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ABSTRACT

Outcomes, processes, and emerging questions associated with using matrix structures as both a teaching strategy used by the instructor and a cognitive learning strategy used by cooperative groups of students were studied. In analyzing these concept learning strategies, an effort was made to triangulate sources of data and take into account aspects of the environment that are important to instructors and instructional designers. This study attempted to: identify major research questions regarding complex learning outcomes, and evaluate the utility of corresponding data sources. Focus was on increasing the effectiveness of studying a complex process (i.e., internalizing a cognitive strategy). Two pairs of matching rational set matrices of coordinate concepts related to chemistry were presented to 45 high school chemistry students in two chemistry classes at a southern public high school. Students (with one exception) worked cooperatively in two learning groups with the same instructor. In a second sequence, Group 1 used the teaching strategy, while Group 2 constructed their own concept matrices. After instructional matrix use, students took a quiz similar to one of the matrices. The result show that the concept matrix was a successful teaching strategy. The group constructing their own matrix as a learning strategy retained less information than did those who were taught via the matrix. Implications for instruction are discussed. Two tables and seven figures present the study data. (SLD)

The Concept Matrix as a Cognitive Strategy:
An Interpretive Inquiry into Concept Training

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Running Head: The Concept Matrix as a Cognitive Strategy

The Concept Matrix as a Cognitive Strategy: An Interpretive Inquiry into Concept Training

Abstract:

Matrices can function as systematic organizing structures for both: (1) concept and simple rule learning, and (2) higher-order rule or problem-solving skill learning. These techniques are, however, approached quite differently for concepts and higher-order rules. In the present study we examine two training processes involved in using a matrix of examples and nonexamples to promote the acquisition of concepts.

This interpretive study triangulated sources of data to observe outcomes, processes, and emerging questions associated with employing matrix structures as both a teaching strategy used by the instructor and a cognitive learning strategy used (in all but one instance) by cooperative groups of students in two high school chemistry class (n=45). Descriptive trends and implications of outcomes, processes, and resultant issues for future inquiry are discussed.

Background and Issues Emerging from Prior Research

Matrices can function as systematic organizing structures for both: (1) concept and simple rule learning, and (2) higher-order rule or problem-solving skill learning. These techniques are, however, approached quite differently for concepts and higher-order rules.

In learning concepts, matrices such as the rational set generator (Dempsey, 1986; Driscoll and Tessmer, 1985) have been very effective in presenting interrogatory instances of examples and nonexamples of concepts. A matrix as a useful model structure may be envisioned in the following manner. A number of examples of concepts or simple rules form a rational set (Markle and Tiemann, 1971). A rational set provides for discrimination learning required to classify concepts (Tennyson,Wooley, & Merrill, 1972). These concepts are crossed by "N" levels of progressive difficulty providing for increasing generalization (Klausmeier & Feldman, 1975). Properly sequenced, a matrix model would provide for concept instances (and noninstances) which adequately fulfill the learning requirements of either successive or coordinate relationships.

Likewise, matrices have been used to good effect as a method for problem solving , particularly those associated with logical detection (Levine, 1988). For example, Hayes (1981) has used matrices to solve difficult Anthropological problems. These problems have solutions which require making assumptions and inferences. In this case, the matrix operates as an externalizing structure, reduces the problem solver's mental load, and frees his conscious mind to assume and infer while systematically keeping track of available data.

The differences in these two methods lies in the approach used to promote student learning. In the concept learning environment, the teacher or instructional designer typically applies a matrix as cognitive strategy which improves the efficiency and effectiveness of students' acquisition of coordinate or successive concepts. That is, the instructor or designer uses her skill to improve the outcome of learning. These structures have been successful in promoting learning in several content areas (e.g., Dempsey & Driscoll, 1989; Driscoll, Dempsey, & Litchfield, 1988; Litchfield, Driscoll, & Dempsey, 1990).

By contrast, in the problem-solving environment, the matrix is often consciously constructed by the student in order to enhance the encoding process and thereby, achieve the required learning outcome. Faced with a logical problem-solving task a learner uses the matrix structure as a complex organizational strategy in the form of a visual

representation. Without using this or a similar strategy, many learners would not reach a solution to complex logic problems requiring inferences. Once learned these strategies are usable by the student faced with similar situations and may be considered self-regulatory or metacognitive in nature (see, for example, Derry & Murphy, 1986).

The first approach, then, is a teaching strategy and the second, a learning strategy. As Weinstein and Mayer (1988) point out, a cognitive approach to learning and instruction requires a focus on the second type of activity. Although teaching structures such as the rational set generator have been effective in increasing retention of concepts and rules, to the authors knowledge, no research has been carried out which uses systematically designed concept matrices as strategies to empower the learner's "cognitive toolbox".

The Problem

Where studies using different methods have similar results one can be feel relatively comfortable that findings were not influenced by the methodology. Unfortunately, as our review of the literature testifies, this is not so in the case of the matrix strategy. Most concept learning studies, including those in which the first author has participated, have refined the micro-strategies involved in presenting concepts, but failed to consider how successful presentation modes may be used by learners as well as instructors.

We know the concept matrix strategy was successful in terms of learning outcomes when instruction had valid content and was presented correctly. Yet, the design of prior concept research concentrated solely on outcomes and ignored the contexts of learning and instruction. Learners were unaware of the control processes which were being used to shape their concept acquisition. This fact alone led us to believe the results of concept acquisition studies require redesign, or at least, the contexts surrounding the research should be reviewed. Thus, the problem becomes one of needing to generate research questions which permit more focused inquiry into ways that effective concept teaching strategies could become effective learning strategies. This points to a need for a more holistic or unfettered model of investigation than has used in the prior related research.

In addition, we wanted to consider this problem in a cooperative learning environment with science content to continue some promising prior related work (Driscoll, Dempsey, Lumsden, & Capozzi, 1989; Okobukola, 1985).

Finally, we wanted to observe the effects of concept teaching and learning strategies on learners' confidence of response in answering content questions requiring retention.

Purpose

The crux of the present study was to identify "richer" and "more focused" major research questions regarding complex learning outcomes and to evaluate the utility of corresponding data sources. Specifically, we wanted to increase the effectiveness of studying a complex process (i.e., internalizing a cognitive strategy).

