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ABSTRACT

Proponents of mathematics education reform have emphasized both cognitive and attitudinal goals, seeking improvement in children's problem-solving skills and in their attitudes toward mathematics. A pretest/posttest experimental design study examined the effects of SQUARE ONE TV, a television series about mathematics aimed at 8- to 12-year-old children, on the problem-solving behavior and attitudes toward mathematics of 240 fifth graders from 4 public schools in Corpus Christi, Texas. Attitude data was collected from a subgroup of 24 students exposed to 30 SQUARE ONE TV programs and from 24 students in a control group having no SQUARE ONE TV contact. Presented in this paper are the analyses of the relationships between problem solving and attitudes toward mathematics prior to and after contact with SQUARE ONE TV. Models are presented to describe these relationships as suggested by results of the study. Among the implications of the research were the following: (1) specifically designed materials can impact on children's problem-solving behavior and aspects of their attitudes toward mathematics; (2) future research on children's attitudes toward mathematics should employ methods of assessment supplemental to paper-and-pencil scales and study other populations of children; and (3) further questions examining the effects of SQUARE ONE TV on problem solving and attitude change should be studied. (MDH)

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Back to Square One:

Interrelationships among problem solving,

attitudes toward mathematics, and **SQUARE ONE TV**

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Paper presented in symposium entitled "Problem solving, attitudes, and television: A summative study of **SQUARE ONE TV**" (Eve R. Hall and Shalom M. Fisch, chairs) at the biennial meeting of the Society for Research in Child Development, Seattle, WA.

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The current period in mathematics education can be characterized as one of reform. There is widespread recognition among educators, researchers, and laypeople alike that children in the United States are not learning enough of the mathematics that will be important in the coming decades and that their conceptions of mathematics are often inaccurate and misinformed. This concern has given rise to an ongoing reform movement whose goal is to restructure mathematics education to place a greater emphasis on those aspects of mathematics that proponents of reform feel will be of primary importance in the coming years.

At the forefront of this reform movement is the National Council for Teachers of Mathematics (NCTM). In 1989, NCTM issued a document entitled <u>Curriculum and Evaluation Standards for School Mathematics</u> (NCTM, 1989), which outlines a number of goals for mathematics education to try to meet in the coming years. Among these goals are that students learn to value mathematics, become confident in their ability, become mathematical problem solvers, and learn to communicate and reason mathematically.

One of the things that is striking about the NCTM <u>Standards</u> is that, whereas school is usually thought of as a place where one learns facts and skills, the <u>Standards</u> emphasize both cognitive and attitudinal goals -- that children show improvement both in their problem-solving skills and in their attitudes toward mathematics. This dual emphasis points to the very important fact that neither problem solving nor attitude operates in a vacuum; the same child who is attempting to solve certain problems also holds certain attitudes toward them. It is important, then, not only to assess problem solving and attitudes independently, but also to see how they relate to each other.

Of course, this is by no means a shocking new insight. We doubt that any researcher would say that relationships among various dimensions of attitude or between problem-solving performance and attitude are not important. However, while these relationships have been examined to some extent in attitudinal research on mathematics achievement (see Kulm, 1980 for a review), relatively few studies have adopted this focus. In addition, just as attitudes toward mathematics have not been examined in great detail, the relationships among dimensions of attitude or between attitudes and problem solving have not been examined in great detail either. What little research exists frequently uses paper-and-pencil scales to measure attitude; such scales allow for statistical correlations but do not provide much detail on the nature of the attitudes they measure. Indeed, because such scales often ask children to rate how they feel about "math" without any further elaboration of what "math" they're referring to, it would be extremely difficult, if not impossible, to tease apart the relationship between the children's ratings of their attitudes toward mathematics and their conceptions of what mathematics is.

Much of the problem is, of course, one of resources. It requires a great deal of time, effort, and money to investigate any aspect of problem solving or attitude in depth, let alone to investigate the relationships among them. The present study provided us with a unique opportunity in this respect. Because we tested the same children in each domain of inquiry, the data allow some insight into the relationships that exist among them.

The purpose of this paper is to discuss some of the relationships we observed among various dimensions of attitude and problem-solving behavior. First, we will describe the relationships that appeared to exist in the absence of any intervention, that is, in the pretest. Then, we will turn to the various changes that the viewers showed over time to investigate how change in one area was related to change in others, in an attempt to gain a deeper understanding of the nature of the effects of exposure to **SQUARE ONE TV**. Finally, we will turn to the implications of these relationships for future research and for reform in mathematics education.

Relationships in the Absence of Intervention: The Pretest

Our analysis of the pretest data consists of two components, one qualitative and one quantitative. As Elizabeth and Dorothy have explained, the pretest responses of all 48 children (viewers and nonviewers) were used to construct what we call a descriptive analysis investigating children's attitudes in great detail. Dorothy has begun to talk about the common themes that emerged in children's discussions of motivation and enjoyment and the potential links between these two dimensions. The qualitative component of our analysis continues that discussion, pointing to the common themes that emerged among all of the attitude dimensions that we examined: the children's constructs of mathematics and problem solving, their conceptions of usefulness and importance, their motivation, and their enjoyment of the subject.

