student learning models and inventories.

The students' conceptions about all kinds of aspects of studying turned out to be interrelated in such a way that five mental models of learning can be discerned. The first three, intake of knowledge, construction of knowledge, and use of knowledge, correspond to Säljö's (1979) original descriptions of learning conceptions, later replicated and extended by Van Rossum, Deijkers & Hamer (1985) and Marton *et al.* (1993). They represent three positions on a dimension that Lonka *et al.* (1996) called 'constructivity'. The last two models, stimulating education and co-operative learning, refer to views on the task division in learning activity between the student, teachers and fellow students. These represent different positions on a dimension that Lonka *et al.* (1996) labelled as 'active epistemology'.

The empirical studies also showed that five learning orientations are sufficient to describe the variation in motives, expectations, attitudes and concerns of students with regard to their studies: a personally interested orientation, a certificate-directed orientation, an orientation aimed at testing one's own capabilities, a vocational and an ambivalent orientation. They include study motivation dimensions such as Tait & Entwistle's (1996) 'active interest', 'intention to excel', and 'lack of direction', Biggs' (1987) intrinsic and extrinsic motivation, and Gibbs *et al.*'s (1984) vocational, academic and personal educational orientations. In contrast to the unidimensional scale 'motivation' from Weinstein's (1994) LASSI, these learning orientations represent several, qualitatively different, student motivation dimensions.

As far as we know, no studies until now addressed mental models of learning, learning orientations and the use of processing and regulation strategies in their mutual coherence. This research showed strong interrelations among these learning components, so strong that one may indeed speak of learning styles. Four such styles could be identified. The meaning-directed and reproduction-directed styles encompass Entwistle's (1988) meaning and reproducing orientation, and Biggs' (1987) and Tait & Entwistle's (1996) deep and surface approaches. The undirected style is similar to Tait & Entwistle's (1996) apathetic approach. Geisler-Brenstein *et al.*'s (1996) elaborative processing style is an element of what we named the application directed style. The consistent finding that undirected and application-directed learning styles should be distinguished from meaning- and reproduction-directed styles indicates that the study behaviour of students consists of more than a deep or surface approach. There are indications that the application-directed learning style develops later than the other styles (Roosendaal & Vermunt, 1996). This may explain why this concrete, elaborative, application-oriented way of learning often is absent as a distinctive dimension in models of student learning (e.g., Biggs, 1987; Pask, 1988; Tait & Entwistle, 1996; Weinstein, 1994).

It was also found that the stability of learning styles is rather high in general, but not so high that these styles should be conceived of as unchangeable traits of people. The interval between the two ILS-administrations, three months, was much longer than usual in this kind of research, which is typically between two and four weeks (e.g., Weinstein *et al.*, 1988). It is remarkable though, that this stability is somewhat higher for mental models of learning and learning orientations than for processing and regulation strategies. This indicates that strategies are adapted to the circumstances faster than mental models of learning and learning orientations.

The learning components turn out to be more differentiated than can be denoted with bipolar dimensions like deep versus surface approach, serialistic versus holistic strategy, productive versus reproductive learning conceptions, intrinsic versus extrinsic learning orientations, and field dependent versus field independent learning styles. These bipolar descriptions insufficiently cover the empirical variation found among students in these learning components, and underestimate the complexity of study behaviour in a real study context. In view of the variation found in learning strategies and styles, it can be stated that many students do not realise constructive, self-regulated, high-quality learning processes. When we reserve these qualifications for the meaning and application-directed styles, it means that the learning style of a considerable group of students can be typified as not constructive and not self-regulated, namely undirected or reproduction directed.

The research findings discussed so far have, besides clarifying a number of theoretical issues, also generated a problem. When external regulation is so large a component of a reproduction-directed learning style, what does that mean for the design of instruction? As stated in the Introduction, classical instructional design theories emphasise a high degree of control over learning processes by instructional agents. Does this high degree of external control lead to reproduction-directed learning? (see also Biggs', 1996, and Shuell's, 1996, discussion of this problem). To achieve greater clarity about this issue, the interrelations among the use of processing and regulation strategies, mental learning models and learning orientations were explored by means of regression analyses. Most comparable studies only conduct factor analysis to study interrelations among the various aspects of their student learning model. The results showed that learners mainly regulate their use of processing strategies themselves. Self-regulation of learning processes is positively associated with the use of *all* processing strategies. External regulation of learning processes, in which learners let themselves be directed mainly by the didactic measures in the study materials or of the lecturers, is only related to the extent to which students process subject matter in a stepwise way and especially analyse it in detail and thoroughly. External regulation is not related to the use of relating, critical and concrete processing strategies. A mental model of learning in which constructing own knowledge and insights is stressed is related to an important degree to the use of self-regulation strategies. A mental learning model in which the intake of provided knowledge is central is mainly related to the use of external regulation strategies. Learning orientations only play a minor role in the use of learning strategies.