The authors operated from the assumption that used separately, qualitative and quantitative studies provide different kinds of questions and information. Further, we posit that the hitherto quantitative focus generated a inaccurate (incomplete) picture of the phenomenon. Instead, we argue that when focused on the same issue, qualitative and quantitative data collection can triangulate the research questions to better focus the investigation of complex topics such as cognitive strategies.

In the present study we examine two training processes involved in using a matrix of examples and nonexamples to promote the acquisition of concepts. Specifically, we conducted an introductory study using qualitative and quantitative data sources to generate questions emerging from a teaching strategy and a learning strategy.

- As a teaching strategy, what were the critical processes involved in a teacher's presentation of a concept matrix?
- As a learning strategy, what were the critical processes involved in training learners to construct their own concept-learning matrices?

Secondly, we considered the comparative effectiveness of these strategies in terms of both outcomes and processes.

The Method & Procedures

Subjects and Setting

The subjects of the study were two chemistry classes (N=45) from a Southern U.S. public high school. The high school used in this study was located in an older urban area where the community was no longer growing and the area home owners were maturing in age. As a result, the school had witnessed a 20% decline in enrollment over the past two years. The enrollment was approximately 850 students. The majority of students were from broken homes and low SES environments.

Descriptive data regarding student demographics (e.g., co-curricular activities, GPA, School Index scores, NASA Science Pretest Scores, attendance, age, race, and sex) are summarized in Table 1. The classroom consisted of 15 lab tables arranged three abreast. Two or three chairs were placed at each table.

Table 1 about here

Of the contextual factors considered, there were no differences between the two groups prior to the study except in the areas of race, year in school, and NASA mathematics pretest scores. There were fewer whites in Group Two. Eleven percent of the students involved in the study were in grade 12 in both classes. Of the remaining students, more Group One students were in grade 11 than grade 10 (50% = grade 11, 39% = grade 10). In other words, the subjects in Group Two were less advanced toward their graduation requirements (37% = grade 11, 53% = grade 10).

The marked difference between the NASA mathematics pretest scores (65%=mean for Group One, 41% for Group Two) can be explained in part by the composition of the groups. Fifty-three percent of Group Two were 10th graders with one less year of mathematics.

Both groups were approximately 2/3 female. Group Two was dominated by black females. Although both groups were equally involved in extracurricular activities, Group Two was more involved in sports related activities, while Group One was largely involved with academic clubs.

The classroom instructor was also one of the researchers. She has taught science and mathematics for fourteen years at the secondary school level.

Procedures

The sequencing of the matrix strategy investigation is illustrated in Figure 1. Two pairs of matching rational set matrices of coordinate concepts related to Chemistry were designed by the third author, an experienced high school Chemistry teacher with formal training in Instructional Design. The concepts covered in Sequence A were much different than those of Sequence B. All matrices are composed of interrogatory examples of rational sets of concepts. Each matching pair of matrices covers a specific content area. Each pair consisted of one matrix for instruction.and one matrix for testing purposes. Equivalent items were assigned to one matrix or the other. The matrices are formatively evaluated with advanced high school chemistry students and adjusted for bad or incorrectly placed interrogatory instances.

Figure 1 about here

Pretreatment.

At the beginning of the school year, extensive demographic data was collected concerning such factors as age, sex, race, and career aspirations. One week before the sequence, students were administered a generalized expectancy premeasure (Rotter, 1966, 1975; Tyler, Gatz, Keenan, 1979). Around this time, the instructor/researcher met with the other members of the research team and rehearsed the teaching strategies necessary for sequences A and B.

The day before the first sequence, students formed pairs and triads and selected their seating placement. To promote cohesion among members, each learning group chose a name of a particular chemical element to represent themselves (e.g., helium, oxygen, and so forth). Subjects were informed that "some people from the university" would videotape the class the following day and a few times thereafter using four cameras set up around the periphery of the classroom.

Sequence A.

Both classes received the same instruction and testing in ence A. After roll was called and the students were settled, the instructor explained to the class that they were going to learn some new concepts related to Chemistry. To achieve this goal, the teacher explained, the class was going to play a game similar to the Concentration TV show. Students were instructed that they need to work with others in their learning group to win the game.

The object of the game was to classify interrogatory concept examples dealing with physical states of matter. The matrix consisted of six concepts (states of matter) and three generalization levels. The generalization levels consisted of pure science, applied science, and natural phenomena. Figure 2 illustrates the composition of this matrix.

Figure 2 about here

After the instructor felt most class members understood the assignment, she passed out identical introductory handouts relating to the rational set of concepts to be taught. Handouts included definitions and a minimal amount of expository information. This material was reviewed with the class and students were told to begin the assignment.

Each group worked cooperatively until members reached consensus regarding their classification and generalization choices. At this point, a 4 ft. X 5 ft. matrix was

displayed at the front of the room. The names of the concepts were labeled down the left side of the matrix. Each of the eighteen examples cells in the matrix was covered with a piece of paper so that the concept instances were hidden. The order by which learning groups were selected to classify was determined by selecting labeled ping-pong balls from a beaker. Teams were asked to pick an example they had read and to classify by designating the appropriate cell on the game board. If the team answered correctly, the cell's label was uncovered and the instructor wrote the group's mascot name in the cell. If the team answered incorrectly, another learning group was picked to classify the example which went in the cell. The instructor also provided elaborated corrective feedback based on student queries. The game continued until all cells of the matrix were uncovered. The winning team had the name of their mascot in the most cells.

The next week, students in both classes were given the matched rational set of concepts in a written quiz using a multiple-choice format. For this observation, subjects classified concepts and indicated their confidence of response on a Likert-type scale below each item. Expressed differently, classification achievement scores and confidence of response data were collected for later comparisons.

Sequence B.

Sequence B compares the effects of a teacher-presented concept matrix (similar to that used in Sequence A) and a learning matrix involving the same rational set of concepts constructed by students in their cooperative groups. The classes were assigned, by coin toss, to the teacher or learner-constructed matrix conditions. We will call the teacher-presented concept students, Group One. The subjects who constructed their own examples will be referred to as Group Two.

