The effect of students' perceptions of the learning environment on mathematics achievement. Explaining the variance in Flemish TIMSS 2003 data.

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In this contribution the merits of a constructivist learning environment in fostering the learning of mathematics in secondary school are discussed. Starting from a theoretical model of powerful teaching, a 33 item instrument measuring individual students' perceptions of the learning environment has been constructed and included in the Flemish part of the TIMSS 2003 study. The 33 item measurement is reduced to six scales by means of exploratory factor analysis. An educational effectiveness approach is employed to determine whether Flemish math classes are different from the perspective of constructivist learning and whether these differences are related to differences in mathematics achievement.

1. Introduction

During the last decades, research has led to the identification of important characteristics of effective learning processes. These can be summarised in the following definition: learning is a constructive, cumulative, self-regulated, goal-oriented, situated, collaborative, and individually different process of knowledge building and meaning construction (De Corte, 2000). Furthermore, a series of guiding principles for the design of powerful learning environments—in line with the preceding features of effective acquisition processes—have emerged from the available research and literature (De Corte, 2000). Richardson (2003) points to the necessity of elaborating on a framework related to effective constructivist teaching as follows: "A second issue that confronts us in constructivist teaching is that because constructivism is a theory of learning and not a theory of teaching, the elements of effective constructivist teaching are not known" (p. 1629) and an "area of needed development in constructivist pedagogy is theory building. Theories of constructivist teaching will provide us with ways of identifying more and less effective teaching practices for use in teacher education and professional development" (p.1636).

There are some important points which need attention while constructing a model for the design of learning environments (De Corte, 2000). Firstly, learning is complex. As a consequence, when designing appropriate learning environments we have to start from a "holistic (as opposed to a partial) approach to the learning-teaching environment, i.e. all relevant components of the learning environment should be addressed" (De Corte, 2000, p. 249). This means that one will have to take account of the various views of the nature of knowledge and learning. These views have different educational implications that sometimes seem to be contradictory. However, they form different aspects of the same learning and educational process in which the different perspectives should be acknowledged (Anderson, Greeno, Reder, & Simon, 2000).

This contribution starts with a description of a four-dimensional model of learning environments. Due to space restrictions, only a summary of the model can be presented. For an extensive account of this model and an in-depth discussion of its underlying paradigms, we refer to Schelfhout et al. (2006).

Next, we discuss an application of the model in the construction of an instrument for measuring students' perceptions of their learning environment. This instrument has been employed in order to supplement the TIMSS-2003 data collection in Flanders. A factor analysis of the measurements revealed six dimensions which can be interpreted in terms of the theoretical model.

In a subsequent step, scores for six scales corresponding to these dimensions have been calculated and aggregated, yielding six characteristics of the class as a constructivist learning environment (as perceived by the students). We have examined the explanatory power of these class characteristics with respect to individual students' mathematics achievement, as measured in TIMSS-2003. In contrast with the international TIMSS-2003 design, the Flemish study included two classes in most schools. Consequently, it is possible to use three-level models of students within classes within schools to model the relationships. Moreover, a Flemish extension of the TIMSS teachers'

questionnaire included a measure of the teacher's perception of the class as a constructivist learning environment, providing an interesting addition to the students' perceptions.

2. A theoretical model related to powerful teaching with four dimensions

2.1. Operationalisation of constructivist powerful learning environments in 13 sub dimensions and 4 main dimensions

When designing powerful learning environments one will have to search for an answer to the following basic educational dilemma. On the one hand, a student has to initiate, direct and regulate the learning processes as much as possible himself. This becomes possible in activating and student-controlled learning environments (e.g. Scardamalia & Bereiter, 1991). On the other hand, a student needs coaching, sometimes even external steering, during these learning processes. A certain degree of teacher control will have to be built into the learning environments (e.g. Schwartz & Bransford, 1998).

A general research-based operationalisation of this dilemma was given by means of a series of guiding educational principles (De Corte, 2000, p.254). These guidelines were taken as a starting point for our own research. Based on an extensive literature study, we established a list of different teaching activities which were indicated by the authors as being important for fostering learning for understanding. We next considered how to describe these many different activities using a limited number of components. We identified 13 dimensions within the whole group of teaching activities. In Table 1 an overview of the different dimensions is given, together with important teaching activities which form an operationalisation.

With the aim of designing an iterative, gradually more complex model, we summarized these 13 sub dimensions into a basic, but comprehensive model, with fewer main dimensions. We started with comparing our 13 dimensions with Bransford, Brown and Cocking's (2000) four perspectives model of effective learning environments. This model describes "four perspectives on learning environments that seem particularly important given the principles of learning" (p.133). In the following section, we discuss the four main dimensions of our model, each time shortly linking them to the corresponding perspective in the Bransford model, also indicating certain differences, and describing the sub dimensions with which we further operationalised the different aspects of each main dimension.

