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ON PUPILS' MATHEMATICAL SELF-CONCEPTS: DEVELOPMENTS, RECIPROCAL EFFECTS AND FACTORS OF INFLUENCE IN THE ESTIMATION OF PLEASURE, DILIGENCE AND ACHIEVEMENTS

Abstract:

The present empirical study deals with the question of the mathematical self-concepts of German pupils from secondary school ("Gymnasium"). The basis of the study is a survey by means of a closed questionnaire of about 1,650 pupils.

In this article, only three parts of the self-concept are considered in isolated, global items: namely the estimation of pleasure in mathematics, of the mark and of the diligence. The mark given by the teacher is also taken into account.

We describe what attitudes pupils possess towards themselves in these dimensions and how their self-concept develops from grade 6 to grade 12. Furthermore, the relationships between these items are investigated prompting the question “Is there a circle showing that the pleasure in math education influences the diligence and the commitment, which then have effects on the achievements, and, do good or bad achievements have effects on the pleasure?” Another question is if boys and girls possess different self-concepts. Finally, we examine the relationships (reciprocal effects) between pupils' view of mathematics and their self-concepts.

1. The theoretical framework of the "self-concept towards mathematics"

The term "self-concept" can be built up within, or integrated into different theoretical frameworks, for example those of subjective theories or belief-systems. We would like to view self-concepts within the framework of attitude-systems as attitude-structures about oneself as a learner and user of mathematics.

1.1. The general concept "attitude"

The basic theoretical concept is that of "attitude". There exists a great variety of different definitions for this concept (depending on both author and time) (see B. Six in Dawes 1975, pp. 44 ff.; Triandis 1975, p. 3; Meinefeld 1988, p. 121). Most of these definitions correspond in the way that "attitude" denotes a lasting, permanent and stable orientation and readiness (or intention) to action of an individual towards a social object (for example: mathematics or here: oneself). In modern, cognitive terms, "orientation" means a consistency in perception, cognitive representation and abstract valuation.

When we think of the concept a person holds about themselves, we mainly think about the "personal knowledge" that this person has. From the answers to a questionnaire, we measure mainly only that "knowledge" which a person tells us about themselves. This cognitive component which can be understood as (a part of the) subjective knowledge is called "belief". (Pehkonen describes the variety of understandings of the term "belief" and its relation to the subjectivity of knowledge; comp. Pehkonen 1995). We believe that cognitions (beliefs) are closely connected to feelings, i.e. emotional descriptions of meaning, valuations and judgements. This close relationship between cognitions and feelings is pointed out in some empirical findings.

Furthermore, we believe that cognitions and feelings have a relationship to a distinct readiness (or intention) to action, i.e. to a scheme of action which is well proven in the situation (as it is perceived, represented and valued).
For example, the self-estimation of one's abilities in mathematics contains subjective knowledge about various strong and weak points, themes and topics, about levels of understanding and mastery. The subjective knowledge about strong points may be connected with emotions like pride, self-satisfaction, calmness etc., while the subjective knowledge about weak points may be connected with emotions like shame, dissatisfaction, motivation etc. Furthermore, the subjective knowledge about strong points and the feeling of self-satisfaction may lead to a tendency in action planning to practice this schema again and again or to assimilate similar situations or to generalize the schema, e.g. a tendency to mathematical action.
In total, we hold a concept of attitude which stands next to the classical three-components-approach (see e.g. Triandis 1975, pp. 4 f.; Meinefeld 1988, p. 121). In this three-components-approach of attitude theory, attitudes are a system of cognition, emotion and preparedness (readiness to act), which principally tend to correspond. We accept this three-components-approach (only) as an ideal starting point for research, because it expresses the links between cognition and emotion and between cognition, emotion and the intention to action. We stress however that these relationships must not always be close 1:1 relationships, but can be only principal tendencies.
The intention to action (readiness component) of an attitude enters into the planning of an action. The model of simple consistency between attitude and behaviour has been advocated frequently; this model assumes that behaviour in a certain situation is determined by one attitude, so that attitude and behaviour coincide. We do not advocate this model of simple consistency however. Many empirical investigations have pointed out that attitudes and behaviour are only slightly related (for an overview see e.g. Meinefeld 1988, pp. 122 f.; Mummendey 1983).
We advocate the model of conditional consistency between attitudes and behaviour (see e.g. Meinefeld 1988 or Mummendey 1983). The action or the behaviour in a situation does not only depend on one attitude (and their readiness component), but it depends on the interaction of various factors:

- various attitudes and their attitude-structure;
- personal factors
  (for example the level of centrality, consciousness or universality of the attitude,
  high self-awareness and low self-monitoring of the person);
- situational factors (or the perception of the situation)
  (for example reference-groups, routine situations, norms).