For the quantitative component of our analysis, we constructed a correlation matrix of the children's pretest scores on all of the variables (problem-solving and attitudinal) that were used in our analysis of change. Our hope was that, although these variables measured somewhat different aspects of each dimension of attitude than the descriptive analysis did, we would find that similar sorts of relationships among the dimensions emerged. Together, the qualitative and quantitative analyses provide a detailed picture of both the statistical relationships among these various dimensions and how those relationships were translated into the things that the children actually spoke about.

Mathematics. First, let us turn to the themes that emerged in children's discussions of mathematics. Figure 1 provides a graphic representatic of the relationships that we found among children's discussions of the various dimensions of attitude in our descriptive analysis.

Figure 1 about here

One very clear finding of our analysis was that children's constructs of mathematics-- their conceptions of what mathematics is-- were central to their discussions of all of the other dimensions of attitude. As Elizabeth described, the children typically thought of mathematics in terms of a set of discrete operations that consisted largely of computational arithmetic. Similarly, when the children spoke about applications of mathematics, they spoke about getting change, paying bills, and other applications of arithmetic. Their discussions of motivation and enjoyment, too, often centered on the arithmetic that they learned in school and on the performance demands of the classroom; they typically spoke about being motivated or enjoying mathematics because of their ability to do well and get good grades (or conversely, about not liking it because of its difficulty).

A second finding was that, as Dorothy has discussed, motivation and enjoyment appeared to be closely tied. Children frequently spoke about being motivated to do mathematics because they found it fun, or explained their enjoyment as due to their engagement with the subject (recall that engagement was one of the two orientations used in our analysis of motivation).

Finally, two factors appeared to determine, in large part, the degree to which the children found mathematics important. Approximately 2/3 (65%) of the children said that they found mathematics to be important to the degree that they found it useful, that is, to the degree to which they could find applications for it in or out of school. Sixteen percent of the children said that mathematics was important to the extent that they found it to be fun. Thus, for these children, the importance of mathematics was tied primarily to two dimensions: usefulness and, to a lesser degree, enjoyment. Again, please keep in mind that children's discussions here also reflected their constructs of mathematics as discrete operations; when children spoke about the importance of mathematics, they were speaking primarily about the importance of computational arithmetic.

This model that gains further support from the correlations that were observed among the children's pretest scores in our analysis of change. Before we take a look at these correlations, however, there are two points that should be kept in mind. First, we must recognize that because these data are correlational, they of course do not imply causality among the variables or their respective dimensions; any causality shown in these figures is inferred from the descriptive analysis, not from the correlations. Second, as Dorothy and Elizabeth have noted, the coding schemes and variables used in the analysis of change are not identical to those used in the descriptive analysis, although they are intended to capture aspects of the same dimensions of attitude. Perhaps the largest difference between the coding for the descriptive analysis and for the analysis of change is that there is no variable in the analysis of change that corresponds to the importance of mathematics per se; rather, the analysis of change for usefulness/ importance focuses on children's applications of mathematics, which are shown in Figure 1 under usefulness.

Having said that, let's take a look at the significant correlations that were observed. Figure 2 superimposes these correlations on top of the model shown in Figure 1; the correlations are shown in bold type. (Note that we do not show all of the correlations that came up significant. Some of the significant correlations are not of experimental interest. For example, within enjoyment, valence was combined with the level of sophistication of the children's statements to create a variable called magnitude. Thus, while valence was significantly correlated with magnitude, this finding is neither surprising nor of experimental interest.)

Figure 2 about here

As this figure illustrates, measures were significantly correlated within individual dimensions. For example, within construct, the degree to which children spoke about advanced mathematics (i.e., mathematics beyond arithmetic) was significantly correlated with the number of areas of mathematics that they spoke about (as classified under Goal III of **SQUARE ONE TV**). Within usefulness, the number of applications children produced was significantly correlated with the degree to which they spoke about unique applications, that is, applications that went beyond the context or examples mentioned in the question.

Two significant correlations were observed between attitude dimensions as well. The degree to which children spoke about advanced mathematics was significantly correlated with the degree to which they described unique applications of mathematics. This correlation is attributable to the fact that many of the unique applications that children came up with employed advanced areas of mathematics, such as the case of one child who spoke about a lawyer's having to estimate the amount of time it would take for a group of witnesses to testify.

The second significant correlation between dimensions was between the degree to which children spoke about their motivation within an engagement orientation (i.e., stemming from engagement with the process of mathematics) and the number of positive statements that they spontaneously made regarding their enjoyment of mathematics. This is very much in keeping with the close relationship we observed between these two dimensions in the descriptive analysis.

Of the remaining arrows in the diagram, no correlations could be run to correspond to those involving importance, and the remaining two arrows did not correspond to any significant correlations, although we did find a marginal correlation between advanced mathematics (in construct) and the children's magnitude of motivation ($r = .25$, $p < .10$). The lack of significance for these two arrows might be due to the absence of a variable corresponding to "school context" in the analysis of change, or to the fact that the children overwhelmingly spoke about computational arithmetic when discussing motivation and enjoyment (so that there was relatively little variance in our measures of construct), or simply to our having used somewhat different coding schemes and variables in the analysis of change than in the descrptive analysis. Overall, however, those correlations appear to be largely consistent with the pattern of results observed in the descriptive analysis.