2.2.Motivate to exert learning effort

This forms the first main group of educational activities that are a major point of attention while creating powerful learning environments. On the whole, the different teaching activities within a total educational approach should foster the motivation of students to exert effort to engage in learning activities and to sustain these efforts. Without motivation there is no deep level learning, for which effort is essential (Stipek, 2002). This learning motivation can be fostered on different levels. Firstly, there is learning motivation that can be obtained by initiatives that can be executed within a short period of time, e.g. by arousing interest (sub dimension 1). However, this kind of motivation can be short-lived. Initial interest can disappear when real effort is required. Therefore, a deeper motivation for learning should be aroused and maintained (sub dimension 2) (Boekaerts, 2001). To be able to create this motivation, it will be necessary to anticipate and capitalize on the different characteristics and needs of the learners; their interests, their prior knowledge, their learning strategies. It is important to adapt the curriculum to the interests of the learners as far as possible and thus to differentiate the educational approach towards different learners. Bransford, et al. (2000) refer to the importance of these activities as part of their description of the "learner-centered" aspect of learning environments, referring to the need of environments "that pay careful attention to the knowledge, skills, attitudes and beliefs that learners bring to the educational setting" (p.133). They stress that "accomplished teachers 'give learners reason', by respecting and understanding learners' prior experiences and understandings, assuming that these can serve as a foundation on which to build bridges to new understandings" (p.134).

Table 1. Model of powerful teaching operationalised in 13 sub dimensions

Sub dimension 1. Motivate by arousing interest	Sub dimension 2. Maintain motivation for learning
Give realistic examples	Create challenging learning tasks
Give examples from the news	Create opportunities to be creative
Use realistic situations as a starting point for lessons	Create pleasant lessons
Base assignments on realistic cases	Create a pleasant variation in educational approaches
Create a feeling of usefulness	Avoid coming across as a know-all
General ability to arouse interest	
Sub dimension 3. Motivate by a structured approach	Sub dimension 4. Activate towards self-regulated learning
Keep attention by sequencing tasks and explanations	Make students think for themselves instead of listening
Make use of learning conversations	Explain everything first, pupils have to listen (-)
Explain in a clear and structured way	Make students solve difficult assignments
Keep the class under control	Assignments being too difficult (-)
Students understand learning content through the approach	
Sub dimension 5. Activate towards connecting contents	Sub dimension 6. Give activating feedback during tasks
Ask for connecting of learning contents	Give hints without giving the answers
Give assignments in which to use prior knowledge	Monitor and point to mistakes
Make students search for information to solve problems	Motivate with hints to enable a search for a solution
Sub dimension 7. Give structuring feedback before tasks	Sub dimension 8. Give activating feedback after tasks
Repeat prior knowledge necessary for new content	Give a lot of explanation of the problem solving process
Connect prior and new knowledge	Give answers on paper and make the students correct their tasks
Indicate what knowledge and skills have to be mastered	Encourage reflection on the causes of mistakes
	Repeat content if necessary
Sub dimension 9. Structure contents in an organized whole	Sub dimension 10. Create cooperative learning
Make students synthesize learning content	Make students work cooperatively on assignments
Show how to make syntheses	Organize cooperative learning in an appropriate way
	Solve problems with group dynamics
	Teach how to cooperate
Sub dimension 11. Make use of group discussions	Sub dimension 12. Tailor evaluation to in-depth knowledge acquisition
Organize group discussions	Avoid emphasis on knowledge reproduction
Make students discuss the learning contents	Avoid literal repeating of questions
Make students substantiate their arguments	Stress the importance of understanding the subject matter
	Require the application of knowledge to new problems
Sub dimension 13. Give activating feedback about tests	
Provide ample discussion of tests	
Make test answers available on paper	
Make students correct their tests using solutions on paper	

Further, it will be important to create opportunities for learners to determine their goals and learning paths themselves. As a consequence—because a human being normally strives to integrate in its environment and therefore wants to learn the necessary skills—learning tasks should be sufficiently relevant. They should give opportunities to learn something that can be used in the real world (Brown,

1996). Of course, this differs between people. A constant however is that every learner wants to learn to become a part of a community; social skills are thus essential. Learners need the opportunity to experiment with different roles in groups of learners. They also need to experiment with using/building certain knowledge in groups, because real insight in different domains of knowledge is often bound to the way it is used/co-constructed in social communities. Therefore motivation to exert learning effort can be created in meaningful communities of learners (Brown & Campione, 1994; Slavin, 1991). In the Bransford model this is indicated with the "community centered" perspective, referring to the need for environments in which learning is "enhanced by social norms that value the search for understanding and allow students (and teachers) the freedom to make mistakes in order to learn" (p.145). Creating cooperative learning environments (see sub dimensions 10 and 11) can have these positive effects, at least if realistic and for the learners meaningful group tasks are created and/or if these are environments in which the learners can experiment with different roles and social interactions in a constructive way. However, cooperative tasks can also have an activating quality, even if they happen in less realistic settings and with more traditional tasks. We discuss this as part of the following main dimension, 'Activate towards self-regulated learning'.

The former two sub dimensions are important in creating long lasting motivation. However, also other educational activities are essential in order to prevent this motivation to be undermined. Learners need to get the feeling that all their efforts lead them to understand what they're busy with. An ongoing feeling of uncertainty will decrease their efforts (Good & Brophy, 2000). Therefore an effectively organized and structured approach to the lessons is needed (see further sub dimension 3, discussed in main dimension 4). This uncertainty—even within an authentic problem solving environment—can also be reduced by giving appropriate feedback. This will be discussed in sub dimensions 6, 7 and 8, as part of main dimension 3, 'Give feedback and coach'.