In both classes, the instructor passed out identical introductory handouts relating to the rational set of concepts to be taught (with definitions, expository exemplars, and text page references). The procedures and materials were again reviewed with the class until students appeared to understand the assignment. Students in Group One were informed that they would participate in another matrix game and quiz similar to Sequence A only with new content (Atomic Structure, see Figure 3).

Figure 3 about here

Students in (Group Two) received strategy training regarding the construction of concept-learning matrices. The instructional matrix from Sequence A was used again, this time as a teaching example for learning strategy training only. Students were informed of the process objective of the exercise (i.e., to construct an interrogatory learning matrix

with other members of their group). Next, they were led through the processes a teacher or designer uses to construct a concept matrix. Finally, the instructor answered questions about their assigned task. At that point, learning groups in Group Two constructed their own atomic structure matrix examples. Group Two teams shared examples of their matrix construction with other students in the class and received feedback from instructor.

One week following the instructional matrix construction, students in both conditions were given a quiz similar to sequence A. The content of the matrix-quiz was matched by content analysis to that content taught in sequence B. A few days following the quiz a second generalized expectancy indicator measure was taken by both classes and students were debriefed regarding their learning experiences.

Sources of Data.

Both quantitative and qualitative data sources were collected. During sequences A and B, data was collected regarding concept mastery, confidence of response, and matrix-quiz completion times. Data was also collected using the Rotter I-E scale (1966,1975), a generalized expectancy measure. Both instructional sequences were videotaped to capture interactive variables such as matrix completion times, on-task/off-task behavior, intragroup and intergroup student behaviors. An individual interview was conducted with the teacher and a group interview was conducted with a sample of students from each group following the study.

Descriptive analysis.

Retention Trends.

In the present study, we were looking for retention trends which, considered with other trends in the present study, may be useful for future investigations. We offer comparative descriptive results without looking for statistically significant outcomes. As we have indicated, we were interested in both the outcomes and processes of concept matrix use as a teaching and learning strategy. As a measure, we viewed achievement on a retention measure as an indicator of those things which may be improved, regardless of the strategy employed to enhance learning.

Having offered that caveat, what were the trends? The mean retention scores for both groups for sequences A and B are shown in figure 4. The reader will recall that during the first sequence, the teaching strategy (a Concentration-like game) was used for both groups. In the second sequence Group One again used the teaching strategy. Group Two, on the other hand, constructed their own concept matrices. Both groups scored almost exactly equally on the retention test for the first sequence. Although the content was

more difficult, the retention test for the second sequence shows some improvement for Group One, whereas Group Two did much worse.

Figure 4 about here

A further breakdown of these findings by sex (see figure 5) shows males performed much better than females regardless of which group they were in or the subject matter. No appreciable differences by race were detected.

Figure 5 about here

Confidence of Response

Confidence of response, as a measure, has been used in a series of studies related to feedback (e.g., Kulhavy, Yehkovich, & Dyer, 1976, 1979). As in the present study, subjects rated the surety of their response on a five-point scale. In the studies by Kulhavy et al., high confidence correct answers were remembered significantly better on tests of immediate recall and retention regardless of the correctness of response on a particular item. Based on Kulhavy's work, one might expect that confidence of response results might be directly-related to student retention.

Other, more recent experimental studies by Dempsey and Driscoll (1989), have found that the types of errors learners make can be isolated using concept matrices and that the content of the learner's error during instruction could be used as a direct measure to predict retention. Results of work in progress by Dempsey and Driscoll (1990), however, have indicated that the type of errors learners make (judged by analysis of content) is not directly correlated to learners' self-report of confidence of response. Accordingly, in the present study, we were curious to see how confidence of response and retention achievement trends compared.

Our principle reason for employing a measure of confidence of response, however, was to observe the effect of the teaching or learning strategy on learner's confidence in making responses which require content retention. As Figure 6 illustrates, the trends were that confidence of response and achievement on a retention test were not directly-related. On both quiz A and B, each group was somewhat similar in their mean confidence of response, with Group Two a bit more confident on both quizzes. On quiz A, the two group's similarity was to be expected because both groups performed somewhat equally. On quiz B, however, Group Two (who constructed their own matrices) was slightly more confident, yet performed a good deal worse on the quiz.

Figure 6 about here

In breaking down the confidence of response findings, there again were trends related to the sex of the students. Just as the males performed better on the retention test, so were they more confident that their responses were correct. As Figure 7 indicates, this was true regardless of the strategy used to instruct or learn the concepts or the nature of the content.

Figure 7 about here

Generalized Expectancies

A constructivist analysis of the Rotter I-E scale was conducted. This analysis of the I-E scale assumed the learner's responses involved internal or external attributions about oneself and about the learning situation and therefore about how one's outcomes come about (Tyler, Gatz, & Keehan, 1979, p. 12). This was the only study which could be found using high school subjects. Their study reported mean External scores of 11.3 with a standard deviation of 3.6. This score represented the student having chosen the external attribution on any 11 of the 23 items of the test. While the composite scores were similar in the Tyler study (males had M=11.4, SD=4.2 and females earned M=11.1, SD=3.1), item analysis revealed males and females organized their locus of control differently. Males asserted a more active agent stance and stronger internal control over task areas of their lives than females. On the other hand, females evidenced a more passive attribution of control, a focus on individual personal areas of activity versus tasks, and a balanced pattern of choice between luck and chance (versus male attributions of effort and ability).

Though generally consistent with Tyler's findings, this study revealed slightly higher external scores in both sexes. During Sequence A, Group One earned an external mean score of 12.0 (SD=3.4) and Group Two earned an external mean score of 12.3 (SD=1.7). During Sequence B, Group One showed little change in spite of the increased difficulty of the task (M=11.9, SD=3.4), while Group Two scored in an even more external direction (M=13.5, SD=2.8). In terms of composite scores, females chose more external attributions compared to males. Items directly related to school tasks (i.e., items 4, 8, 9, and 18) are summarized in Table 2. Group Two consistently averaged higher external scores than Group One. In the Tyler et al study, the most external preference for males and females was on item 4. This was generally the case in the present study. Males in both groups and over both sequences earned their highest external orientations on item 4.