An attitude is relevant for action in a certain situation under the condition that it corresponds to other attitudes (which are active in that situation) and to personal and situational factors. (Ajzen 1982 holds a similar opinion.)

1.2. The self-concept towards mathematics

We can assume that attitudes (or attitude-dimensions) are related to, and connected with, each other thus the relationships between attitudes build an attitude-structure.
The self-concept as a learner of mathematics is such an attitude structure. This self-concept consists of the subjective knowledge (beliefs, cognitions), the emotions, evaluations and intentions of action about oneself related to mathematics and mathematics education.
The most important elements are the subjective knowledge and the emotions concerning

- the interest in mathematics and the interests (aims, motives) in using mathematics,

- the motivation and the pleasure in mathematics as well as their reasons,
- the efficiency in mathematics, the strong and the weak themes and topics,
- the causes of one's success or failure.

The questionnaire contained three items about the self-concept, namely the estimation of pleasure in mathematics education, the estimation of achievements, and the estimation of diligence. Furthermore, the pupils gave their mark in mathematics. These items only measure two elements of the self-concept, that is the "pleasure with mathematics" and the "estimation of efficiency in mathematics". Above all, the measurement is very general and identified only in single, isolated items.

It may also be noted that the self-concept is one part, one substucture of the "mathematical world view". This term denotes the system of all the attitudes which are related to mathematics (single attitudes and their structure). It consists of four main components: attitude-structures towards mathematics (view of mathematics), mathematics learning, mathematics teaching and oneself as a learner and user of mathematics (self-concept).

2. Research Questions

In my interpretation, the study of self-concepts (as well as mathematical beliefs, views or attitudes in general) has the following structure:

(1) at first, pupils' self-concepts (or elements) are "measured" and described;
(2) we then have to examine whether these attitudes towards oneself are relevant for action, i.e. do attitudes have an effect on the learning and using of mathematics? Most importantly, we have to examine the question "are there some attitudes which have a negative influence and others which have a positive influence on the motivation and the success in learning and doing mathematics?";
(3) in order to plan and optimize processes of attitude change, we need the best knowledge of how attitudes (self-concepts) are developed and which factors have an influence on this development;
(4) finally we should investigate how an attitude change can be optimized and which factors contribute to attitude change.

Within the framework of belief-research, there is a great variety of empirical investigations concerning the self-concept (see Pehkonen and Törner 1996; bibliography in Törner and Pehkonen 1996 or http://www.math.uni-duisburg.de/projects/mavi). Some investigations contribute to step (1) and describe self-concepts of teachers, students and sometimes pupils. Another popular topic is the identification of the causes of success and failure in mathematics. Furthermore, there are some contributions to step (2) which focus on the relationship between the self-concept and mathematics achievement, problem-solving behaviour or mathematics anxiety and performance. Investigations relating to steps (3) and (4) seem to be rare.

This work neither claims to extend those investigations (and their open questions) nor to make extensive, far-reaching statements about the self-concept. Here, we will only look at a few, isolated items of the self-concept from a global perspective - a few items which have been noted within the scope of a larger inquiry about pupils' view of mathematics as background information (to differentiate pupils) (comp. Grigutsch 1996 or 1998). Nevertheless, the work is an initial inventory of some data about German pupils.

In this work, some aspects of steps (1) and (3) are studied concerning items of the self-concept:

- what attitudes do pupils have (towards their achievement, diligence and pleasure) ?
- how do these attitudes develop from grade 6 to grade 12 ?
- what are the relationships between these attitudes ?
- how far does gender influence pupils' attitudes (self-concept) ?

