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ON SOME PSYCHOLOGICAL ASPECTS OF MATHEMATICS ACHIEVEMENT ASSESSMENT AND CLASSROOM INTERACTION

ABSTRACT. The way students and teachers evaluate mathematics achievement differs in certain respects. To which causal performance is ascribed determines the teacher's strategy to interact with the student on the one hand and influences the student's willingness to invest additional effort on the other. Certain possible causal factors for success and failure in mathematics and their relation to teacher-student-interaction are discussed in the present article. A rather general cognitive scheme, the teachers reference norm, explains differences between the teacher's perception and assessment of student characteristics and subsequent teaching interventions.

1. INTRODUCTION

Students' achievement and errors in mathematics are due to several possible causes and are subjected to the teacher's diagnostic and remedial treatment. Local deficiencies such as the student's mistakes in computation or geometry may easily be recognized and handled by supplying him with additional material, reformulating the problem in question, working with him in a one-to-one way, assigning a peer-tutor, or just by calling on another student. Which kind of remedial assignment the teacher chooses depends on his assessment of the student's ability to solve the problem in question with additional help. High ability students only need slight hints to come up with the right solution, whereas low performing students may not even come near it despite tremendous teacher effort. In any case the diagnostic and 'therapeutic' process contains at least two stages:

(a) the identification of the content or problem specific errors/mistakes at the level of information acquisition/processing (Mann *et al.*, 1974; Reisman, 1977; Johnson, 1979; Radatz, 1980). This diagnosis is followed by curricular aids based upon

(b) assumptions about underlying causes of the student's mathematics performance at the level of personality dimensions and characteristics. These characteristics are perceived as (relatively) stable and resistant to the teacher's remedial endeavours. They serve as explanations for students' success and failure (Kelley, 1972, 1973).

The following study concentrates on the second diagnostic stage, the rather general factors influencing mathematics performance as perceived by teachers and students.

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TABLE I
Scheme of causal factors determining achievement outcome (according to Heider, 1958)

		Locus of control	
		Internal	External
Stability	Stable	Ability	Task difficulty
	Unstable	Effort motivation	Luck

2. ACHIEVEMENT AND ITS CAUSAL FACTORS

The determinants of achievement may be assessed according to two dimensions: 'stable versus unstable' and 'internal versus external' (Kelley, 1972, Weiner, 1974, 1975 and Table I). Stable factors such as ability and difficulty of the problem are seen as being invariant, whereas unstable factors such as motivation, effort and luck may vary from task to task, and from lesson to lesson. The dimension 'locus of control' (Rotter, 1966) describes whether the causal factor lies within the student (internal) like ability, effort, concentration, and practising at home, or beyond his influence (external) like task-difficulty, luck, and teaching style.

Teacher and student may ascribe success and failure to one or several of these factors, each attached with a certain weight. These causal attributions will be discussed under three headings: (a) their sources in the classroom, (b) individual differences between teachers, and (c) their consequences.

2.1. *Sources of Causal Attribution*

Within the process of teacher-student-interaction, teacher and student build up a concept of the student's mathematical ability according to his (average) level of performance, its consistency, stability, and distinctiveness with respect to his peers (Kelley, 1973; McArthur, 1972). The student's performance may be rather stable and above (or below) that of his class-mates, leading to a perception of high (low) ability. It may vary from task to task which leads to an ascription of medium ability but inconsistent effort or motivation. Or his performance in arithmetic could be distinct from that in geometry leading to content-specific attributions. In any case, the variability and level of performance with regard to his peers accumulates to become a concept of the student's ability to solve mathematical problems.

The teacher's and student's concepts are not to be seen independently from one another as the teacher gives hints to the student as to how he assesses his achievement. These signs of the teacher's evaluation are rarely expressed explicitly but mainly implicitly in the communication process by making special moves, giving certain help, or asking high- (or low-) level questions. The teacher thus influences the student's self-concept of his mathematics ability as he is a 'significant other' (Mead, 1934; Sullivan, 1947) for this particular part of the child's self-concept.

Obviously, different concepts of one's own ability (or of others) lead to different explanations when an achievement outcome is observed. Assuming low ability and observing failure will tell one little about the effort, and the failure is totally attributed to lack of ability. Assuming high ability, on the other hand, and seeing the student fail leads to an attribution of lack of effort (Meyer, 1973; Lorenz, 1979).

2.2. *Individual Differences*

In general, an observer and an actor will come to different conclusions about the determinants of an achievement result (Jones and Nisbett, 1971). Primarily, their criterion for calling an outcome success or failure could be different. Seeing only one result, the perceiver takes the outcomes of a reference group into account and assesses success and failure according to the average achievement of this group. The actor, knowing his own past results, takes himself as the criterion for comparison. His prior achievement outcomes determine whether this particular result is a success or failure. (This distinction refers to an 'ideal' actor and observer; 'mixed' reference norms are the rule rather than the exception.)