2.3. Activate towards self-regulated learning

Creating motivation for making learning efforts will not lead automatically towards deep understanding that can be applied in different situations. Learners also will have to be engaged in effective learning tasks deliberately aiming at this goal. A first important aspect of these tasks is that they should be what Bransford et al. (2000) call "learner-centered", referring to environments "that pay careful attention to the knowledge, skills, attitudes and beliefs that learners bring to the educational setting" (p.133). "By selecting critical tasks that embody known misconceptions, teachers can help students test their thinking and see how and why various ideas might need to change. The model is one of engaging students in cognitive conflict and then having discussions about conflicting viewpoints" (p.134). In our model, this dimension incorporates all teacher activities which aim at engaging pupils in learning tasks in which they have to link/question their prior knowledge with new information to be able to construct meaning. Further, we assume that during assignments in which more self-regulation is expected from the pupils, they will make more use of their prior knowledge and will construct meaning in a more active way (Schunk, 2001).

However, self-regulative processes have to be learned. Therefore, teachers have to move gradually towards more student regulation of the complete learning process (Corno & Randi, 1999). As a consequence, on the one hand learning assignments should be sufficiently complex in order to activate pupils towards self-regulated learning and not only to apply memorized knowledge mindlessly or to add little pieces of information without considering the whole (see sub dimension 4). They should be aiming to connect new knowledge with prior knowledge, and this within an expanding well-organised body of knowledge (Shuell, 1996) (see sub dimension 5 and also sub dimension 9 in main dimension 4, 'Structure and steer'). On the other hand, these activating tasks should not be too complex in order to avoid misconceptions and/or demotivation (Schwartz & Bransford, 1998) (see sub dimension 4, but also main dimension 1, 'Create motivation'). Further, these tasks should be supported by feedback during the tasks which activates the pupils to take the next step in their learning process in a self-regulated way (see sub dimension 6). If necessary, feedback after assignments should be given and this feedback should also be activating (see further sub dimension 8 in main dimension 3). Part of this feedback will be on the learning content, but another important part will have to be on the metacognitive learning processes which the learners have to go through (Marton & Booth, 1997).

A cooperative learning environment bears special features that can activate learners towards self-regulated learning (see sub dimensions 10 and 11). On the one hand it can encourage them to articulate their thoughts towards the co-learners, connecting these thoughts to what has already been discussed in the group (Slavin, 1991). Further, social pressure can encourage them to make more effort to master the learning contents at hand and thereby stimulates self-regulated learning. However, many aspects of a cooperative learning environment also can hinder these activating effects. Therefore, cooperative learning should be organized and monitored in an appropriate way (Druckman & Bjork, 1994) and the communication within the groups of pupils should stay focused on the learning content (Cohen & Lotan, 1995). Also assessment can play an important role in activating students (see sub dimension 12). Students adapt their learning efforts towards the tests they will get. Therefore, it is important that in tests students are asked to use their knowledge to solve (new) problems. This gives a signal to the students that they have to aim at this goal during studying/learning in class and it can increase their extrinsically motivated learning effort (Dochy & McDowell, 1997).

2.4. Give feedback and coach

For reasons of certification summative assessment is necessary to indicate whether a certain level of mastery has been reached. However, the most important educational interest of assessment lies in its formative use. Bransford et al. (2000) refer to this in describing their "assessment-centered" perspective of a learning environment, referring to formative environments that "provide opportunities for feedback and revision" and in which "what is assessed must be congruent with one's learning goals" (p. 140). In our model we stress that assessment is just one important constituting part of the total process of giving effective feedback.

With assessment we mean these activities with which the learning coach can find out where a learner stands at a certain point in time; what are his prior experiences, knowledge, misconceptions concerning the learning content as well as his/her metacognitive skills related to the learning content in question (Rice, 1991). Based on the data of this assessment, a teacher will then be able to choose adjusted tasks (see sub dimensions 4 and 5), give adjusted structuring feedback before the learning assignments (see sub dimension 7), during (sub dimension 6) and after assignments (sub dimension 8). This feedback should be aiming at learning content as well as supporting the necessary self-regulative processes (Schunk, 2001). Constant assessment of the reached level should be built in the teaching-learning process. Feedback should then be given in such a way that the learner is activated to take a next self-regulated step in his learning process (Vygotski, 1978). Adapted to the needs of the learner, limited hints or more extensive explanation (for instance to indicate complex misconceptions), can be given. In each case, situations have to be created in which the learner actively uses this feedback to learn (Winne, 1997). Furthermore, it is clear that appropriate feedback should be given on the summative assessments (see sub dimension 13).