In addition to that, we can offer a few opinions on step (2), e.g. ideas concerning the effect of the view of mathematics on the self-concept or vice versa.

3. Some remarks on the method of the study

In the year 1994, 1,650 pupils and their mathematics teachers in 20 secondary schools ("Gymnasium") in Northrhine-Westfalia (West-Germany) filled out a closed questionnaire. The questionnaire related to their experiences in mathematics education, their view of mathematics and a few items about the self-concept as a learner of mathematics. In each of the 20 schools, one grade 6, one grade 9, one basic course (3 hours weekly) and one high-performance course (6 hours) in grade 12 were explored.

Concerning the self-concept, the pupils were asked

- about the mark that they would give themselves for their achievements (estimated mark);
- about the mark that they would give themselves for their diligence (estimated diligence);
- about their pleasure in mathematics (pleasure).

Furthermore, they gave their last mark in mathematics (from the teacher).
The marks were measured on the German scale for school marks from 1 = very good to 6 = very bad. In reality this scale is actually a scale from 1 to 5, and the middle of the scale is 3 rather than 3.5. The pleasure was measured on a scale from 1 = very high to 5 = very low.

All results reported in the following sections have been tested for statistical significance; mean differences have been tested non-parametrically with the Wilcoxon-test or with the U-test from Mann-Whitney. The correlation coefficients are partial correlation coefficients and all probabilities are Bonferroni-adjusted.

4. Results of the survey

4.1. The attitudes in the items of the self-concept

Table 1: Arithmetic means in different items and grades

grade 6	EM: 2.7	ED: 2.9	M: 3.0
grade 9	EM: 2.9	M: 3.1	ED: 3.2
12 basic	EM: 3.0	M: 3.2	ED: 3.5
12 perform.	EM: 2.6	M: 2.9	ED: 3.3

(arithmetic means; EM = estimated mark, M = mark, ED = estimated diligence; the scale is the scale of school marks from 1 = very good to 6 = very bad with the middle of the scale being 3 rather than 3.5)

In grade 6, most of the pupils (60 %) like mathematics. They estimate their diligence mediocre (average 2.9) and this corresponds with the mark of the teacher (3.0). They judge their achievements with an average about 2.7 relatively good, higher than the teacher and higher than their diligence. Thus the pupils in grade 6 have a positive view of themselves in relation to mathematics.
In grade 9, the opinions about the pleasure in mathematics education split (distribution bimodal). There is a group of pupils, who dislike maths education, and a larger group who like it. The mark tends to be below average (3.1), which might have negative effects on the self-concept. The pupils judge their achievements with an average of 2.9 higher than the teacher and therefore tend to be above average. They estimate their diligence rather low (3.2), especially in comparison to their achievements.
In the basic course, there is a group of pupils who enjoy maths education, and a larger group who do not (bimodality). The pupils obtain marks that are slightly below average (3.2), which might have negative effects on their self-concept. They judge their achievements higher than the teacher, but mediocre (3.0). In comparison to this, they judge themselves to be "idle" (3.5).
In the high-performance course, a high percentage (70 %) of the pupils like math education. They obtain slightly above average marks (2.9), and this may have positive effects on their self-judgement. Indeed, the pupils estimate their achievements even higher (2.6), while they estimate their diligence rather low (3.3).

4.2. The age-dependent developments in the items of the self-concept

The development of the self-concept is, like the development of the view of mathematics, to be regarded as an essential part of mathematical socialization, perhaps even the most important part. We investigate differences between ages in the grades 6, 9, 12 basic and 12 performance (see Table 2).

Table 2: Arithmetic means in different items and grades (compare Tab. 1)

	M	EM	ED	Pl*
grade 6	2.95	2.7	2.9	2.5
grade 9	3.14	2.9	3.2	2.9
12 basic	3.2	3.0	3.5	3.1
12 perform.	2.9	2.6	3.3	2.3

(*scale for "pleasure": 1 = very high, 3 = undecided, 5 = very low)

Mark (Figure 3): In grade 6, the pupils obtain an average mark (2.95). In grade 9, their achievements are judged a little worse (3.14). In the basic course, the mark (3.2) remains on a similar level to grade 9, while in the high-performance course, the pupils receive a better mark (2.9) and reach the level of grade 6.
Estimated Mark (Figure 3): The development in the estimation of the achievements follows the development in the marks, but on a higher level. Pupils in grade 6 judge their abilities and achievements with an average of 2.7 very positively. The self-judgement worsens to grade 9 (with a mark of 2.9) and in the basic course remains at a similar relatively poor level, (3.0). On the other hand, the pupils in the high-performance course estimate their achievements better (2.6) and judge themselves similarly to be as good as in grade 6.