Accordingly, a teacher can assess the student's achievement as 'good' or 'bad' according to the average level of the class or according to the individual student's prior performance. Teachers may prefer one or the other of these 'reference norms' (Rheinberg, 1975, 1976 and Table II) or a mixture of both. Let us outline some theoretical differences between these two.

A teacher with a 'social orientation' typically compares the results of his students with the class average in a cross-sectional manner. As there are some students whose achievement is always above (or below) the average, he perceives stable factors, like ability, socio-economic status etc., as determinants of achievement. These stable attributions have a high phenomenological validity and are constantly reinforced. This teacher expects 'typical' developmental processes, e.g., 'good' students getting better, 'bad' students getting worse. His strategy of criticism and praise depends on the comparison between the student's result and that of his peers, so that some students are mainly

TABLE II

Assumed differences between an ideographic and social reference norm

	Social reference norm	Ideographic reference norm
Perception of achievement outcome	According to the outcome distribution of the class; cross-sectional comparison	According to the outcome distribution of the particular student; longitudinal comparison
Causal ascription	Attribution on stable factors; high subjective validity	Attribution on unstable factors; low subjective validity and open towards revision
Achievement expectancy	Expectation of constant achievement development and 'typical' progress	No expectancy
Strategy of sanctions	Sanctions according to social comparison	Sanctions according to comparison with prior achievement
Instructional style	Equality of task assignment; all students work on the problem at a time	'matching' principle; individualized task assignment

praised, while others are more criticized. His teaching style will be one of 'equality for all', e.g., each student is working on the same task at a time, for the demands must be the same for all students to get a social comparison.

A teacher with an ideographic orientation differs from this description in several respects. He typically makes longitudinal comparisons, each student being his own criterion for success or failure. Success has a different meaning here as it means advances with respect to prior achievement, failure being a stagnation. The causes for this sort of success/failure cannot be stable factors but are effort, motivation or external variables having a low subjective validity. The teacher does not expect any 'typical' development because fast advances and stagnation may occur with any student. The frequency of praise and criticism is the same for all students as acceleration and retardation in the learning process are equally likely to occur for each student in the long run. The teaching style will be 'the best fit', matching task difficulty to the student's momentary state of knowledge irrespective of his peers' achievement (Rheinberg, 1977).

2.3. *Consequences of Causal Attributions*

Ascribing success or failure in mathematics to stable characteristics of the student, like ability in the case of social reference norm orientation, leads to the expectation of the same or similar results for future achievement on the part of the teacher and student. A teacher's low concept of the student's ability is likely to result in an unwillingness to interact with, or to give help to, this particular student because neither promises to help him cope with the problem. On the student's part, even increased effort will not lead to a positive outcome because of his low ability.

If, on the other hand, teacher and student attribute failure to variable factors like lack of effort, low motivation or concentration, then additional stimuli and help from the teacher, and further investment of effort by the student, are likely to produce the desired learning progress. Positive results afterwards reinforce the attribution of variable determinants of student achievement which then serve as motivational factors for future mathematics learning. Attributions of stable or variable factors thus seem to be at the heart of the self-fulfilling prophecy in the educational process. (This might explain the 'pygmalion-effect' (Rosenthal and Jacobson, 1968).)

3. HYPOTHESES AND METHOD

The theory outlined above was explored in this study. Questions studied were:

To which causal factors do students ascribe their success/failure in mathematics?
Do teachers and students assess these factors similarly?
Do teachers with different reference norms interact differently with students?

To study these general hypotheses, eigh fifth-grade mathematics classes ($N = 262$) were observed for a period of five months. The teacher-student interaction was coded by the Brophy-Good-Teacher-Child-Dyadic-Interaction-System (Brophy and Good, 1969) which covers dyadic interaction but not general teaching style or 'atmospheric' aspects as this seemed to be irrelevant for the purposes of the study. Students had to take four mathematics tests in this half-year course after each of which they were asked to specify the main reason for their result. After excluding factors which were too specific to the situation (e.g., "I had not enough time to solve the problems", "I had an important football game yesterday afternoon. We won but I could not prepare for the test", "My mother was ill. I had to do all the shopping"), the students' answers could be categorized into seven factors: ability in mathematics, classroom participation, nervousness or lack of concentration, interest in mathematics, effort, preparation for class, and luck. At the end of the course each student had to assess each of these seven characteristics on a five-point rating scale and, on a similar sheet, they had to assess the influence of each of these variables on their half-year grade. The teachers were asked to fill out the same questionnaires for each of their students. Students' mathematics self-concept was measured by a modified form of a self-concept test specified for mathematics (Meyer, 1972). The teachers' reference norm was measured by the Rheinberg-Test (Rheinberg, 1975), in which one is asked to evaluate the test scores of nine fictitious students, given their scores on two prior tests and the three class average scores.