2.5.. Structure and steer

In the former three dimensions the main ingredients for creating powerful learning environments have been described. Strictly speaking, there is no need for a fourth dimension in the model. However, we created a separate dimension to stress the importance of all these educational activities which are needed to deliberately organize the former three main activities over a longer period of teaching in order to foster deep level learning and transfer. This dimension resembles to a certain degree the "knowledge-centered" perspective in the model of Bransford et al. (2000), referring to environments "which take seriously the need to help students become knowledgeable by learning in ways that lead to understanding and subsequent transfer." It "requires well-organized bodies of knowledge that support planning and strategic thinking" (p. 136). In our model this dimension incorporates all teacher activities which aim to structure and steer the learning processes. Firstly, there is the structuring of the previously mentioned teaching activities:

a) learn to know your learners (prior experiences, knowledge, interests,…),
b) create (and/or maintain) motivation to exert effort to learn,
c) create activating, self-regulated learning tasks, adjusted to the learners at hand,
d) give activating feedback before the task,
e) constantly assess the learners, as far as possible during the tasks and eventually after the tasks,

f) give activating feedback during and after the task,
g) assess the whole learning process and the learning outcomes and decide on the assignment of a new learning task (while maintaining motivation), etc.

Certain aspects of these structuring tasks have already been discussed above: activating pupils towards connecting learning contents (sub dimension 5), and giving structuring feedback before, during and after learning assignments (sub dimensions 6, 7 and 8). In sub dimension 9 other aspects are stressed: a structuring approach has to be organized within an elaborative view on the curriculum, encouraging the pupils to structure the learning contents in an organized whole (Reigeluth, 1999). As part of this, certain learning activities which (some) learners would not perform independently will have to be steered (Singley & Anderson, 1989), certain insights will have to be automatised to prevent unnecessary cognitive load (Anderson, 1993). Misconceptions have to be worked on more directly. Another important point of attention which cannot be passed over by the teacher is the available learning time and means: an effective trade-off with goals and educational approaches has to be searched for.

Further, structuring the educational approach also has an essential motivational aspect. Students expect from the teaching approach that they start to understand the subject matter and that they feel able to solve the learning assignments, preferably quite soon after the lesson/assignment started. For most students these positive feelings of mastering the situation go together with a teacher explaining the contents in a clear way and with a good class management (Good & Brophy, 2000). Teachers can create these feelings more easily in traditional educational settings because students are more used to them and they are more easy to manage. It is clear that these conditions also have to be met related to more complex learning tasks which activate towards self-regulated learning. If too many lessons are unstructured and unclear, this will demotivate the students (see sub dimension 3) (Schwartz & Bransford, 1998).

3. Measuring perceptions of the learning environment in the Flemish part of TIMSS 2003

In common with students in the other countries participating in the TIMSS 2003 study (see, for example, Mullis, Martin, Gonzales, & Chrostowski, 2004), the Flemish students have been presented with tests of their achievement in science and in mathematics. In addition, students, teachers and principals have filled out the international TIMSS 2003 questionnaires.

In Flanders, the internationally defined measurements of TIMSS 2003 have been supplemented with a numerical and spatial intelligence test for the students and with a parents' questionnaire. Moreover, some elements have been added to the international students', teachers' and principals' questionnaires. One of the additions to the students' questionnaire is central to the present paper, namely: an instrument which measures the students' perceptions of the learning environment. The construction of this instrument, which consists of 33 4-point items (see Table 3), has been based on the theoretical model described in Section 2. This detailed 33 item instrument is related to a 6 item precursor administered in the Flemish part of TIMSS 1999 (Van den Broeck et al., 2005) in that it includes the six previously used items. (See Table 3, items 3, 5, 15, 27, 32, and 33.) Moreover, six closely similar items were included in the Flemish extension of the teachers' questionnaire of TIMSS 2003 (Table 2).

Table 2. Six items about the learning environment in the teachers' questionnaire

During math lessons in this class …
… I introduce each new chapter or new topic by means of varied examples from daily life. (a)
… I give pupils the opportunity to discuss their approach to math problems with other pupils. (b)
… I give pupils the opportunity to ask other pupils to explain their way of solving a problem. (c)
… I bear in mind pupils' remarks when searching for suitable assignments or practice materials. (d)
… I organize team work or individual work to get a picture of the actual difficulties the pupils encounter while solving a problem. (e)
… I organize team work or individual work to get a picture of the actual time needed by pupils to solve a problem. (f)

These are 5-point items. Potential answers: 'Almost never', 'Seldom', 'Sometimes', 'Often', or 'Almost always'. Items a, b, c, d, e, and f are closely similar to items 5, 32, 27, 3, 15, and 33 in the students' instrument (Table 3).

4. Sample, variables, and analyses

The sample

The Flemish sample of the TIMSS 2003 study consists of 5213 eighth grade pupils in 276 classes in 148 schools. The eighth grade is divided into a general or academic track (A-stream) and a vocational track (B-stream). The A-stream part of the TIMSS sample has 4521 pupils in 228 classes in 119 schools, whereas the B-stream is represented by 692 pupils in 48 classes in 29 schools. The remainder of the text refers to the A-stream, unless it is explicitly indicated otherwise.