Problem solving. As Elizabeth explained, the children's constructs of problem solving (or, to use their term, "figuring out") were very different from their constructs of mathematics. Problem solving was seen as a process of thinking hard to figure out problems. Like their constructs of mathematics, the children's constructs of problem solving were evident throughout their discussions of the other dimensions of attitude as well. In fact, their discussions of their attitudes regarding problem solving formed a pattern similar to that observed for mathematics, as illustrated in Figure 3.

Figure 3 about here

As this figure suggests, the children's notions of problem solving as an active process of figuring out were evident in their discussions of the usefulness of problem solving; they saw such skills as applicable to solving problems in their present and future lives and to the work of detectives and inventors. In motivation, they defined "challenge" and challenging tasks in terms of the mental effort that would be required. And in enjoyment, many of the children found working with complex problem-solving tasks such as PSA C* (the "Doctor Game" problem described elsewhere in this symposium) to be fun because of the hands-on process involved and interesting because of the thinking it required.

As in our investigation of mathematics, enjoyment and motivation appeared to be closely linked. Novelty was a theme in the children's responses in both dimensions; over one tenth of the children (13%) defined "challenge" in terms of mastering something new, and 30% of the children found novelty to be a source of enjoyment as well. Moreover, in the enjoyment dimension, inherent in many children's discussions of what made PSA C* interesting was a sense of challenge, while 7% of the children asked about "challenge" defined it explicitly in terms of fun.

The one thing that differentiated the pattern of relationships for problem solving from the one for mathematics was the factors that seemed to play a role in children's conceptions of importance. As in their discussions of mathematics, the children found problem solving to be important as a result of its usefulness in their present and future lives. However, unlike mathematics, they did not speak about enjoyment as a source of importance. Rather, they spoke about problem solving as inherently important because of the inherent rewards associated with mastery-- as one child said, when you know how to figure something out, "you know that you did it on your own. Nobody else helped you"; this sense of inherent value was largely absent from their discussions of mathematics.

Again, the correlations among the children's pretest scores provide some support for this pattern of themes (Fig. 4). The significant correlation between enjoyment and motivation is the same one included in the previous figure since it relates to both mathematics and problem solving, but an additional correlation was found to be significant as well. The degree to which children spoke about practical and sophisticated problem solving (as opposed to solving computational problems or unelaborated "figuring out") was significantly related to the degree to which they spoke about unique applications of problem solving, that is, applications that extended beyond the context and examples described in the interview questions.

Figure 4 about here

A natural next question would be to what extent attitudes toward problem solving interact with the children's actual problem-solving behavior. To address this issue, correlations were run between the combined P-scores that the children received in the pretest (reflecting the number and variety of problem-solving actions and heuristics that they used in working on the three PSAs) and each of the attitudinal variables used in the analysis of change. The significant correlations are shown in Figure 5.

Figure 5 about here

The children's use of problem-solving behaviors was found to be significantly related to two variables within the usefulness/ importance dimension. P-scores were significantly related both to the number of applications of problem solving that the children described and the the degree to which those applications were unique. For reasons that we will describe shortly, we believe that there is causality here: children who have a greater number and variety of problem-solving behaviors available (or, perhaps, who are more prone to seeing those behaviors as applicable to given problems) are also likely to find a larger number and variety of applications for their problem-solving skills.

The Role of SQUARE ONE TV: The Analysis of Change

Given the above relationships among problem solving and attitudes in the absence of any treatment, let us now consider how **SQUARE ONE TV** might play a role in effecting change. The previous papers in this symposium have described the effects of exposure to **SQUARE ONE TV** on each of the variables we examined; our purpose now is to look at some of the ways in which its effects upon these variables might relate to each other.

Our analytic strategy for examining these issues consisted of two steps. First, we entered the viewers' pretest-posttest change scores on all of the analysis of change variables into a correlation matrix to determine which variables appeared to be related to each other. Then, we used those significantly related variables to construct models that we tested via a model-fitting analysis using the structural equations computer program EQS (Bentler, 1985).

As we describe our findings, please bear two things in mind: First, as above, we are reporting only those significant correlations that are of interest for the present discussion. Second, because of time, I am going to present only a few of the models we tested, and because of limited resources, we have not yet tested all of the possible models suggested by our correlation data. Thus, we are open to suggestions for future analyses, and we would be happy to speak to you after the session about any ideas you may have.

One set of pairwise correlations revealed a number of significant positive correlations among problem solving, motivation, and usefulness/importance. Changes in viewers' P-scores (representing the number and variety of actions and heuristics they used) were significantly correlated with the number of applications of mathematics they mentioned ($r = .46$, $p < .05$), and in the posttest, viewers' P-scores were significantly correlated with their magnitude scores for motivation ($r = .42$, $p < .01$). At the same time, changes in viewers' valence scores for motivation (reflecting the degree to which they were motivated to pursue or avoid mathematics and problem solving) were significantly correlated with changes in the degree to which they spoke about unique applications of mathematics ($r = .52$, $p < .01$). These correlations led us to test the first three models shown in Figure 6.

Figure 6 about here

Model-fitting analyses revealed that each of these three models fit the data. That is, exposure to **SQUARE ONE TV** led to changes in children's use of problem-solving actions and heuristics, which in turn affected both the number of applications they came up with and their motivation. In addition, changes in the degree to which children were positively motivated toward mathematics had an impact on the degree to which they spoke about unique applications of mathematics and problem solving. (Note that in each case, we also tested alternate models such as:

SQUARE ONE TV --> Number of Applications --> P-score.