4. RESULTS

As the elementary school in Germany covers Grades 1 through 4, students have to change school at the beginning of the fifth grade. Three different types of schools are offered: the 'Gymnasium' for the best students, the 'Realschule' for the students with average achievement or above, and the 'Hauptschule'. (This is not the place to discuss the German school system extensively nor actual endeavours to reform it.) The eight classes included in this study were all from Realschule, which means that (a) the teachers did not know their students before the course and (b) the students were average 'mathematicians' or above in the elementary school.

4.1. *Assessment of the Seven Factors*

Figure 1 shows the mean of the assessment of the seven extracted factors by students and teachers. A hierarchial analysis of variance allowed us to partial

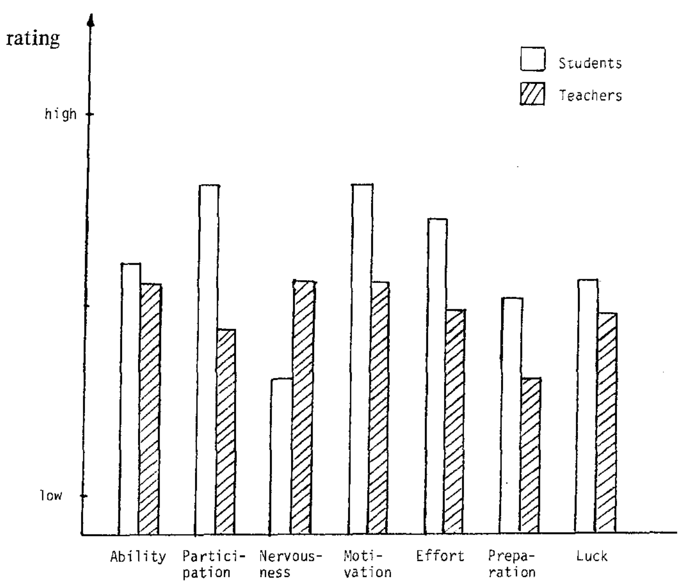

Fig. 1. Means of teacher and student assessment of seven student characteristics.

out the strong class effects and the gender effect. First of all, there were strong class effects on all assessments but they were not determined by any correspondence between the teachers' and their students' answers. Differences in the data between the classes were probably due to differences between the teachers' general cognitive schemes on the one hand, whereas the reasons for student differences remained unclear and could not be related to differences in performance, interaction, or teaching style.

Concerning the gender effects, the girls reported that they had a lower ability for mathematics than did boys but this did not reflect the actual differences in performance. This discrepancy between the genders is often mentioned in the literature (Fennema, 1974; Sherman and Fennema, 1977; Fennema, 1979). It seems as if role stereotypic mathematics self-concept is built up over the years with no differences at the elementary school level (or in the opposite direction) and increases from then on, whereas performance differences are not discovered until the tenth grade. The teachers did not share their students' point of view with regard to gender differences. They estimated boys' and girls' ability for mathematics alike, but they believed that the boys expended less effort and prepared less for class than the girls!

Let us now turn to the grade score effects. As expected, better half-year grades corresponded with higher ability assessment by students and teachers, higher interest, lower nervousness, more classroom participation, and luck. These results do not allow us to draw any conclusions yet about the causal direction between these factors.

After eliminating the grade effect, there remains an effect of the self-concept of students' mathematical ability (see Figure 2) on their assessment of participation, nervousness, interest and luck. Students with a high self-concept report that they are less nervous, that they participate more, that they are more interested in the subject etc. than their classmates with low self-concept *but the same grade.* These findings are in accordance with, and support, a cognitive motivation theory (Meyer, 1973; Weiner, 1976) which conceptualizes task specific self-concept as the main factor for motivational behaviour.

4.2. *Differences Between Pupils' and Teachers' Assessments*

An analysis of the seven factors revealed that, from the teacher's point of view, ability, participation in class, interest, and (lack of) nervousness were intercorrelated as were effort and preparation for class. This result, though not astonishing at all, stresses the point of an 'implicit personality theory' for a teacher. If one tries to find out which cues make a teacher assess one or the