The fact that the Flemish sample contains more than one class per school constitutes an extension to the international study design. In the A-stream (B-stream), we have 109 (19) schools with two classes in the sample and 10 (10) schools represented by a single class. As in the Flemish TIMSS 1999 study (Van den Broeck et al., 2005), this design enables us to distinguish between the class and the school level in the analyses. In most (namely: 92) of the 128 schools with two classes in the sample, the two classes have different math teachers.

Characteristics of the learning environment in the class

Exploratory factor analysis has been employed to structure and reduce the 33-item measure of the learning environment as perceived by the students. In the next sections, the result will be presented and discussed from the perspective of the theoretical framework. Next, student level scale scores have been calculated and aggregated (averaged) per class. Thus, each scale yields a class-level learning environment variable.

Furthermore, the scores on a 6-item learning environment scale based on the teachers' questionnaire (Table 2) have been calculated, yielding an additional class-level learning environment variable. This variable will be compared with a variable derived from the six closely similar items in the student questionnaire (which were also available in the Flemish TIMSS 1999 study). The latter variable is constructed in the same way as the class-level variables derived form the 33-item questionnaire: by calculating student level scale scores and averaging per class.

Mathematics achievement

We have used the TIMSS 2003 Rasch score for mathematics achievement (Martin, 2005) as a response variable to which we seek to relate the class-level learning environment variables. For the A-stream of the eighth grade in Flanders, this math score is available for 4328 students in 224 classes in 119 schools, with a mean value of 152.8 (0.4) and a standard deviation of 8.3. The total variance partitions into 69% variance between students within a class, 17% between classes within a school, and 15% between schools.

Further analyses

Having explored the structure of the 33 item measurement of the learning environment characteristics by means of a factor analysis, our aim is to relate this structure to the theoretical model which served as our point of departure. Before doing so, however, we study these dimensions further by examining the corresponding learning environment variables in two ways: (1) we estimate their within-school between-classes differences and (2) we determine their explanatory power with respect to individual students' math achievement.

Our final learning environment variables refer to the class level. For each variable, a two-level model of classes within schools is estimated in order to partition its variance into a within-school between-classes component and a between-schools component. The explanatory power of each learning environment variable is assessed by means of a three-level model (of students within classes within schools) explaining math achievement.

5. Results

The exploratory factor analysis yields an acceptable 6-factor solution, which is described in Table 3. For each factor, Table 3 lists all items which load significantly on the factor and are included in the corresponding scale.

Table 3. Six learning environment scales from the Flemish part of the TIMSS students' questionnaire

'Activation' scale (11 items, $\alpha = 0.76$): In the math class …
… the teacher asks about relationships between different parts of the subject material during tasks. (8)
… the teacher explains as little as possible, letting us think and try for ourselves instead. (11)
… during team work or when I am working on my own, the teacher inquires after the difficulties I encounter while solving a problem. (15)
… the teacher points out connections between new and previously treated subject matter. (16)
… the teacher gives tasks that encourage us to keep looking for a solution. (17)
… the teacher's tests require us to apply the subject matter to new problem contexts. (19)
… the teacher gives small clues that help us to find solutions by ourselves. (22)
… when an assignment or test goes rather wrong, I am encouraged to think about what has caused the problem and what I can do about it. (24)
… when we start with a new subject, the teacher takes time to repeat previous subject matter that will be relevant to the new topic. (30)
… it is important to understand the subject matter in order to obtain good marks on tests. (31)
… during team work or when I am working on my own, the teacher inquires after the time I need to solve a problem. (33)
'Clarity' scale (7 items, $\alpha = 0.82$): In the math class …
… the teacher bears in mind pupils' remarks when searching for suitable assignments or practice materials. (3)
… the teacher is able to explain new topics in a clear and well-organized manner. (6)
… we get the opportunity to explain our solution to the teacher. (7)
… the teacher keeps the class under control. (9)
… the teacher tries to make us understand new subject matter by alternating questions to the class with explanations. (23)
… the teacher takes into account pupils' answers. (25)
… it's thanks to the teacher's approach that I understand the subject matter well. (29)
'Authenticity' scale (3 items, $\alpha = 0.74$): In the math class …
… the teacher gives examples of situations in daily life where the subject matter can be applied. (1)
… each new chapter starts with examples from daily life that clarify the new subject. (5)
… situations are described that can happen in the real world and that need a mathematical solution. (14)
'Motivation' scale (4 items, $\alpha = 0.76$): In the math class …
… the teacher makes sure that I get interested in the subject matter. (2)
… the teacher uses an agreeable diversity of approaches in his/her teaching. (4)
… we work in a pleasant manner. (12)
… I feel that the subject matter will be useful to me later. (21)
'Feedback' scale (3 items, $\alpha = 0.70$): In the math class …
… the teacher explains the solution after an exercise. (18)
… the teacher repeats the subject matter when it is not properly understood by some pupils. (26)
… the teacher clarifies errors in tests. (28)
'Cooperation' scale (2 items, $\alpha = 0.74$): In the math class …
… we have the opportunity to ask other pupils to explain their way of solving a problem. (27)
… we have the opportunity to discuss our approach to math problems with other pupils. (32)
Items from the 33-item questionnaire not used in the scales: In the math class …
… after a test we receive the solutions on paper. (10)
… the teacher's way of handling the subject matter costs me to much effort. (13)
… we have to correct our own tests by means of the right answers on paper. (20)

For each item, the number between brackets indicates its position in the list of 33 items presented to the student. These are 4-point items, with as potential answers: 'Nearly always', 'Rather often', 'Now and then', or 'Never'. The internal consistency of the scales has been expressed by means of Cronbach's α. The value of α reported here has been calculated in the complete Flemish TIMSS 2003 sample, i.e.: A-stream and B-stream together.