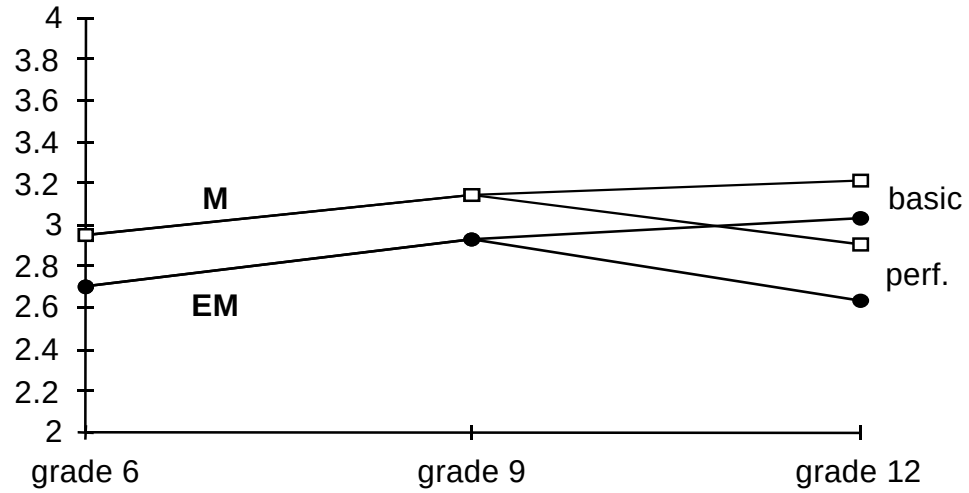

Figure 3: The developments in the mark (M) and the estimated mark (EM)

Estimated Diligence (Figure.4): Pupils in grade 6 think that they have an average diligence (2.9). In contrast to this, older pupils judge themselves to be "idle". The diligence of the pupils decreases continually - in their own estimation - from grade 9 (3.2) in the basic course to the relatively low value of 3.5 in grade 12. In the high-performance course in grade 12, the diligence remains about the level of grade 9, but with an average of 3.3 it too is rather low.
Pleasure (Figure 4): The pupils' pleasure with math education changes very clearly in the course of their school career. In grade 6, the pleasure is still relatively high - the average lies between pleasure and indifference. In grade 9, the pleasure decreases and lies in the area of indifference. The pleasure decreases further in the basic course, while in the high-performance course it increases again and becomes higher than the value in grade 6.