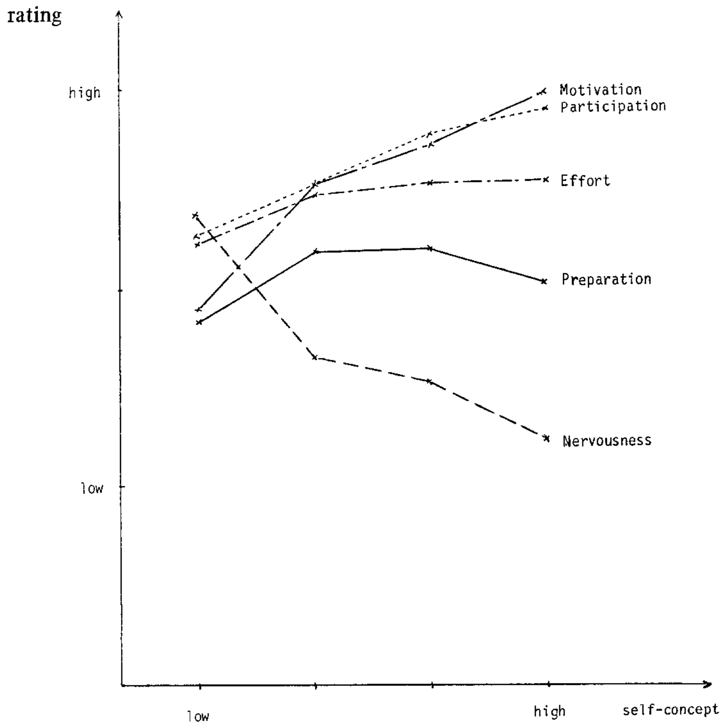

Fig. 2. Student assessment of five factors in relation to mathematics self-concept.

other factor as being high or low, one might find that these cues are implicit rather than explicit, and overlapping in a wide range. Achievement scores might be the key factor for a teacher in deducing some student characteristics (in fact, for the teachers the correlation between grade points and their ability assessment was high, $r = 0.76$, whereas for the students the correlation was only moderate, $r = 0.42$, and about the same as luck, $r = 0.41$).

From the student's point of view, the factors under discussion are more or less isolated and only slightly related in the case of ability and interest ($r = 0.46$).

A general feature of the assessment data is the extremely low correlation *between* teacher and student scores in the assessment of the seven factors (none exceeding $r = 0.27$). These low correlations between teacher and student data are not fully explainable by the fact that the teachers did not know their students prior to the course. A half-year interaction seems to be a reasonable amount of time to assess ability reliably. Rather the data supports the hypothesis that both sides take different cues for achievement factors into account.

For example, an analysis of the classroom interaction data revealed that teachers assessed students' participation according to their volunteering to answer questions, whereas the students believed they were participating more when they actually gave answers independent of their volunteering. This result indicates that teachers have to rely on visible cues to assess student characteristics (some might even call it traits) but that students use different 'data' and come to different conclusions. (This does not imply that teachers are generally wrong in what they think about their students but that the difference between teachers' and students' evaluation needs consideration on the part of the teachers and researchers.)

A further astonishing point is that teachers evaluated the students to be more nervous than the students did themselves! But the students reported that they had more motivation for mathematics than was observed by their teachers, and the same holds true for effort and preparation. Luck did not seem to be a factor taken into consideration by teachers in an educational setting, whereas the students felt they could have 'good' or 'bad' luck.

4.3. *Assessment of Influence of Student Variables*

The assessment of the factors under discussion is neither theoretically nor empirically connected with their influence on mathematical achievement; e.g.,

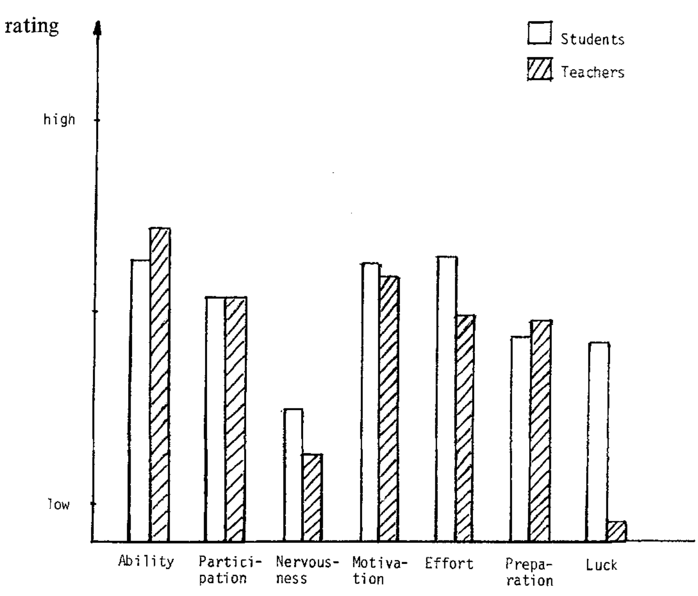

Fig. 3. Means of teacher and student assessment of the influence of seven student characteristics on the half-year grade.