Table 4 shows the correlations between the class-level variables derived by aggregating the scales defined in Table 3. We have also added the correlations with the variable derived from the 6-item scale defined in TIMSS 1999, which combines items from the scales 'activation' (items 15 and 33),

'clarity' (item 3), 'authenticity' (item 5), and 'cooperation' (items 27 and 32) and has an internal consistency α=0.76. Finally, Table 4 shows the correlations with the 6-item learning environment scale from the teachers' questionnaire (α=0.74). Note that the correlation between the teachers' scale (CT) and the corresponding variable (CP) derived from the students' questionnaire, and also the correlations between CT and the other variables determined by the students, are clearly smaller than the correlations amongst the variables from the students' questionnaire.

Table 4. Correlations between class-level learning environment variables

	CLAR	AUTH	MOTIV	FEEDB	COOP	CP[a]	CT[b]
ACTIV	0.80	0.56	0.72	0.77	0.57	0.78	0.16
CLAR		0.47	0.75	0.88	0.55	0.71	0.16
AUTH			0.59	0.41	0.40	0.69	0.14
MOTIV				0.67	0.60	0.76	0.14
FEEDB					0.52	0.66	0.12
COOP						0.85	0.19
CP							0.19

[a] CP is based on the TIMSS 1999 6-item measure of the student's perception of the learning environment (see Section 3). [b] CT is the 6-item scale from the teachers' questionnaire (Table 2). Each correlation refers to up to 228 A-stream classes. Note: the variables have been defined in a 'positive' sense: a class with score 4 experiences more 'activation' than a class with score 1, etc.

Table 5 summarizes the basic statistics of these eight class-level learning environment variables. Moreover, it shows the partitioning of the variance of each variable into a within-school between-classes component and a between-schools component. Although there are sizeable between-schools differences for some variables, the between-classes component is dominant for the seven variables derived from the students' questionnaire; for the variable CT, the two components are more or less equal. We conclude that the learning environment variables, in keeping with their intended meaning, are true class level variables (instead of school level variables).

Finally, Table 5 lists the coefficients of the learning environment variables in their role as predictors of mathematics achievement. None of the coefficients is significantly different from zero at the 5% level, although some have a p-value below 10%.

Table 5. Characteristics of the class level learning environment variables

	Basic statistics			Var. comp.[c]		Single predictor model[d]			
Variable	N[e]	Mean	SD	Class	School	N[f]	Coeff.[g]		p[h]
Activation	227	2.56	0.19	67%	33%	4328	2.9	(1.7)	9%
Clarity	227	3.01	0.35	69%	31%	4328	1.8	(0.9)	6%
Authenticity	227	2.08	0.33	69%	31%	4328	-1.5	(1.0)	14%
Motivation	227	2.34	0.34	95%	5%	4328	-0.1	(0.9)	89%
Feedback	227	3.24	0.35	65%	35%	4328	1.1	(0.9)	25%
Cooperation	227	2.15	0.36	91%	9%	4328	-0.8	(0.9)	39%
CP[a]	227	2.15	0.28	86%	14%	4328	-1.9	(1.1)	10%
CT[b]	216	3.15	0.65	47%	53%	4088	0.9	(0.5)	9%

[a] CP is based on the TIMSS 1999 6-item measure of the student's perception of the learning environment (see Section 3). [b] CT is the 6-item scale from the teachers' questionnaire (Table 2). Note that CT potentially ranges from 1 to 5, whereas the other variables have a potential range from 1 to 4. [c] Variance components according to a two-level model (classes within schools). [d] Three-level model (students within classes within schools) explaining mathematics achievement by means of a single predictor. [e] Number of classes. [f] Number of students. [g] Note: the variables have been defined in a 'positive' sense: a class with score 4 experiences more 'activation' than a class with score 1, etc. Between brackets: standard error. [h] The p-value refers to a deviance test comparing the model with and without the predictor.

6. Discussion

Table 5 shows that none of the coefficients in the single predictor models is significantly different from zero at the 5% level. In this respect it must be noted that the dependent variable in this first exploration is not optimally suited for our purpose. Firstly, the math achievement score refers to an international test which is less than perfectly adapted to the Flemish curriculum. Secondly, we can

envisage a more sensitive analysis by restricting the dependent variable to those items—such as: problem solving items—on which a positive effect of a constructivist learning environment is expected. In the remainder of the discussion, we will consider the coefficients with a p-value below 10% as (marginally) significant from zero.

The composition of the six scales of Table 3 is largely in agreement with the combination of a number of the sub dimensions derived from the theoretical framework.