This pattern also operated for all female groupings except Group One in sequence B. As in the Tyler study, the degree of external preference was lower for the other three items across both groups and sexes.

In terms of changes noted between Sequence A and Sequence B, Group One males showed an increase in external scores for three items (4,9, and 18) compared with a female increase in external scores in only two items (9 and 18). For Group Two, males showed an increase in external preferences on three items (4, 8, and 9) whereas females showed an increase in external preference on only one item (9).

An interesting pattern emerged when one examines the range of percentage differences between males and females. It appears that while Group One males showed an increase in external preferences in Sequence B, the range of percentages remained a constant 33 percent. Group One females demonstrated a slightly lower external preference and reduced the range by half in Sequence B. Group Two females showed no overall change in external preferences on task items but were similar to Group One females in reducing the range of responses. Group Two males were very similar in external preferences in both sequences though they displayed a greater range of response in Sequence B.

Overall, Group Two appears much less stable in their scores than Group One, especially the females. Males in both groups consistently asserted a more "active agent" stance.

ANALYSES OF OBSERVATION DATA

An adaptation of a four-stage model used in the field of visual anthropology (Collier& Collier, 1986) was used to analyze approximately three and one-half hours of video tapes recorded on each of four cameras. Our model for analysis used the following procedure. First, similar and contrasting patterns were sought. Secondly, classroom contexts were examined around interactive variables such as matrix completion times, on-task/off-task behavior, intragroup and inter-group student behaviors. Thirdly, detailed descriptions were generated and specific questions were identified for future studies. Finally, the detailed descriptions were then compared to the complete field record.

What differences exist in the way Sequence A occurred?

No differences (i.e., in content, length of time to introduce the task, teacher expositions, and student questions) existed between the delivery of the teaching strategies used with Groups One and Two as evidenced by videotape analysis. In both classes, most students worked cooperatively within their own pairs/triads. Prior to game onset, the explanation of procedure and time spent by students in the classifying activity took 27 minutes for Group Two and 30 minutes for Group One. This slight time difference

appears to be more due to increased teacher familiarity and efficiency rather than difference in content or method.

More students in Group Two engaged in interactive as well as competitive behaviors with students beyond their pair or triad. Further analysis of the videotapes revealed that both groups averaged two teacher contacts per team. Also, the time-on-task behaviors of Group One appeared to be much lower than Group Two.

The characteristics of winning teams varied between the two groups. 55% of Group Two teams (tables 2,5,6,8,11) earned a minimum of two correct answers while in Group One, only 21% of Group One teams (tables 13,7,11) were able to answer two items correctly. The winners in Group One were predominantly white (4/6), predominantly male (5/6), predominantly below the average on their Rotter score (4/6 earned a score of 10 or below) and at least one member in each pair earned at least 116 on the School Index Scale and a minimum of 68 on the NASA. The highest scorers in Group Two (table 5) and Group One (table 11) tended to be male, white, earned a higher than average Rotter external score and averaged a 2.9 GPA.

What differences exist in the way that Sequence B emerged?

The concepts covered during the second session (i.e., Sequence B covered atomic structure) appeared to be more difficult for both groups. During the first 20 minutes, Group Two students displayed more on-task behaviors and more enthusiastic behaviors when generating their own examples compared to Group One who engaged in debate with the teacher over how she chose to classify the levels of example difficulty. Overall, Group Two students generated their own examples more slowly (28 minutes) than the time it took Group One to classify teacher generated examples (20 minutes). It also appeared that Group Two's team productivity greatly slowed down in the last 8 minutes of generating examples.

As in Sequence A, more students in Group Two engaged in interactive as well as competitive behaviors with students beyond their pair or triad. Further analysis of the videotapes revealed that Group One teacher contacts averaged 2 per team and Group Two teacher contacts averaged 3 per team. The students with the most teacher contact did worst and the students who interacted with the teacher the least did the best. Also, the time-on-task behaviors of Group One appeared to be much lower than Group Two.

Comparison of the characteristics of the top winners in the two groups indicated a very similar pattern. The winner in Group Two (table 11) was the only student to work alone. He was able to generate three examples of increasing difficulty. One team in Group One (table 1) earned three points while four teams earned two points (tables 3,6,12,13). In the same way that the Group Two winner had worked without a partner

during both sequences, video analysis revealed the Group One winning pair consisted of one on-task member and one member who was rarely on-task. Thus, if we focus on the actual winning "workers", they had much in common. They were both white, male, had a school index of at least 1 standard deviation above their classmates, had quite average GPAs, were older than their peers, and earned highly externally oriented Rotter scores (both earned scores of 17).

Discussion

Our primary purpose in this study was to examine two training processes intended to promote the acquisition of concepts. In this section we will discuss the outcomes, processes, and emerging questions related to the concept matrix as a teaching strategy and a learning strategy.

The Concept Matrix as a Teaching Strategy

Outcomes

In one of those curious coincidences that happen in life, the two groups' mean retention scores for Sequence A (the sequence in which both groups received the Concentration game teaching strategy) were exactly equal. Neither group did very well, which had been expected from the more difficult than usual new content and unfamiliar processes. Even so, the teaching strategy, within the obvious limitations of the present study, tended to perform much as one might expect. To the extent that it was successful in teaching the Chemistry content, it adapted to individual needs and both groups, although different in some respects, retained about the same amount of information.

The tendency for males to perform better than females in both classes was surprising, although it did not seem a highly irregular result of Sequence A given the limitation of sample size. The fact that mean confidence of response self-reports for males closely mirrored their comparative retention scores (i.e., they were higher) was as we hoped.

Sex differences were also found on a test of generalized expectancies (i.e., the Rotter I-E Scale). Males appear to be more internally responsible, especially on task-related items. Females seem to organize their attributions of control around a more passive stance and where task-related topics were not as important. This overall picture suggests different organizing outcomes in their adolescent lives.

Processes

Examining the processes that operated during both conditions, it appears that students were not accurate at assessing what contributed to their success or failure, nor at

weighing the confidence demanded of a task (especially by males). Other sex differences in the operant processes were indicated, notably the tendency for females to become less disparate in their attributions over time.