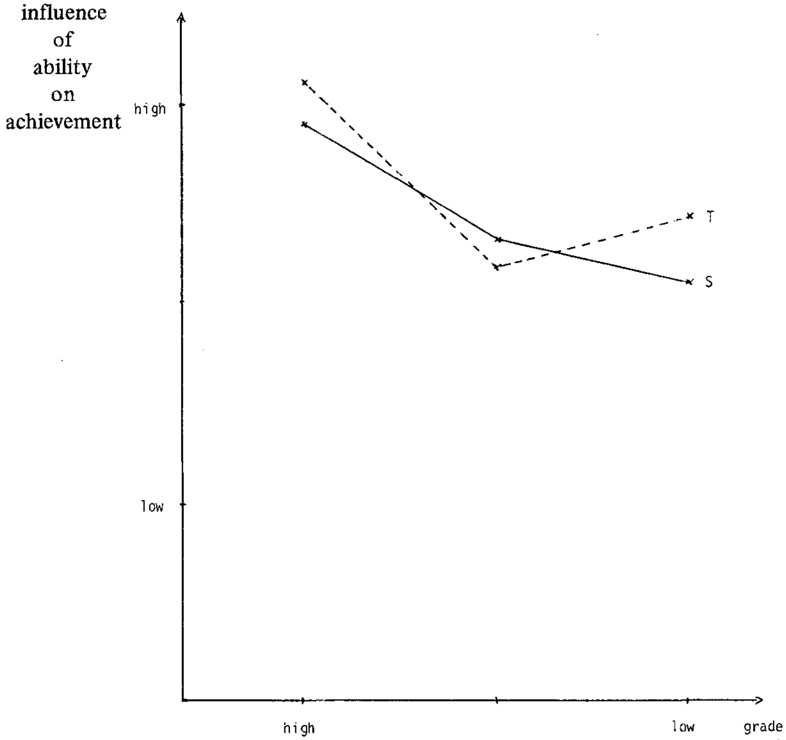

Fig. 4. Assessment of the influence of ability on achievement by teachers and students in relation to grades

effort could be regarded as extremely high but the student failed because of lack of ability (or vice versa). Preparation for class could be perceived as moderate or low, but the student did not perhaps need any because he is a 'good mathematician'. Thus, the influence certain factors have on the achievement must be evaluated separately.

From the teachers' point of view, the main determinant of mathematics achievement is ability, ranking significantly above the second factor, motivation (see Figure 3). Students saw their grades mainly influenced by effort, and even luck played as much a role as preparation for class.

Student assessment of these two differed significantly from teacher evaluation and again, the generally low correlation between teacher and student evaluation is remarkable. A closer look at the data reveals that teachers evaluate the influence of ability high if student performance is above or below average whereas students ranked it low the lower the grade (see Figure 4). For the teachers, high ability is connected with high achievement, and low

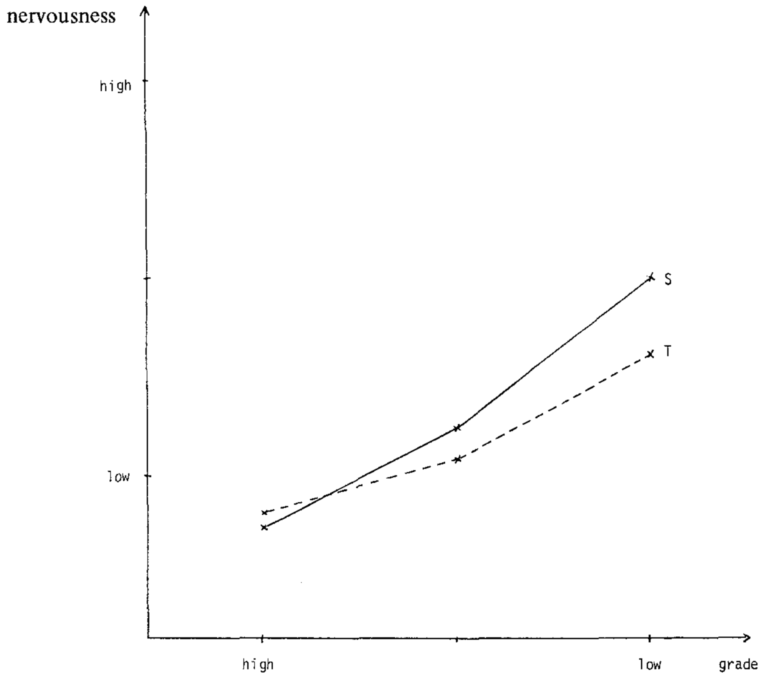

Fig. 5. Assessment of the influence of nervousness on achievement outcome by teachers and students in relation to grades.

ability is the reason for low achievement, whereas the causal factors for mediocre achievement are not quite clear. There remains an area of uncertainty and any factor seems reasonable; the teachers obviously were not willing to discount one factor in favour of another.

For the students, peculiarities of the sample could account for the decreasing influence of mathematics ability on school grades. The students' mathematics self-concept appeared to be uniformly high and therefore (lack of) ability was not perceived a possible cause for failure. But it could as well be a general tendency for most students not to ascribe failure in a school subject to low ability thus maintaining a high self-concept by lack of effort or high nervousness attributions. Unfortunately, the second explanation though motivationally favourable for the learning process (Heckhausen, 1974) is not supported by other studies, suggesting rather a sample-specific aspect (Jopt, 1977).