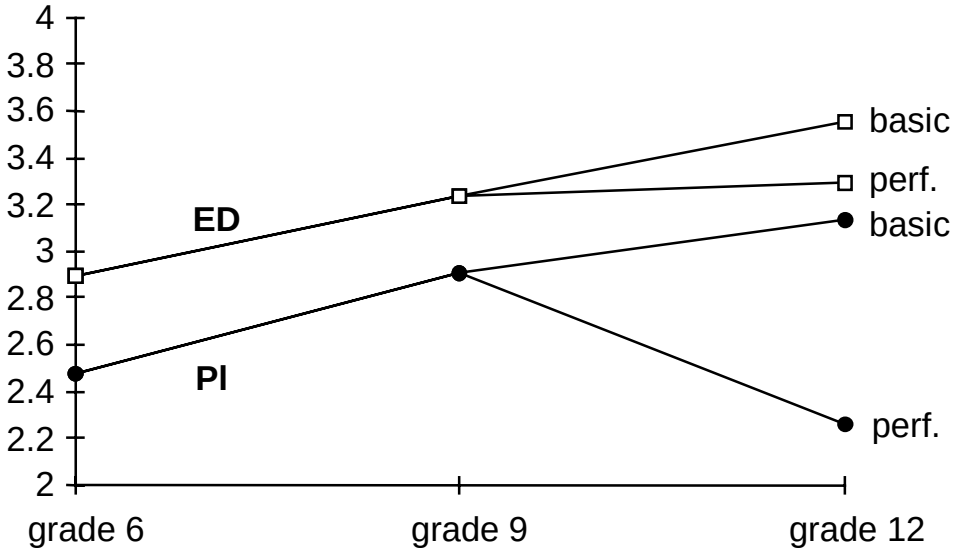

Figure 4: The developments in the estimated diligence (ED) and the pleasure (PL)

All developments of the pleasure, mark, estimation of mark and estimation of diligence have the same direction. From grade 6 to grade 9, the self-concept in these attributes gets worse, and from grade 9 to the basic course it remains at this poor level or even decreases further. In the high-

performance course, there is an improvement, at least on the grade 6 level whereas in the estimation of diligence there is no further change for the worse (in contrast to the basic course). If one takes into consideration that the estimation of diligence is uncoupled (untied) from the other variables from grade 9 onwards (see next section), and that it therefore makes a smaller contribution to the character of the self-concept, one can postulate that at the end of their school career only the pupils in the high-performance course have a positive self-concept. For pupils in the basic course, the development of the self-concept is a process of decrease and change for the worse. The pupils feel less and less pleasure, they demonstrate less and less commitment and diligence, and they credit themselves with less and less knowledge and abilities. They see themselves drifting away from mathematics. Therefore the development in the basic course can be interpreted as a disassociation from mathematics.
Normally, there are mechanisms which inhibit a change of the self-concept; self-concepts tend to be constant over longer periods of time. Thus, it is very important that such negative developments should have been observed. The pupils must have undergone significant experiences over longer periods of time.

4.3. The relationships between the estimations of pleasure, diligence and marks and the marks

The starting hypothesis about the relationship between the elements of the self-concept can be represented as a process in a circle (Figure 5). The pleasure in math education influences the diligence and the commitment, which have effects on the achievements in mathematics. On the other hand good achievements have effects via an encouragement confirmation on the pleasure. This mechanism is circular and cumulative. It is a very simple and naive theory which can describe and explain how achievements and motivation arise and become stabilized. However it can very often be found in the thinking of pupils and teachers, especially when explaining decreasing motivation and achievements.

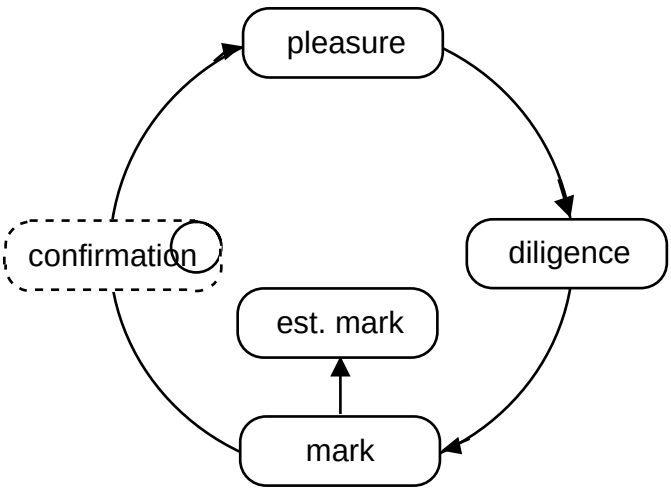

Figure 5: The starting hypothesis about the relations in the self-concept

According to the results of this inquiry, the starting hypothesis cannot be kept. Ultimately, this model describes the reciprocal effects between pleasure and achievements. If we only regard the relationship between pleasure and marks without controlling the influence of the other variables,

then the results show that pleasure and marks are closely connected. On the one hand, pleasure has an influence on the marks while, on the other hand, marks then in turn influence the pleasure. If this reciprocal effect is described in detail - as in the model of the starting hypothesis - using the variables diligence, estimation of diligence and estimation of achievements, then the results show that there is no direct reciprocal effect between pleasure and achievements (Figure 6).