None of these alternate models fit the data, suggesting that the causality shown in Figure 6 is correct.)

Given this pattern of effects centered around problem solving, motivation, and usefulness/importance, we next tested a slightly more elaborate model that pulled together all three of these dimensions; this is the fourth model shown in Figure 6. The more elaborate model, too, provided a good fit to the data. Under this model, it appears that while people often think of attitude as influencing one's behavior, in this instance, the children's problem-solving behavior influenced aspects of their attitudes. We will return to this point shortly.

First, though, let's take a look at one final model, involving two dimensions of attitude: construct of problem solving and usefulness/importance. After observing a significant positive correlation between change in the degree to which viewers spoke about practical and sophisticated problem solving and the degree to which they spoke about unique applications ($r = .41$, $p < .05$), we tested the final model shown in Figure 6. Again, the model fit the data, suggesting that the effect that **SQUARE ONE TV** had upon children's constructs of problem solving in turn affected the degree to which they spoke about unique applications of mathematics and problem solving.

Together, these models point to the central role played by children's problem-solving behavior and their conceptions of what problem solving is. This is very much in keeping with the patterns of data that we observed in the pretest, that is, that children's problem-solving behavior and constructs of problem solving seemed to underlie other aspects of their attitudes toward problem solving.

These findings, like those of the study as a whole, hold implications, not only for future research on the effects of **SQUARE ONE TV**, but also for more general research on problem solving and attitudes toward mathematics, and for the reform movement in mathematics education as a whole. Let us turn now to a consideration of some of those implications.

Implications

Implications for the reform movement. Clearly, the findings presented throughout this symposium are very encouraging for the reform movement in mathematics education. Our analysis of change demonstrates that materials designed in response to the goals of the reform movement can have a significant positive impact upon children's problem-solving behavior and various aspects of their attitudes toward mathematics. Beyond this basic point, however, let us consider the implications that the relationships among these various dimensions of attitude and problem solving hold for reform.

As our analysis suggests, none of the things that we have measured in this study exist in a vacuum. Each dimension is related to others, and change in one affects change in others as well. One of the main implications of these relationships stems from the degree to which, in the pretest, children's constructs of mathematics and problem solving were central to all of the other dimensions of their attitudes. If we are to change the way children feel about mathematics, it appears that a good way to start would be to expand children's notions of what mathematics is. If they come to see the subject as more than a decontextualized set of discrete operations, then perhaps they will become more positive toward mathematics and find it to be applicable in a wider range of situations (as they did for problem solving).

To some extent, this sort of growth might be accomplished by simply expanding the existing mathematics curriculum to place a greater emphasis on problem-solving skills. As we saw in the analysis of change, changes in children's use of problem-solving behaviors had an impact upon both their motivation and the number of applications that they found for mathematics and problem solving. However, neither the pretest data nor the viewers' change scores showed a significant relationship between children's problem-solving behavior and their conceptions of what mathematics and problem solving are (although there was a marginal relationship between P-scores and discussions of practical and sophisticated problem solving in the pretest: $r = .25$, $p < .10$). Thus, it appears that to enhance children's constructs of mathematics, it may not be sufficient merely to encourage them to use a wider variety of actions and heuristics; it may also be necessary to explicitly label these skills as mathematics if we want children to recognize them as such. Otherwise, they may wind up like the character in Moliere's <u>The Would-Be Gentleman</u> who discovered, much to his surprise, that he had been speaking in prose for over forty years without knowing it.

<u>Implications for research.</u> The relationships among these dimensions also point to implications and questions for future research on children's problem solving and attitudes toward mathematics. Here, too, perhaps the most important implication stems from the centrality of construct in children's attitudes. A great deal of the research to date on mathematics attitude has employed pencil-and-paper scales (such as those developed by Aiken [1970] or Fennema and Sherman [1976]) that ask children to indicate their agreement or disagreement with a set of statements about "math." Yet, our descriptive analysis of children's constructs of mathematics and problem solving indicates that children often conceive of mathematics in ways that may be very different from the conceptions held by mathematicians or researchers. As a result, it seems that it is not sufficient to use such scales and assume that we know what "math" children are referring to; rather, we must assess their conceptions of what mathematics <u>is</u> as well.

Indeed, even the present results are incomplete with regard to children's constructs of mathematics (or, indeed, any of the attitudinal dimensions measured) in that the data are taken only from fifth graders. Similar research involving children of different ages (older and younger) would help us to understand how these aspects of attitude develop over time, and how the relationships among the dimensions might change. For instance, research has suggested that children's attitudes toward mathematics decline in their early teens (National Assessment of Educational Progress, 1988). In light of the present results, this finding gives rise to numerous questions: Is the decline constant across various dimensions of attitude, or does the relationship between the dimensions change as well? Does a decline in one dimension precede (and perhaps contribute to) a decline in others? How is problem-solving performance affected? These questions, and many others, can be answered only through further research.

Implications for research on **SQUARE ONE TV.** As noted earlier, our model-fitting analyses examining the effects of **SQUARE ONE TV** are not exhaustive, and so, questions remain.