There appears to be a need for a more gradual transition between simple to complex matrices. Follow-up interviews with students in both classes indicated that they consistently preferred work groups of three students each. Next fall, we propose to explore peer-tutoring training and mixed ability seating assignments of three students (each with one high, average and low achiever).

The process of managing incentives differs when using the matrix as a teaching strategy and when using it as a learning strategy. The accuracy incentive used under the teaching strategy condition succeeded as anticipated though the time to complete the matrix task may be much more demanding with more complex concepts. Future studies need to have a consistent reward structure which pairs speed with accurate production. Time should also be scheduled for more systematic teacher feedback or debriefings.

Emerging Questions

As a result of analyzing the Sequence A data, we realized that the relationship of incorrect responses to other variables was not documented. This could be a valuable topic for future studies. For example, it is unclear why in Group One most errors were made during the last third of the answer session and in Group Two, the mistakes occurred primarily during the first third of the answer session.

Another area of potential influence seems to be related to the age of students. It seems worthwhile to explore further the connections between correct responses and confidence response data, teacher proximity, time-on-task, and nature of teacher feedback. Tape recordings of each table's productions should be done in follow-up studies.

Finally, our demographic dated confirmed the observation that the voluntary groupings tended to be composed of similarly performing partners. Knowing the potential of mixed ability groups, future studies will need to address how high level students will be rewarded for working with students of less demonstrated ability? For example, students we interviewed after the study was conducted were unanimous in their opinion that this type of instruction would work best in small groups of three -- not pairs, nor groups of four. Their simple explanation was that the "average" student wanted one person in the group to be a more proficient learner, and one a less proficient learner. The more proficient learner would help the "average" student overcome frustrating problems. The "average" student could reinforce his learning by assisting the less proficient learner in acquiring instructional material.

The Concept Matrix as a Learning Strategy

Outcomes

In the Sequence B, Group One used the same teaching strategy employed in Sequence A. Even though the content was more difficult, these students improved somewhat. This improvement, however, was almost entirely due to the performance of male students. Females in Group One performed about the same as they did the first time they were introduced to the matrix teaching strategy. This trend is puzzling but may be influenced by factors suggested by generalized expectancies. Specifically, task-related challenges such as the matrix strategy, if they are perceived in personal contexts, seem to have much more initial appeal to males but there is some evidence (e.g., results of items 4b and 8b on the Rotter I-E Scale) that repeated exposure to a difficult task may reduce female student perceptions of external orientation.

Less puzzling, perhaps, is the performance of Group Two in attempting to acquire a new learning strategy and somewhat difficult new content simultaneously. Although males again outperformed females, both sexes retained less information than Group One.

Confidence of response trends again mirrored their respective retention trends for both groups, even when broken down by sex. This preliminary data encourages our continued interest in exploring the links among self-reported confidence of response, content analysis, and actual retention performance.

Processes

Analysis of Sequence B data highlighted several issues. First, it appears that teacher-directed strategies yielded higher accuracy but less student interaction than that generated by student-directed learning, especially for simpler concept learning. Secondly, when the task was perceived by students as more difficult, the off-task behaviors rose as expected and teaming behaviors deteriorate over the course of instruction. When the concept learning becomes more complex, along with the increased demands of student construction, the content and process of student training comes into play.

Sequence B proved be be more demanding of time as well as the number and complexity of examples to be generated than initially anticipated by the researchers. In fact, most students in Group Two did not generate three progressively complex examples of each concept.

In both groups, there appears to be a need for a more gradual transition between simple to complex matrices. And Group Two students, who used the matrix as a

learning strategy, would seems to need more practice in generating examples as well as developing teaming skills, especially when the concepts to be learned become more complex.

As noted earlier, the process of managing incentives differs when using the matrix as a teaching strategy and when using it as a learning strategy. While satisfactory for Group One using an accuracy incentive, the study's reward structure for Group Two in Sequence B was flawed in the sense that the teacher rewarded "the first four groups that finish", which resulted in both an emphasis on quantity as well as the rest of the groups reducing their effort as soon as the winners were announced. Future studies need to have a consistent reward structure with emphasis on accurate production and time scheduled for more systematic teacher feedback or debriefings.

Emerging Questions

Several questions seem to offer promise of refining the use of concept matrices as learning strategies. For example, data from student interviews suggested that certain high achievers (especially "rigid" internals) may resist using new strategies such as concept matrices. Could average achievers, who lack sophisticated cognitive strategies, be more receptive to acquiring new strategies?

Another issue concerns the use of teacher and student training procedures (e.g., content, sequencing, timing and practice) which need to be implemented. Here practical solutions to genuine problems must be considered. If we, as instructional technologists presume to offer alternatives to traditional teaching practices, we must also offer concrete examples of successful implementation of these strategies in real school settings.

What alternative data sources can be used to more accurately describe critical outcomes and processes operating in matrix studies? Our experience in conducting this preliminary study has lead us to speculate that debriefing strategies (e.g., small group photo-interviewing) would be very useful in learning ways to implement strategies.

It appears that student generated examples of more complex concepts were often literal translations from the text and gave little evidence of comprehension, application, and analysis skills. Further work is needed in examining the content of student generated examples (balance of definitions, expositions, analogies, interrogatives, prototypes, etc.), the process that occurs during student construction of their own matrix examples, and identifying evidence of internalization of the strategy.

The role of teacher feedback was not assessed and yet there appeared to be a relationship between teacher proximity and correct responses. Teacher responses to individual tables were not collected during the current study, but future studies should monitor the nature of teacher corrective feedback more systematically.

Conclusion

The present study sought to observe outcomes, processes, and emerging questions associated with employing matrix structures as both a teaching strategy used by the instructor and a cognitive learning strategy used (in all but one instance) by cooperative groups of students. The study was conducted in a real school setting under those conditions common to many high school Chemistry students and instructors. In analyzing these concept-learning strategies, an effort was made to triangulate sources of data and take into account aspects of the environment which are important to instructors and instructional designers.

Overall, we were not disappointed in the performance of the concept matrix as a teaching strategy. Even so, we feel it would be much more effective if used on a regular basis. This would require some restructuring of lesson plans and initial training of instructors and students to implement the strategy. Our next step in this regard will be to systematically introduce a series of matrices in the chemistry program used in this study.