Nervousness had an effect on low grades only, whereas high grades were not postively affected by (lack of) nervousness (see Figure 5). This agrees well with a naive concept of nervousness (lack of concentration). If high nervousness is experienced it may be regarded as a possible cause for failure,

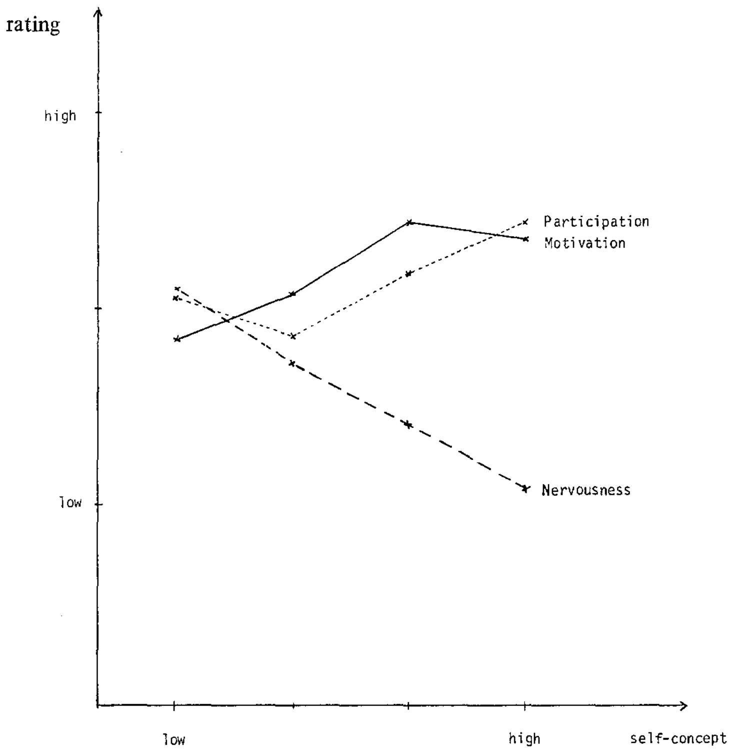

Fig. 6. Assessment of the influence of classroom participation, motivation, and nervousness on achievement outcome in relation to students' mathematics self-concept.

but low nervousness is very rarely consciously experienced and thus, not hindering the achievement, cannot be perceived as a determinant for success.

After eliminating class, gender, and grade effects, there remains a high influence of the student's self-concept of mathematics ability on his evaluation of the influence of motivation, nervousness, and classroom participation. Students with a higher self-concept weigh the effect of nervousness low, whereas students with a lower self-concept experience themselves as highly nervous and evaluate its influence accordingly. High self-concept students believe that they are interested in the subject and give it a high weight, whereas modest interest does not affect the grade from the view point of low self-concept students (see Figure 6).

4.4. *Reference Norm*

As outlined in Section 2.2, teachers with a social reference norm (assessing achievement mainly in comparison to the class mean) should be less sensitive

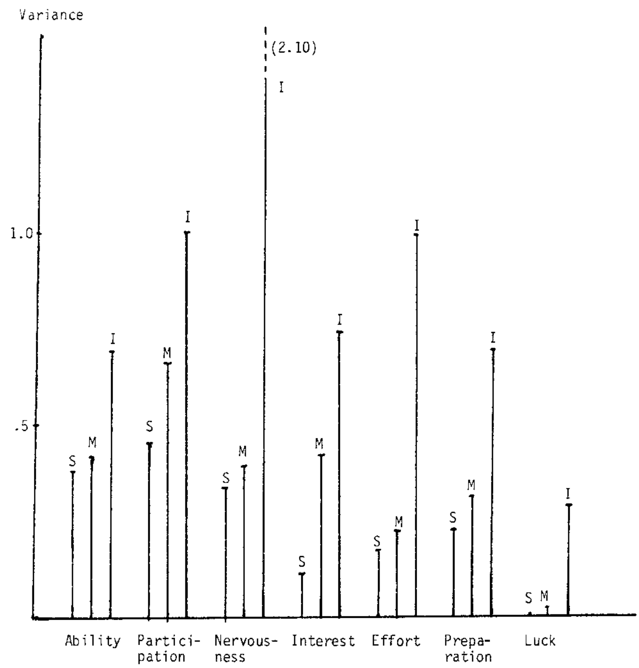

Fig. 7. Variances of ratings of student characteristics for teachers with different reference norms.

to variances of student characteristics than their colleagues with individual standard (taking predominantly the student's own development as criterion for his success/failure). The assessment of the seven factors under the social norm-orientation and of their impact on student mathematics grade should therefore vary very little when compared to the ideographic norm-orientation.