Indeed, even those models we have tested give rise to questions for future research. Recall that the children in the present study viewed **SQUARE ONE TV** without any teacher support; the teachers did not comment upon the series or incorporate it into their lessons in any way. Thus, the question remains open as to how these effects would differ if the series were used, not in isolation, but as part of a larger, innovative mathematics curriculum. Presumably, such a curriculum would result in even stronger effects within problem solving or individual dimensions of attitude, but it is, of course, impossible to say without the benefit of research. Also, it would also be of interest to see whether the relationships among the dimensions would remain the same as those found here (and the effects differ only in their strength) or whether the pattern of relationships would itself change.

In short, it is gratifying to see the positive effects that **SQUARE ONE TV** had on the children in this sample, in terms of both its positive impact on their problem-solving behavior and its effects on various aspects of attitude. However, while the ground has been broken, we are still far from the point where we can completely understanding the potential of the series. Hopefully, future research will help to fill in some of the blanks.

Figure 1. Relationships among dimensions of attitude at pretest: Descriptive analysis of mathematics.

MATHEMATICS

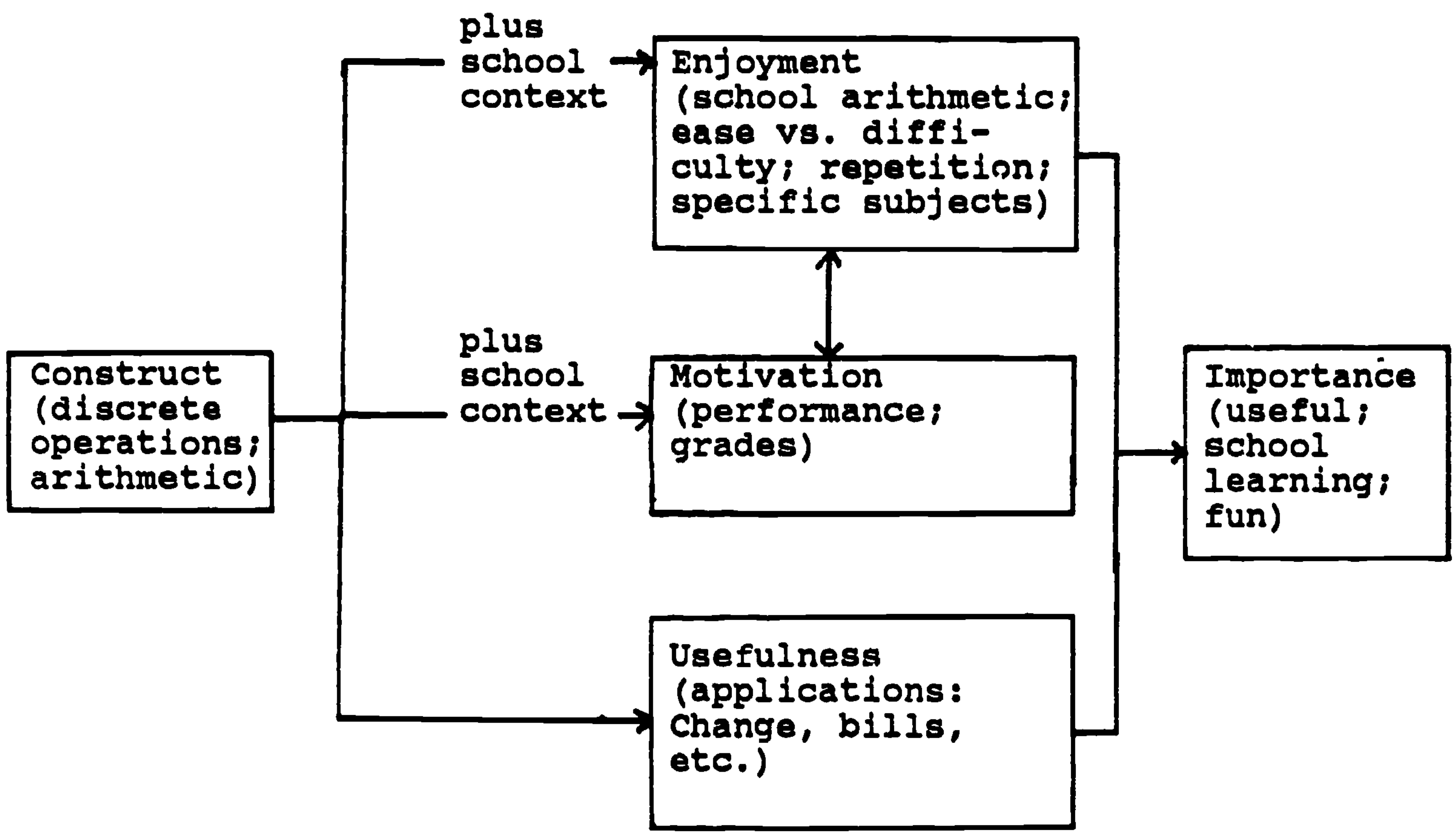

Figure 2. Relationships among dimensions of attitude at pretest: Descriptive analysis with significant (p < .01) correlations.