Based on our analysis of the data we have collected, we also suspect the concept matrix can be an effective learning strategy when students are given adequate preparation. Of what should that preparation consist? One scenario would be to employ a three-tiered approach. This approach would begin with a teaching strategy, provide learning guidance with a training strategy, and promote transfer to student-generated examples in hopes of incorporating the concept matrix as a learning strategy.

The first stage of this process would implement a Concentration-like game similarly to the way it was used in this study (teaching strategy). In the second stage, the instructor would lead a guided discussion of the strategy she used in generating examples for the first stage. This would be coupled with a group brainstorming session in which students yield additional examples. As part of this stage, students would verbalize their personal rules for generating examples (training strategy). In the third stage, students generate matrices with their own examples (learning strategy).

Because our study was of an exploratory nature, it was of short duration. Future research will need to address the impact over longer periods of time. For example, students of different proficiencies and learning styles may need different preparation to optimally generate matrix examples. Also, we suspect that the quality of examples generated at a unit's onset can serve as a type of diagnostic premeasure and that following instruction, matrix-generation experiences could be a valuable feedback and assessment tool.

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	Group 1	Group 2
Year in School	Grade 12 = 11% Grade 11 = 50% Grade 10 = 39%	Grade 12 = 11% Grade 11 = 37% Grade 10 = 53%
Black Students	39 percent	63 percent
Sex	Male = 39% Female = 61%	Male = 37% Female = 63%
NASA Math Pretest, Mean	65 percent	41 percent
GPA, Mean	3.1	2.9
School Index, Mean	109.7	109.2
Number of Advanced Courses	1.2/student	0.9/student
Extracurricular Activities	1.5/ student	1.5/ student

Table 1: Student Demographics and Background Information

	Level 1: Pure Science	Level 2: Applied Science	Level 3: Natural Phenomena
FUSION	aluminum is heated to convert it to molten aluminum	blast furnace converts iron ore to molten steel	burning candle heats its wax until the wax runs down the side in drops
SOLIDIFICATION	molten lead placed in a freezer hardens	to cast tools, molten aluminum is poured into molds to harden	after cooking the ingredients, fudge is poured into a tray to harden
EVAPORATION	a solution of ammonia releases fumes into the air	to lower a fever, alcohol is rubbed onto a person's skin causing the alcohol to change into a vapor	a person is chilled after swimming as water on the skin changes into a vapor
SUBLIMATION	when gently heated the element iodine changes directly into a vapor without passing through the liquid phase	solid CO changes from the solid to the gas phase without passing through the liquid phase	when gently heated, iodine changes directly into a vapor without passing through the liquid phase
CONDENSATION	cold glass of liquid "sweats" on the outside of the glass	to increase proof (% alcohol), ethanol is collected at boiling point and cooled in a closed system	water molecules begin to skick together at high, cold altitudes, forming raindrops
LIQUEFACTION	by increasing pressure & lowering temperature, a gas is forced into the liquid stage	a compressor is used to convert alcohol fumes back into alcohol	when a cold mass of air meets a warm mass of air of high humidity, rain can be formed

Figure 2. Concept Matrix for Phases of Matter

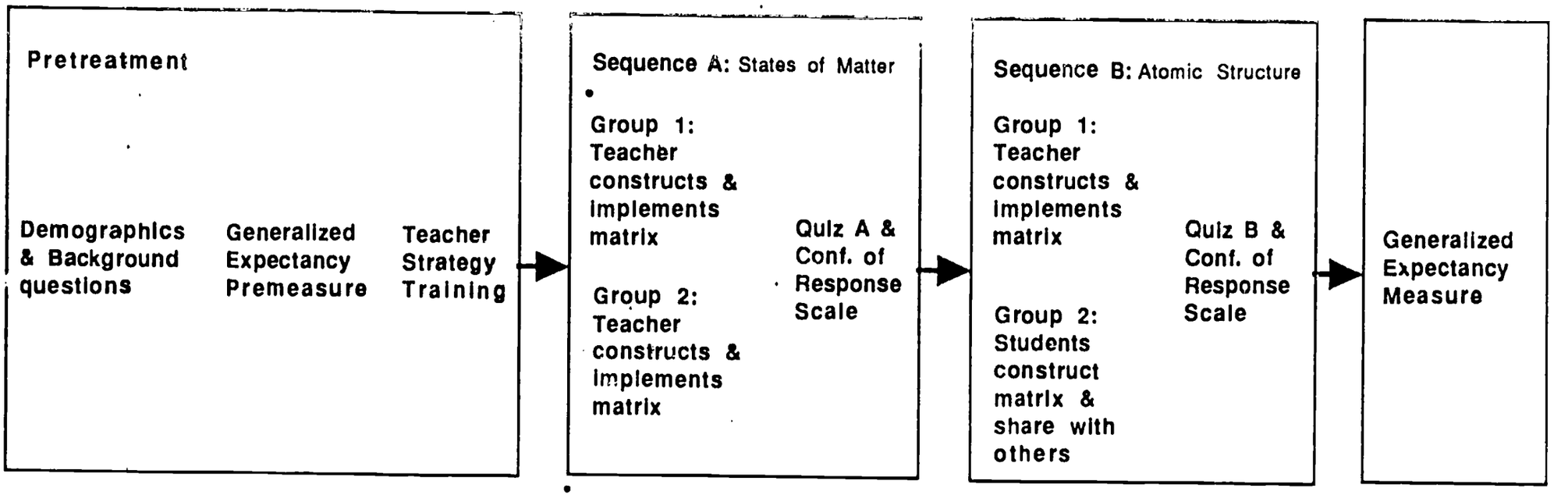

Figure 1. Sequencing of matrix strategy investigation.