It can be concluded that the regulation power of didactic measures, such as learning objectives, questions, directions for studying, and assignments, is minimal with regard to the direct activation of relating, critical and concrete processing strategies. Thus, it should be taken into account that classical instructional design theories, with their high emphasis on external regulation of learning process by instructional measures, only work to a limited extent or for a limited group of students.

The fact that external regulation turns out to have so little influence on the processing strategies of students may support the constructivist view that it is mainly the learners themselves who regulate their learning processes (e.g., Duffy & Jonassen, 1992). It could also mean that external regulation often is simply not aimed at activating constructive processing strategies. This is, however, highly unlikely (see Martens, Valcke, Poelmans & Daal, 1996). It could also be the effect of the fact that external regulation is hardly ever based on a solid diagnosis of the learning activities that students employ of their own accord, in other words their learning styles. The activation of learning activities students already perform of their own accord will, naturally, cause little variance in the use of these learning activities. On the other hand, the distance between the learning activities that are activated by means of learning objectives, questions, assignments, or directions for studying, and the learning styles of students may be too large, so that frictions arise (Vermunt, 1995). It can also indicate a phenomenon that Marton & Säljö (1984) called 'technification' of the learning process. This means that students are only focused, for example, on being able to answer adjunct questions and that they study subject matter to which no questions are added in their habitual way. Finally, it is possible that direct instructions about what to do are not sufficient to realise constructive and independent learning behaviour. Changes in mental models of learning will probably be necessary as well (see Lonka, 1997).

Most studies are restricted to one student population. In our research project two quite different populations were studied: adult students in distance education and young adults in regular education. The results, however, turned out to be highly similar, with regard to learning strategies, the nature of the mental learning models and learning orientations that exist among students, and the relations among the various aspects of learning styles. In these two different contexts with different student populations, very similar results were found with regard to the nature and structure of these phenomena. This points to a high degree of generalisability of findings. Moreover, the results of these quantitative studies confirm in broad outline the results of the qualitative, phenomenographic analyses (Vermunt, 1996).

Implications for practice

In sum, the research results indicate that realising constructive, high-quality learning activities can probably be done most effectively by a systematic transfer of control over the learning process from the teachers to the students. To achieve this, the learning *processes* of students should be more in focus of attention (process-oriented teaching, see Lonka, 1997; Schatteman, Carette, Couder & Eisendrath, 1997; Vermunt, 1995). To influence students' use of relating, critical and concrete processing strategies, direct instructions do not seem to be the best way. To activate relating and critical processing strategies it is probably more effective, in the light of the relations observed here, to teach students to use a self-regulated strategy, coupled with measures to influence the mental learning model of students in the direction of a knowledge constructing view. To activate students to use a concrete processing strategy, those measures seem to be mainly suited that are primarily aimed at the mental learning model of students, and secondly stimulate self-regulation. To encourage, or discourage, students to use a memorising strategy, measures seem to be mainly suited that change students' mental model of learning. Activating students to use an analytic strategy can effectively be done by direct instructions. Taking learning orientations into account does not seem to be very useful, because these hardly contribute to variance in the use of learning activities.

For the design of instruction these results mean that the existence of different learning styles should be taken into account and that, in order to change study behaviour, changes are necessary in mental models of learning and learning orientations. Behaviourial patterns and views based on many years of experience result in stability in learning styles. Durable changes of students' learning styles in a constructive, self-regulated, high-quality direction can probably not be realised from one day to another with simple instructions (see also Lonka, 1997; Volet, McGill & Pears, 1995).

Future research

Future research should be directed at the further construction of an instructional learning theory that places learning activities in the focus of attention and that departs from the fact that learners primarily regulate their learning processes themselves. It also should be directed at the construction and study of learning environments in which external regulation of learning not only activates analytic processing strategies but also the other ones. Research in this direction has recently been reported by Ajisuksmo (1996), and Schatteman *et al.* (1997). Another line of research should be directed at the further exploration of the integrative model of student learning described in this article. Recent research in this direction has been done, for example, by Severiens & Ten Dam (1997), and Lonka (1997).

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