MATHEMATICS

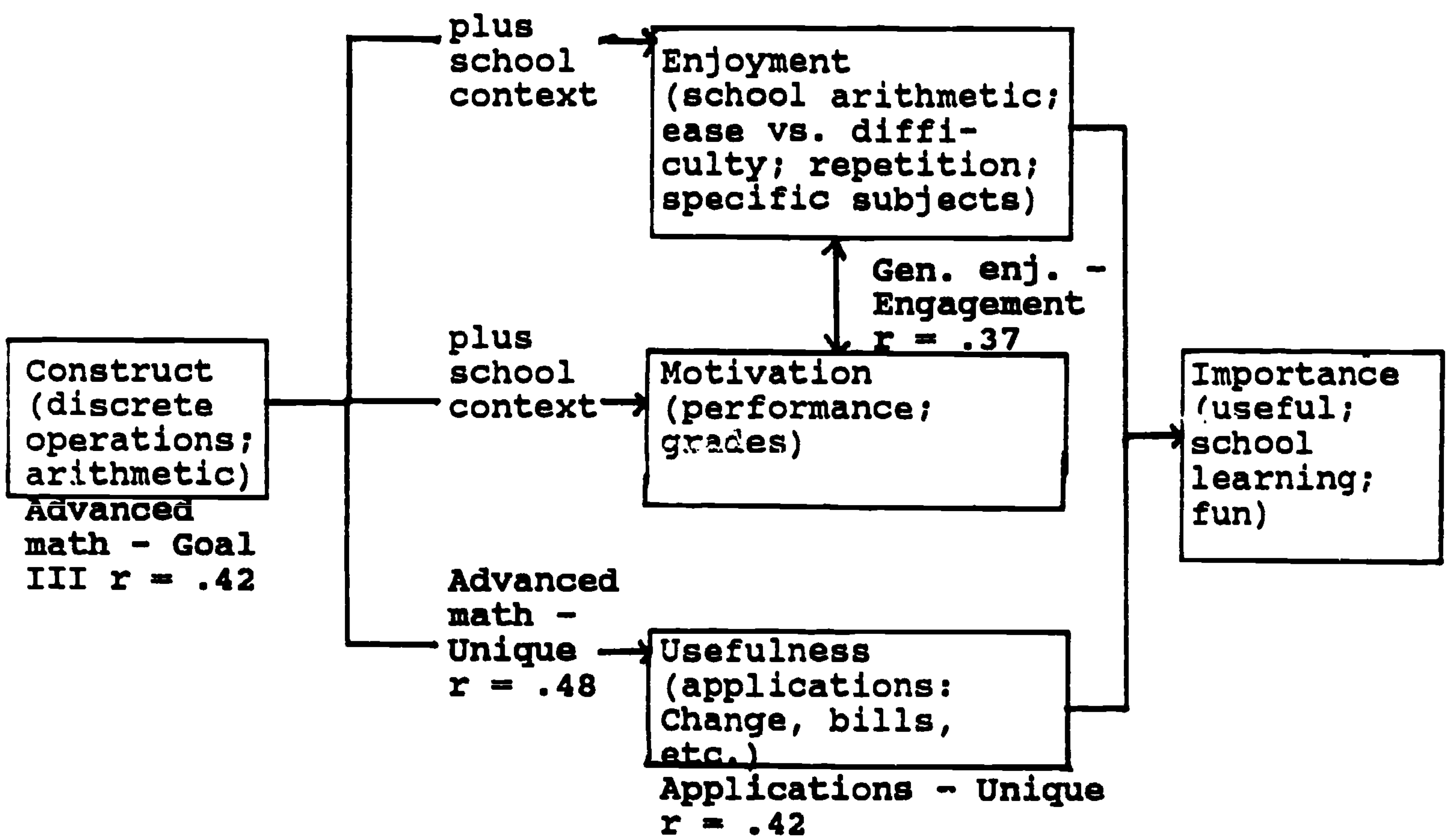

Figure 3. Relationships among dimensions of attitude at pretest: Descriptive analysis of problem solving.