Figures 7 and 8 show the *variance* of teacher ratings for each characteristic on student grades, respectively. The teachers were categorized according to their scores on the Rheinberg-Test as two social type (*S*), three mixed type (*M*), and two individual type (*I*) teachers.

The results point in the expected direction and differences of variance between the teacher groups with different perspectives are significant for almost all student characteristics.

Secondly, it was hypothesized that teachers with an individual reference norm estimate the influence of the relatively unstable factors (nervousness, interest in mathematics, and luck) on students' grades to be high, compared with teachers having a social orientation. Figure 9 shows the means of teachers' assessment of influence of these variables. The differences are significant for each characteristic.

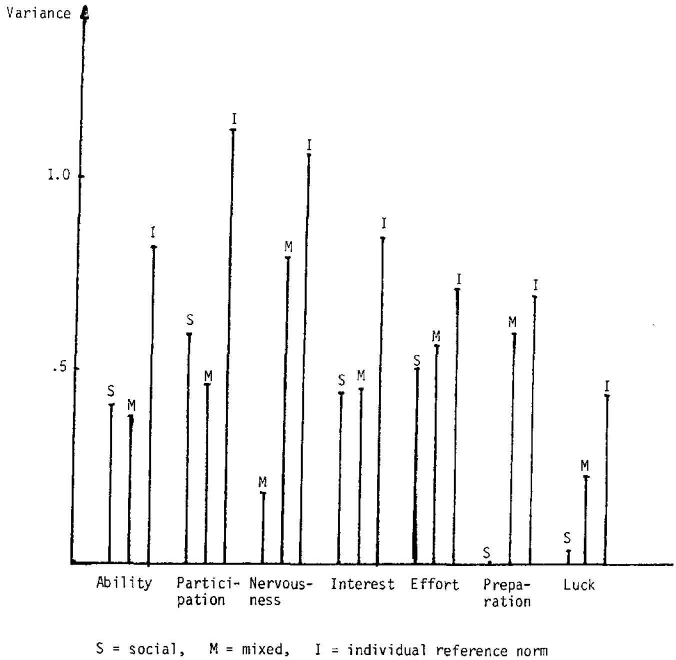

Fig. 8. Variances of the assessment of influence of student characteristics on grades for teachers with different reference norms.

Thirdly, according to the theory (see Sections 2.2 and 2.3), teacher-student-interaction should differ in the kind of teacher intervention after wrong (or no) student answer. It was expected that teachers would give more help concerning the problem process to students whom they evaluated as 'good in mathematics' whereas they would react differently (by repeating or rephrasing the question, turning to the next student, etc.) towards low ability students. Figure 10 shows the influence of the teachers' evaluation of the student's ability on their tendency to interact in a helpful manner. The result is striking, and opposite to most education 'norms'.

Furthermore, teachers with an individual reference norm are more willing to give help for problem solving than their colleagues with a social standard (see Figure 11) who prefer different strategies after wrong (or no) student answer (negative feedback, repeating, starting an interaction with another student, etc.).

5. DISCUSSION

This study can only be regarded as a pilot study because of the small number

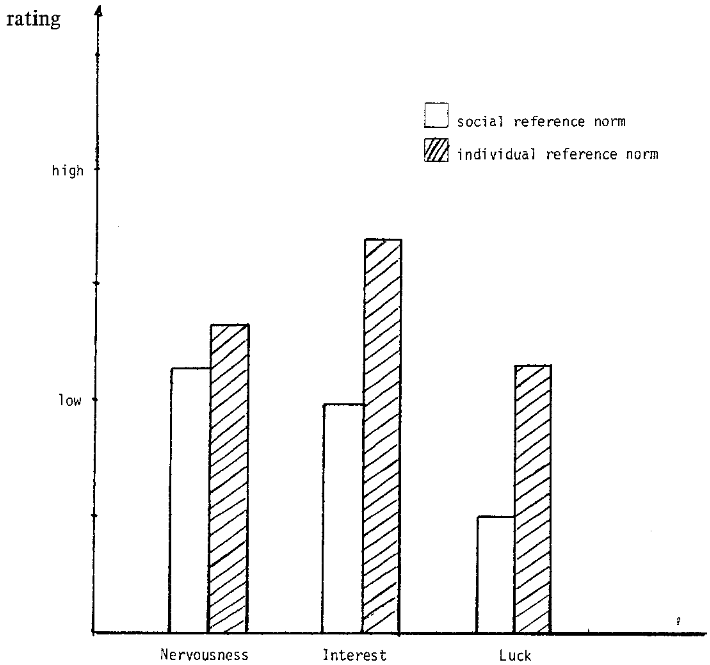

Fig. 9. Mean assessment of influence of selected student characteristics by teachers with social and individual reference norms.

of teachers and students involved. It was conducted to generate some hypotheses on students' and teachers' assessment of mathematics achievement and to examine some aspects of the ideographic versus social distinction in teachers' implicit theories about their students. The following remarks, therefore, are more of a heuristic and tentative kind.