	Leve. 1 (LEAST DIFFICULT)	Level 2	Level 3 (MOST DIFFICULT)
PROTONS	atomic particle with a +1 charge	a nuclear, atomic particle with a mass of 1μ (atomic mass unit) & a +1 charge	the nucleus of a hydrogen atom
ELECTRONS	atomic particle with a -1 charge	atomic particle found outside the nuclesu with almost no mass & a -1 charge	the flow of this atomic particle through a wire is called electricity
ATOMIC NO.	this describes the total number of +1 charges of an atom	the "11" of a sodium (Na) atom means there are 11 protons in the nucleus	this is equal to "6" for a carbon (C) atom
ATOMIC MASS	the atom's total number of +1 particles plus its neutral particles	the most comon form of the boron atom (B-10) has 5 protons and 5 neutrons	this is equal to "12" for the most common form of carbon (C)
NEUTRONS	atomic particles which have no charge	a nuclear, atomic particle with a mass of 1μ (atomic mass unit) and no charge	lithium -7 has 7-3 = "4" of these particles
ISOTOPES	hydrcgen (H) has 3 forms: H-1, H-2, H-3	chlorine -36 ($^{36}_{17}Cl$) is like chlorine -35, except it has an additional nuclear particle	lithium ($^{7}_{3}Li$) is like all the atoms which have 3 nuclear particles with a +1 charge

Figure 3. Concept Matrix for Atomic Structure

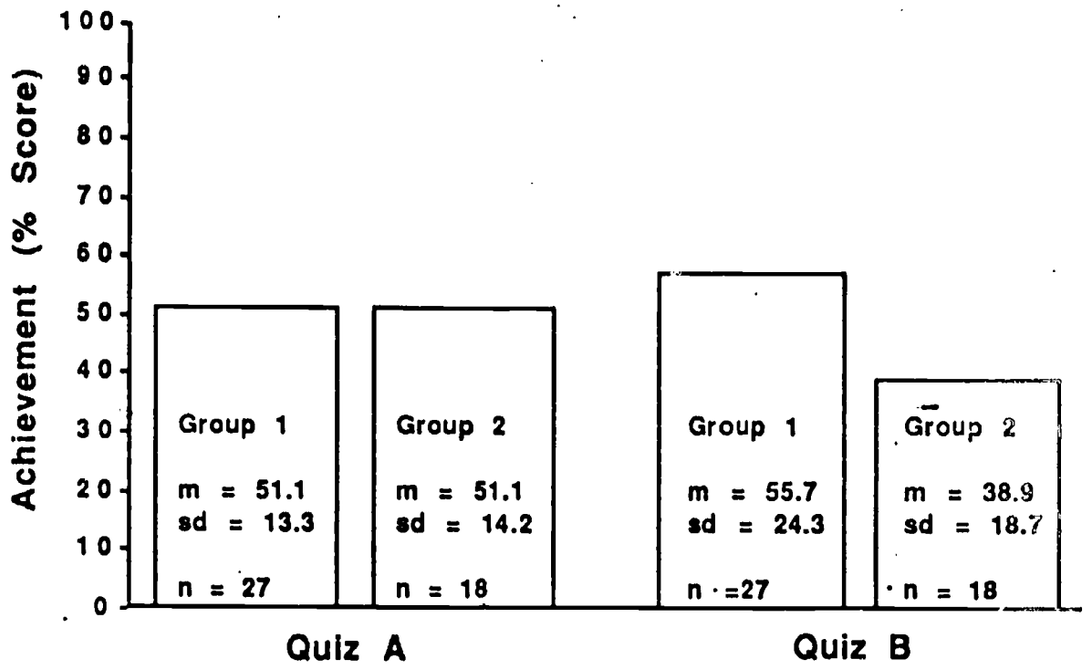

Figure 4. Retention scores for sequences A & B.

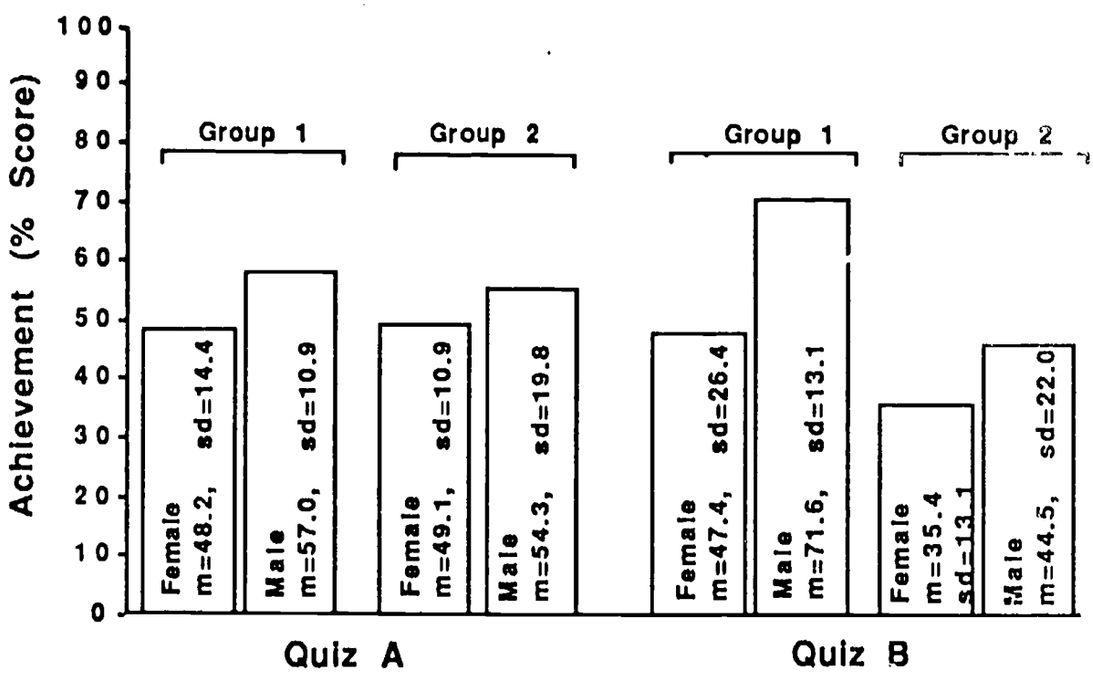

Figure 5. Retention scores by sex.