PROBLEM SOLVING

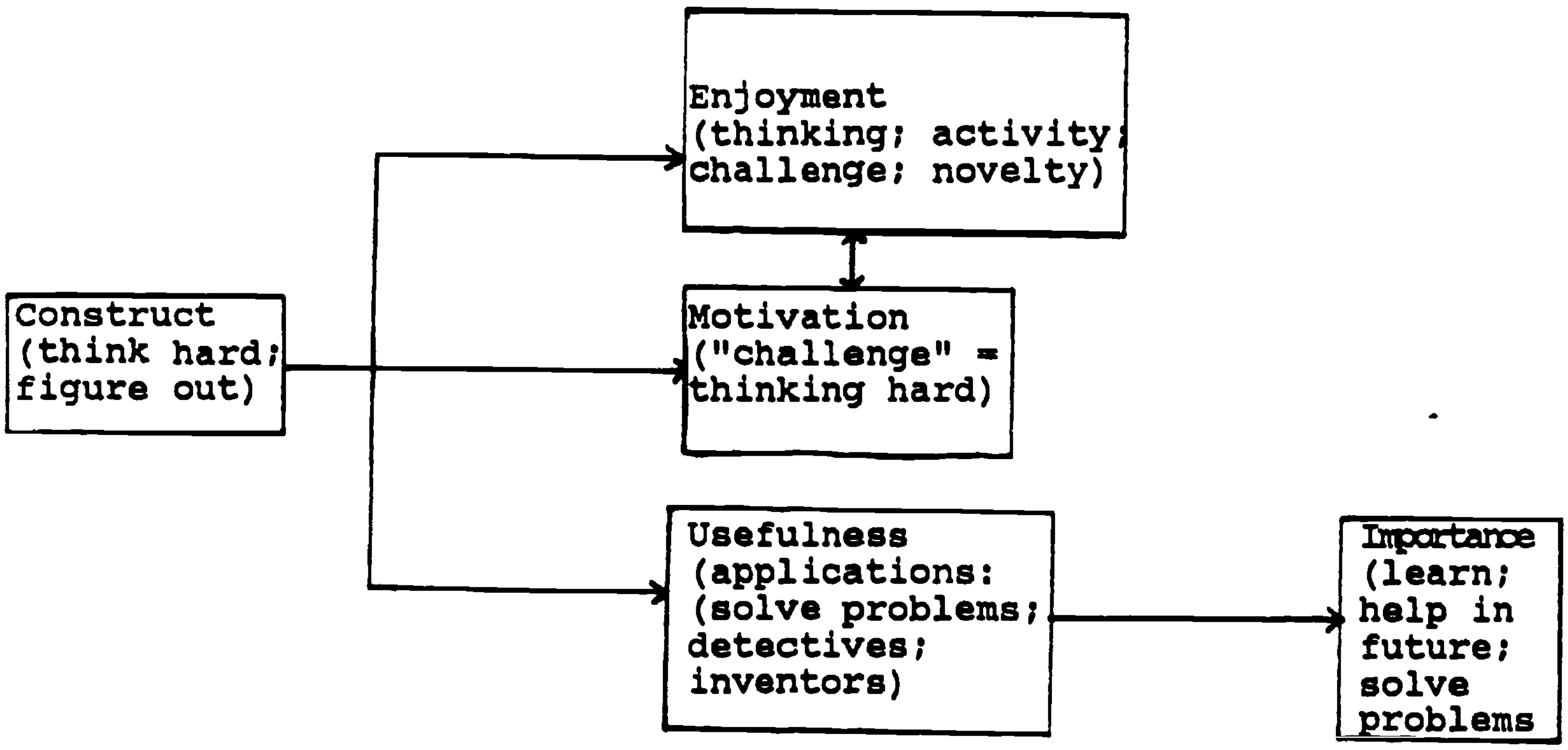

Figure 4. Relationships among dimensions of attitude at pretest: Descriptive analysis with significant ($p < .01$) correlations.