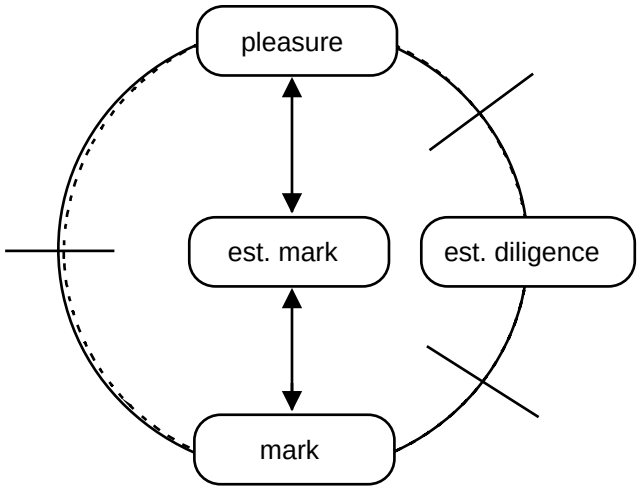

Figure 6: The results about the relationships in the self-concept

Concerning this model, it could not be proved that

(1) the pleasure in math education has an effect, via the estimation of diligence, upon the mark as a measure of achievements. In fact the estimation of diligence contributes nothing to the effect of the pleasure upon the achievements, hence it also contributes nothing when trying to describe and explain how mathematical achievements arise. In particular, the estimation of diligence is uncoupled (untied) from pleasure and achievements at least from grade 9 onwards.
The assumption that the effect of the pleasure upon the marks is mediated by the diligence and the estimation of diligence must be rejected. There are possibly many factors which are influenced by pleasure and which cause achievements.

(2) the marks have an immediate (direct) effect upon the pleasure in math education. Instead, the effect is mediated by the estimation of achievements. According to the inquiry, this estimation of achievements takes a central position in the self-concept and can probably be interpreted as "self-satisfaction" or "confirmation".
The assumption that the effect of the mathematical achievements upon the pleasure are influenced by a variable "self-confirmation" or "self-satisfaction" cannot be rejected.

As an extension to (2), the relationships that have been observed can appropriately be described and explained in the following model. The process of effect of the achievements upon the pleasure is not direct. It consists of partial processes which contribute to this effect.
First the achievements, which are considered as the marks part of the teacher's pupil-concept or which are considered as the objective achievements part of the pupil's environmental world, are integrated in the self-concept of the pupil. Secondly, a transition (passage) from the factual and objective sphere of achievements and judgement into the abstract sphere of pleasure takes place.

This double "passage of borders" makes it seem plausible that there are several partial processes which participate in the process of effect of the achievements upon the pleasure. One partial process surely is the effect of the achievements upon the self-judgement and its effect upon the pleasure. Seen as a whole, the achievements start and involve judging and emotional processes which can be described as confirmation and encouragement.
According to the results of the inquiry and in the framework of the measured variables, the estimation of achievements takes central position in pupils' self-concepts. It plays an important role in determining the effect of the achievements upon the pleasure and thus lies at the cutting-point that is the diffuse domain of borders between the factual and objective sphere of achievements and the abstract sphere of pleasure. On one hand, the objective achievements, the objective and factual marks of the teacher have an essential influence on the estimation of achievements, while on the other hand the emotional pleasure has an influence. Therefore, the estimation of achievements contains both an objective and factual as well as an abstract component. In my opinion, it is best interpreted as "pupils' self-satisfaction with their achievements".

4.4. The influence of gender on the self-concept

There are gender-specific self-concepts as learners of mathematics. Boys and girls have different though not opposite self-concepts. Boys at all ages feel higher pleasure and estimate their achievements in mathematics higher than girls. Thus boys have a better concept (image) of themselves and their achievements and a higher self-satisfaction. On the other hand, girls from grade 9 onwards estimate their diligence higher than boys, and this difference continues to increase to grade 12. The gender-specific difference in the attribution of diligence probably only develops during the social interaction aspects of secondary school.
Boys and girls have gender-specific self-concepts, especially in the estimation of their mathematical achievements, although there is no objective reason for this. Indeed boys and girls get (in grade 6, grade 9 and basic course) similar marks and therefore probably obtain similar mathematical achievements. Obviously, they have different gender-specific mechanisms (or patterns) of interpretation which mean that objectively similar mathematical achievements are interpreted differently and then integrated into the self-concept. These different patterns of interpretation already exist in grade 6, so they are probably already developed in earlier social settings.