The theoretical model assumes that activating the students towards self-regulated learning will be the main determinant in the design of powerful learning environments. Tasks assigned by the teacher with this objective in mind, are in tune with the constructivist nature of learning processes. Students are asked to use their acquired knowledge to put a meaning to new information and/or are prompted to solve related or even new problems. The 'activation' scale comprises a number of aspects (sub dimensions) of the main dimension 'activate towards self-regulated learning' in the theoretical framework. First, this involves assigning tasks with a sufficient degree of complexity and by which students are urged to think for themselves (items 17, 11). This fits the 4-th sub dimension. Furthermore, the activation scale stresses the importance of figuring out the connections between components of the subject matter, either by the teacher (items 16 and 30) or at the teacher's request during assignments (item 8). This corresponds to the 5-th sub dimension. Next, the scale also expresses the importance of providing activating supervision of these assignments (items 22, 15, 33). Here we find sub dimension 6. Finally, the need for activating assessment is represented in the scale: on the one hand through the items referring to the complexity of the tests (items 19 and 31, see sub dimension 12), on the other hand via the concept of tests or assignments as learning moments (item 24). According to the model, activation is essential for in-depth learning. The three-level model revealed a significant effect ($p=0.09$).

An important idea in the theoretical framework is that activating towards self-regulated learning must not be allowed to impair the students' confidence in being able to master the subject matter. It implies that a clear-cut and structured approach is essential (items 6, 29, 23, 9). This tallies with sub dimension 3. Such an approach is also thought to foster motivation. In a similar vein, the theoretical model draws attention to students' need for understanding and respect during their efforts to master the subject matter. In addition, students need clarity with regard to their role in the educational process. In our model, this is embodied in the aspect 'avoid coming across as a know-all' (sub dimension 2) and in 'keep attention by sequencing tasks and explanations' (sub dimension 3). In the clarity scale, we find the corresponding items 25, 3, and 7. Thus, according to our theoretical framework the clarity of the learning environment is an equally important predictor of achievement as activation and should be balanced with activation. The multilevel analysis yields a significant effect ($p=0.06$).

The items 1, 5, and 14 which constitute the 'authenticity' scale (Table 3) refer to the advisability of promoting interest by the use of real-life examples. This conforms to sub dimension 1 of the theoretical model. The scale 'motivation' (items 12, 4, 2, and 21) fits sub dimension 2, 'maintain motivation for learning'. This scale mainly concerns the fostering of long-term motivation by means of agreeable and diversified instruction. While we consider this to be an important factor in the implementation of a pleasant learning process, we do not regard it as essential for attaining in-depth mathematical insight. Of course, this does not mean that deadly dull and repetitive lessons may not have a detrimental effect, preventing learning through a total lack of attention among the students and perhaps even causing rebellious behavior. In our analyses, we did not find a link between the authenticity and motivation scales and math achievement ($p=0.14$ and $p=0.89$, respectively). This may mean that most teachers do not let it come to that and provide enough variation in the lessons to get the students to put in sufficient effort.

The scale 'feedback' (items 26, 28, 18) corresponds to the eighth sub dimension 'give activation feedback after tasks'. We look upon this dimension as important, specifically when students have not yet benefited from good supervision during activating assignments. The importance of carefully targeted and limited hints especially during activating tasks is a point which is stressed by our theoretical framework. The effect of the 'feedback' variable is, however, not significantly different

from zero (p=0.25). On the other hand, it must be noted that the feedback aspect is partly covered by the 'activation' scale (items 22, 15, 33) and also by the quality of the interaction with the teacher as expressed in the 'clarity' scale (items 25, 3, 7), which did have some predictive power.

The sixth scale in Table 3—'cooperation', items 32 and 27—matches the tenth sub dimension of the model (Table 1). The theoretical framework suggests that cooperation has a considerable activating value, but we did not find a significant effect in our analysis (p=0.39). As a potential explanation, we bring forward that the activating value of cooperation is conditional on the quality of the interaction (Slavin, 1991), an aspect which is not explicitly included in the 33 item questionnaire.

Finally, with regard to the (limited) opportunity within the Flemish TIMSS 2003 study to compare the point of view of the students and their teachers concerning the learning environment, we note that both views are positively related, but the relationship is rather weak. Thus, it seems desirable in future studies to question the teachers about the learning environment in their classes as thoroughly as we have questioned the students in the TIMSS 2003 study.

The main conclusion of this contribution is that some important features of the theoretical framework seem to be reflected in the TIMSS 2003 data. There is substantial agreement between the sub dimensions postulated by the model and the factor structure found in the data. Also, there is some indication that the aspects of the learning environment which are theoretically the most essential—namely: activation towards self-regulated learning and clarity of the learning environment—are related to achievement in mathematics. For several other potential links between the learning environment and achievement put forward by the theoretical framework we did not find any evidence in the data. Additional research is necessary to find out whether a restriction of the dependent variable to those items on which a positive effect of a constructivist learning environment may be expected influences the results.

7. Bibliography

Anderson, J.R. (1993). *Rules of the mind*. Hillsdale NJ: Lawrence Erlbaum.