PROBLEM SOLVING

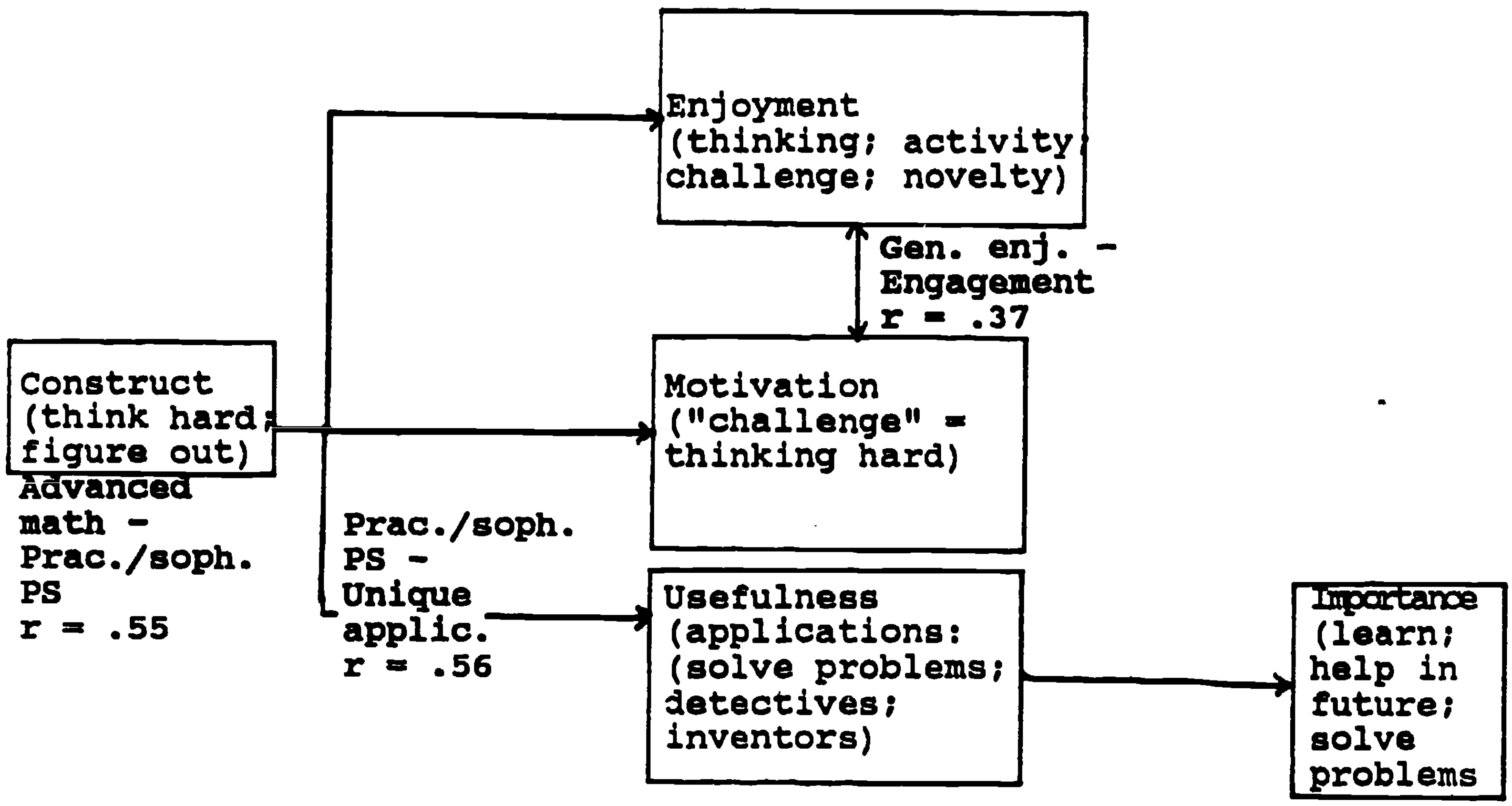

Figure 5. Relationships among dimensions of attitude at pretest: Descriptive analysis with significant ($p < .05$) correlations with problem solving.

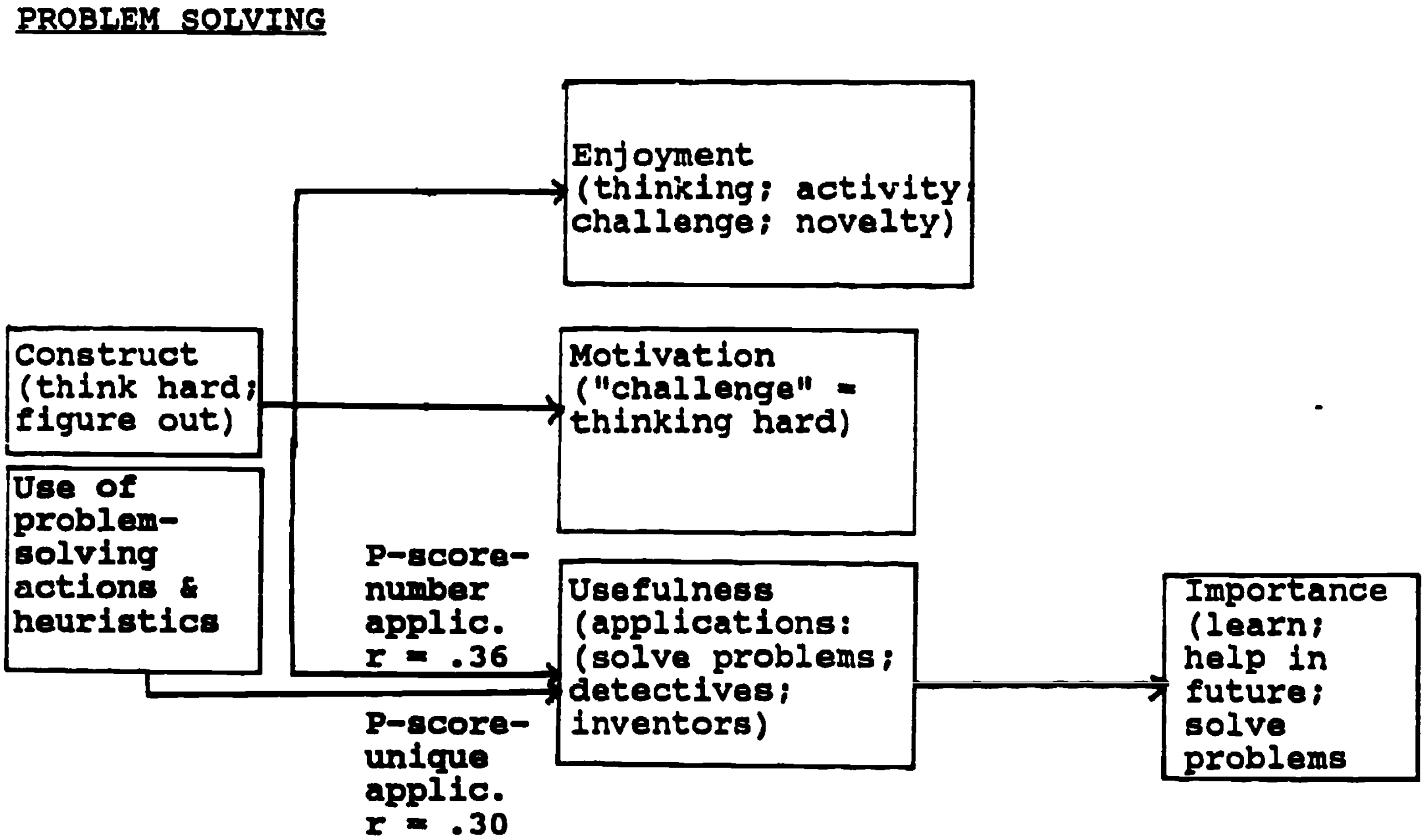

Figure 6. <u>Models of effects of SQUARE ONE TV across problem solving and attitude.</u>