5. The relations between the view of mathematics and the self-concept

Within the scope of the inquiry, from which the part about the self-concept is presented here, the focus mainly lies on the view of mathematics, e.g. on the subjective theories of the pupils about mathematics, on its structures, its development and its factors of influence (comp. Grigutsch 1996 or 1998).
The closed questionnaire (which was handed out to the pupils) contained 67 statements concerning the view of mathematics. By means of factor analysis, four to five dimensions were defined and subsequently verified as dimensions relevant to the view of mathematics (and as the most important dimensions in the answer behaviour on the questionnaire). In the formalism-aspect, mathematics is characterized by strength and exactness concerning terms and language, thinking ("logical" thinking) and argument and reasons ("proofs"). In the process-aspect, mathematics is described as a problem-orientated process of finding (discovering, re-inventing) and understanding mathematics. The application-aspect deals with the question whether

mathematics is directly applicable or is of practical use in everyday life or in jobs. The schema-aspect characterizes mathematics as a "toolbox" and a "formula package" e.g. mathematics is a collection of calculating procedures and rules which prescribe precisely how to solve a task. In the rigid-schema-aspect it is stressed that mathematics is not a "toolbox" that an individual can develop and understand: mathematics requires learning knowledge only for a short time. This knowledge is "ready", is often misunderstood but is tested in exams.

Certain views of mathematics are connected with certain self-concepts and certain achievements. A (higher) algorithm- and rigid algorithm-orientation corresponds with low pleasure, poor mathematical achievements and low estimation of achievements, while a process-based orientation and a conviction in the usefulness of mathematics are connected with high pleasure, good mathematical achievements and high self-judgements. The formalism-orientation is in principle not related to the self-concept. The estimation of diligence in the self-concept is also largely independent of the view of mathematics.

From the viewpoint of the self-concept, we can summarise the results with the following statements: Objectively poor pupils without pleasure are

- more algorithm-orientated,
- more orientated in rigid algorithms,
- less process-orientated and
- less convinced of the usefulness of mathematics

than objectively good pupils with pleasure in mathematics education.

An algorithm-orientated view of mathematics corresponds to a negative self-concept and poor mathematical achievements, while a process and application-orientated view of mathematics is closely connected with a positive self-concept and good mathematical achievements.

The fact that there are significant and systematic relationships between the view of mathematics on the one hand and the mark and the self-concept on the other hand, is important in the theory of attitudes. It supports the assumption that attitudes have a relevance for action. These effects - in both directions - between the view of mathematics and the self-concept cannot easily be explained with internal cognitive processes. A more plausible explanation is that the view of mathematics influences the behaviour of learning and doing mathematics and that the experiences gained influence the success in math education, the self-concept and the self-satisfaction, or vice versa.

The relationships between the view of mathematics and the self-concept make it possible to set up hypotheses founded upon an evaluation of views of mathematics as either positive or negative. This evaluation does not depend on such areas as superior and global aims (e.g. preparation for science), conceptions and schools in the didactics of mathematics education or pedagogical aims (e.g. emancipation), which are often value-bound. In contrast to this, the aim of improving pupils' mathematical achievements and of making their self-concept positive is very "natural" and evident, largely free from values and free from superior pedagogical and didactical aims.

If the aim of mathematical education is to support pupils' mathematical achievements and make their self-concepts positive, then the results allow the following hypotheses to be made:

- the view of mathematics mediated to pupils differs significantly;

- a view of mathematics, which strongly emphasises the algorithmic aspect of mathematics and which neglects (or emphasises too weakly) the process and application-orientated character of mathematics, should be considered negative. It should not be included in math education;
- a view of mathematics, which does not emphasise the algorithmic aspect too strongly, but which emphasises the character of mathematics as an application-orientated process of understanding and finding, should be considered positive. This view of mathematics should be central to math education.

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