Obviously, mathematics teachers differ from their students in their perception of students' characteristics and of the influence of these characteristics on students' performance. Stressing ability as the main determinant of mathematics achievement has the effect of making more unstable factors play a lesser role. This could be significant for mathematics (Bölts *et al.*, 1978) but quite different for other school subjects.

The students' self-concept of their mathematics ability seems to be a crucial construct in explaining differences not only in performance (Bloom, 1971) but also in their perception of task relevant characteristics such as nervousness, motivation and classroom participation. Mathematics self-concept, like any self-concept, is formed by previous achievement (in relation to a reference group, which, in this case, are the classmates) and by the teachers' evaluation expressed explicitly or implicitly by his interaction mode.

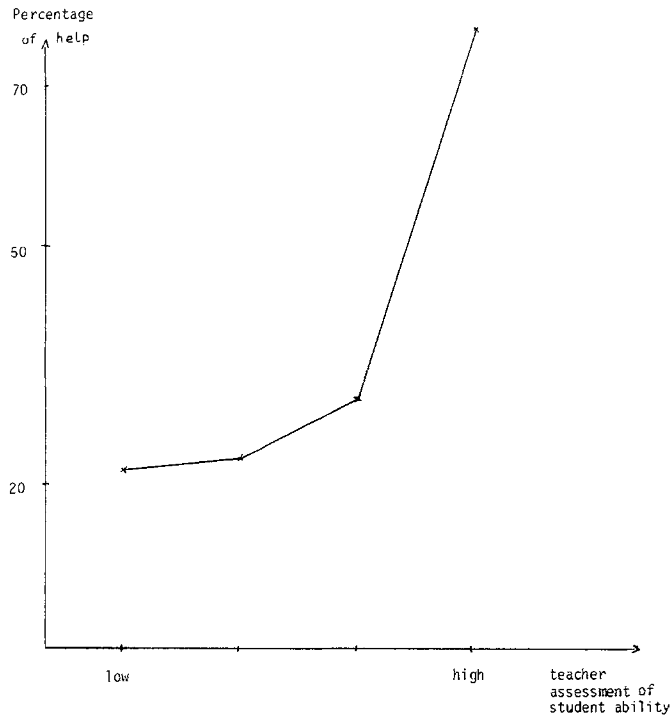

Fig. 10. Percentage of *helpful interactions* in relation to teachers' evaluation of students' ability after wrong (or no) student answers.

The motivational consequences of students' self-concept leading to a self-fulfilling prophecy are well known and extensively examined by follow-up studies to the Pygmalion-effect research (Rosenthal and Jacobson, 1968; Heckhausen, 1974; Brophy and Good, 1972, 1974).

Differences between teachers in explaining school achievement may be accounted for, to some extent at least, by differences in their underlying fundamental cognitive schemes. The individual versus social reference norm is a way of looking at students' developmental processes and evaluating performance. Different factors are emphasized in explaining students' results by the teacher groups and different teacher intervention strategies were observed.

If one regards teachers' behavior from a more clinical-therapeutic point of view (NIE, 1975) in which mathematics instruction is individualized so as to correct students' errors, then this implies diagnostic competence on the part of the teacher. Help and remedial interventions for an individual student depend on the teacher's causal ascription. But the success of any

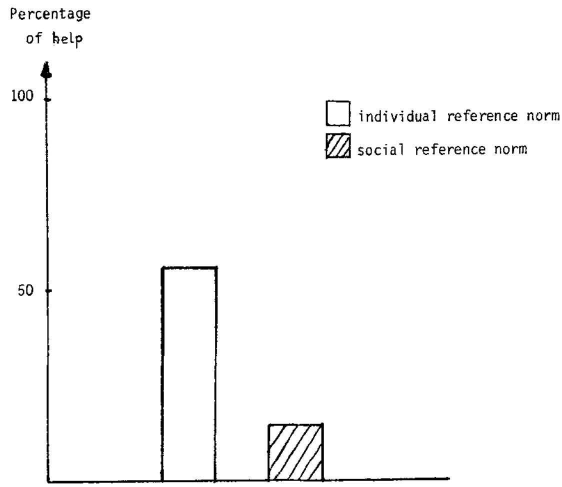

Fig. 11. Percentage of *helpful interactions* (as opposed to other interaction strategies) by teachers with individual and social reference norm after wrong (or no) student answers.

clinical approach in mathematics education seems doubtful as long as the teachers' perceptions of students' mistakes and underlying difficulties are inaccurate not only because of shortcomings in their diagnostic competence which could be treated in pre- and in-service courses, but also because of interference with subjective norms and fundamental preferences. Explaining students' failures by lack of ability leads to a different 'therapeutic' treatment than taking nervousness, lack of motivation or low effort into account.

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