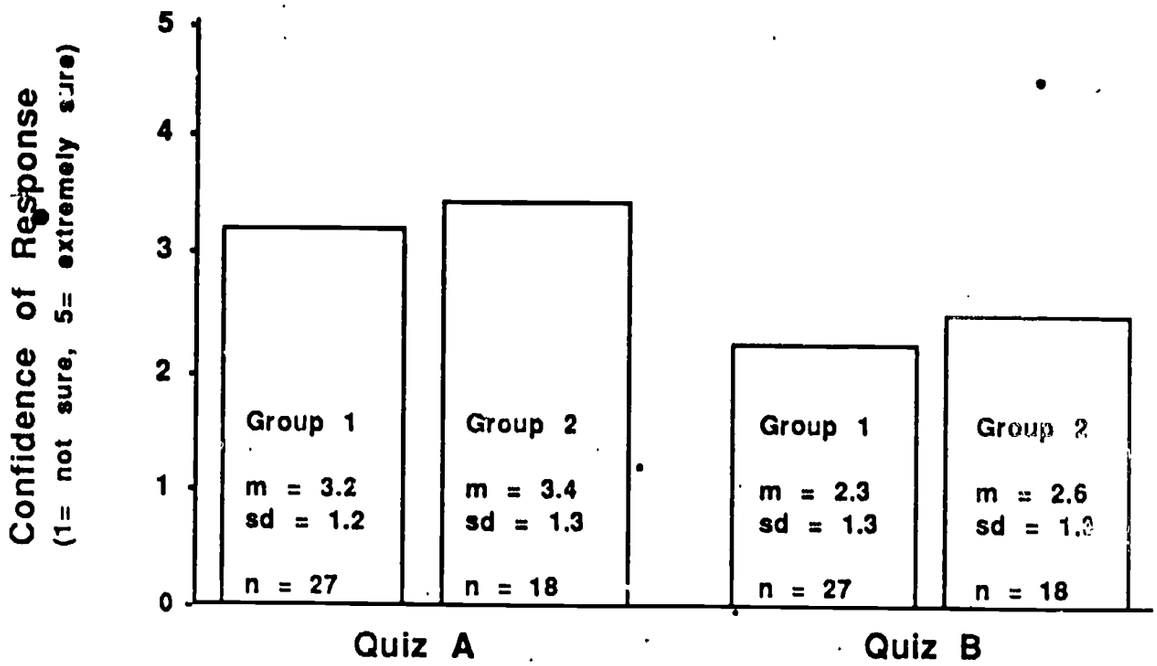

Figure 6. Mean Confidence of Response self-report for sequences A & B.

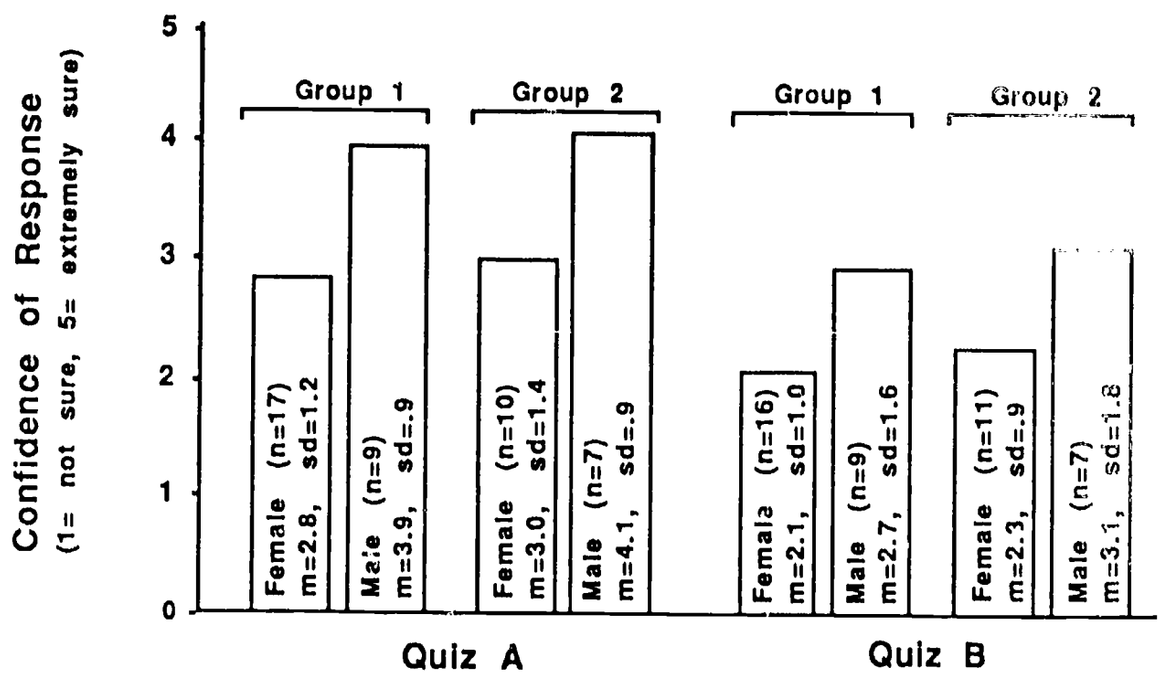

Figure 7. Mean Confidence of Response self-report for sequences A & B by Sex.

		Percentage of external response preferences									
		Tyler (1978) results		Group One				Group Two			
				Sequence A		Sequence B		Sequence A		Sequence B	
Item	Stimulus	Males	Females	Males	Female	Males	Females	Males	Females	Males	Females
4 b.	Most students don't realize the extent to which their grades are influenced by accidental happenings.	65%	67%	44%	57%	55%	21%	50%	91%	80%	75%
8 b.	Many times exam questions tend to be so unrelated to course work that studying is really useless.	33%	51%	22%	50%	22%	43%	50%	45%	60%	33%
9 b.	Getting a good job depends mainly on being in the right place at the right time.	31%	38%	33%	29%	55%	36%	50%	9%	60%	25%
18 a.	Sometimes I can't understand how teachers arrive at the grades they give.	39%	37%	22%	29%	44%	43%	50%	55%	40%	50%
	Average external response on Task-related items	39%	43%	26%	36%	42%	33%	50%	45%	48%	45%

Table 2. External response preferences on Rotter I-E Scale for Task-related items.