Anderson, J.R., Greeno, J.G., Reder, L.M. & Simon, H.A. (2000). Perspectives on Learning, Thinking and Activity. *Educational Researcher, 29*(4), 11-13.

Boekaerts, M. (2001). Pro-active coping: meeting challenges and achieving goals. In: E. Frydenberg (Ed.), *Beyond coping: meeting goals, visions and challenges.* Oxford, UK: Oxford University Press.

Bransford, J.D., Brown, A.L. & Cocking, R.R. (2000). *How people learn. Brain, Mind, Experience and School.* Washington DC: National Academy Press.

Brown, A.L. & Campione, J.C. (1996). Psychological Theory and the design of innovative learning environments: on procedures, principles, and systems. In L. Schauble & R. Glaser, *Innovations in Learning: new environments for education* (pp. 289-325). Mahwah, NJ: Lawrence Erlbaum Associates.

Brown, A.L. (1996). Distributed expertise in the classroom. In G. Salomon (Ed.), *Distributed Cognitions: psychological and educational considerations*, p. 188-228. Hillsdale NJ: Erlbaum.

Cohen, E. & Lotan, R. (1995). Producing equal-status interaction in the heterogenous classroom. *American Educational Research Journal, 32*, 99-120.

Corno, L. & Randi, J. (1997). Motivation, volition and collaborative innovation in classroom literacy. In J. Guthrie & A. Wigfield (Eds.), *Reading, engagement: motivating readers through integrated instruction*, p. 14-31. Newark, DE: International Reading Association.

De Corte, E. (2000). Marrying theory building and the improvement of school practice: a permanent challenge for instructional psychology. *Learning and instruction, 10*, 249-266.

Dochy, F. & McDowell, L. (1997). Assessment as a tool for learning. *Studies in Educational Evaluation, 23*, 279-298.

Druckman, D. & Bjork, R.A. (Eds.) (1994). *Learning, remembering, believing: Enhancing team and individual performance.* Washington DC: National Academy Press.

Good, T. & Brophy, J. (2000). *Looking in classrooms, 8th ed.* New York: Longman.

Martin, M. O. (ed.) (2005). *TIMSS 2003 user guide for the international database*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center.

Marton, F. & Booth, S. (1997). *Learning and awareness.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Mullis, I. V. S., Martin, M. O., Gonzales, E. J., & Chrostowski, S. J. (2004). *TIMSS 2003 International Mathematics Report*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center.

Reigeluth, C.M. (1999). The elaboration theory: Guidance for scope and sequence decisions. In C.M. Reigeluth (Ed), *Instructional design theories and models* (pp. 335-381). Hillsdale NJ: Lawrence Erlbaum Associates.

Rice, D.C. (1991). *The design and validation of an instrument to identify preservice elementary teachers' intuitive and school knowledge of the concepts of surface area/volume and states of matter.* Paper presented at the annual meeting of the National Association for Research in Science Teaching. Lake Geneva, USA.

Richardson, V. (2003). Constructivist pedagogy. *Teachers College Record, 105* (9), 1623-1640.

Scardamalia, M. & Bereiter, C. (1991). Higher levels of agency for children in knowledge-building. A challenge for the design of new knowledge media. *Journal of the Learning Sciences, 1*: 37-68.

Schelfhout, W., Dochy, F., Janssens, S., Struyven, K., Gielen, S., & Sierens, E. (2006). Educating for learning-focused teaching in teacher training. The need to link learning content with practice experiences within an inductive approach. *Teaching and Teacher Education* (accepted).

Schelfhout, W., Dochy, F., Janssens, S., Struyven, K., Gielen, S., & Sierens, E. (2006). Towards an Equilibrium Model for Creating Powerful Learning Environments. Validation of a Questionnaire on Creating Powerful Learning Environments. *European Journal for Teacher Education* (accepted).

Schunk, D. (2001). Social Cognitive Theory and Self-Regulated Learning. In B. Zimmerman & D. Schunk (Eds.), *Self-Regulated Learning and Academic Achievement.* Mahwah NJ: Lawrence Erlbaum Associates.

Schwartz, D.L. & Bransford, J.D. (1998). A time for telling. *Cognition and instruction 16*(4), 475-522.

Shuell, T. (1996). Teaching and learning in a classroom context. In T. Berliner & R. Calfee, eds. *Handbook of Educational Psychology*, p. 726-764. New York: MacMillan.

Singley, M.K. & Anderson, J.R. (1989). *Transfer of cognitive skill*. Cambridge, MA: Harvard University Press.

Slavin, R. (1991). Group rewards make groupwork work. *Educational Leadership, 5,* 89-91.

Stipek, D. (2002). *Motivation to learn. Integrating theory and practice.* Boston: Allyn and Bacon.

Van den Broeck, A., Opdenakker, M.-C., & Van Damme, J. (2005). The effects of student characteristics on mathematics achievement in Flemish TIMSS 1999 data. *Educational Research and Evaluation, 11*(2), 107-121.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Winne, P.H. (2001). Self-regulated learning viewed from models of information processing. In B. Zimmerman & D. Schunk (Eds.), *Self-Regulated Learning and Academic Achievement.* Mahwah NJ: Lawrence Erlbaum Associates.