AAMRL-TR-90-004

EXPLORATIONS IN COOPERATIVE SYSTEMS: THINKING COLLECTIVELY TO LEARN, LEARNING INDIVIDUALLY TO THINK

Michael D. McNeese

DECEMBER 1989

Approved for public release; distribution is unlimited.

HARRY G. ARMSTRONG AEROSPACE MEDICAL RESEARCH LABORATORY
HUMAN SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6573

NOTICES

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Please do not request copies of this report from the Armstrong Aerospace Medical Research Laboratory. Additional copies may be purchased from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161

Federal Government agencies and their contractors registered with the Defense Technical Information Center should direct requests for copies of this report to:

Defense Technical Information Center
Cameron Station
Alexandria, Virginia 22314

TECHNICAL REVIEW AND APPROVAL

AAMRL-TR-90-004

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

CHARLES BATES, JR.
Director, Human Engineering Division
Armstrong Aerospace Medical Research Laboratory

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a REPORT SECURITY CLASSIFICATION: Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; distribution is unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S): AAMRL-TR-90-004	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION: Armstrong Aerospace Medical Research Laboratory; 6b OFFICE SYMBOL (If applicable): AAMRL/HED	7a NAME OF MONITORING ORGANIZATION
6c ADDRESS (City, State, and ZIP Code): Wright-Patterson AFB OH 45433-6573	7b ADDRESS (City, State, and ZIP Code)
8a NAME OF FUNDING/SPONSORING ORGANIZATION; 8b OFFICE SYMBOL (If applicable)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (City, State, and ZIP Code)	10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO
62202F	7184	10	46

11 TITLE (Include Security Classification)
Explorations in Cooperative Systems: Thinking Collectively to Learn, Learning Individually to Think

12 PERSONAL AUTHOR(S)
McNeese, Michael D.

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (Year, Month, Day)	15 PAGE COUNT
Technical	FROM JAN 88 TO NOV 89	1989 December	67

16 SUPPLEMENTARY NOTATION

17 COSATI CODES		
FIELD	GROUP	SUB-GROUP
05	08	12 09
05	06	

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
cooperative learning, group problem solving, naturalistic problem solving, metacognition, computer-supported cooperative work, group decision support systems, ([illegible]

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Cooperative learning and group problem solving each focus on the collective interaction of group members. Conventional wisdom suggests that in some situations "too many cooks spoil the broth", whereas in other circumstances "many hands make light work". This paper reviews three major issues (the complexity of measuring success, the conditions underlying success, and the transfer of success of future endeavors) to understand groups which enhance learning. Results often fail to address metacognition and specific contextual knowledge within group collaboration. They also do not assess whether cooperative learning/problem solving will transfer to new situations which a member encounters alone. In response, a cooperative systems approach is described for integrating cooperative learning and problem solving. Cooperative systems are discussed as a means of distributing intelligence across group function as well as facilitating spontaneous individual use of knowledge for future problem solving.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	21 ABSTRACT SECURITY CLASSIFICATION: Unclassified
22a NAME OF RESPONSIBLE INDIVIDUAL: Michael D. McNeese	22b TELEPHONE (Include Area Code): (513) 255-8805; 22c OFFICE SYMBOL: AAMRL/HED

DD Form 1473, JUN 86 *Previous editions are obsolete*

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

BLOCK 18. SUBJECT TERMS (Continuation)

collaboration, situational awareness, thinking.

Preface

The work underlying this report was performed by the Harry G. Armstrong Aerospace Medical Research Laboratory, Human Engineering Division, Wright-Patterson AFB, Ohio in support of Work Unit 71841046, Strategic Information and Force Management.

Also, the author gratefully acknowledges the support of Dr. John Bransford, Centennial Professor of Psychology, Vanderbilt University, for his guidance which helped form the foundation for this review. I also acknowledge the insightful comments from the following Vanderbilt Professors: Drs. Kazuhiko Kawamura, Howard Sandler, Robert Sherwood, and William Smith.

In addition, I would like to thank Dr. Clifford Brown, Wittenberg University Psychology Dept., and Dr. A. Rodney Wellens, University of Miami Psychology Dept., for their expertise/research within the area of group problem solving, which helped to evolve the cooperative system concept..

I would also like to thank Lt. Col. William Marshak, Major Michael McFarren, and Mr. Don Monk, AAMRL/HE, for their continued support of this work.

Table of Contents

List of Tables

BACKGROUND

The goal of this paper is to take an expansive view of the *group collaboration* terrain to include a variety of tasks and settings in which this interaction transpires.[1] This diverse view will focus on deriving the complexity, conditions, and transfer of group processes to understand why groups detract or enhance performance/learning. Group collaboration may be seen as the aggregation of 2 distinct research domains: Cooperative Learning (CL) and Group Problem Solving (GPS). Although this review focuses on the cooperative learning literature, certain viewpoints from group problem solving will be presented/contrasted as appropriate to facilitate understanding of CL.

It is interesting to note that the beginning of CL was embedded in the group dynamics area (Deutsch, 1949; Lewin, 1935) and the GPS/Group Productivity (GP) research (e.g., Lanzetta & Roby, 1957; Shaw, 1932; Steiner, 1972). Much of this research was conducted in laboratory settings without a naturalistic or educational context. The advent of CL applied some of the findings in group settings to education to form a more applied perspective for GPS (see Johnson & Johnson, 1975). It is this initial application of GPS that has given rise to CL as it exists today.

Although the theoretical foundations of the group literature provided the impetus to form CL in an education application, there are still major differences between each area. CL and GPS both involve group collaboration but for different purposes. The objectives within CL are to form groups with the intent to help/enhance each others learning about a given problem. The group collaboration often facilitates training of metacognitive or general cognitive skills (e.g. self monitoring, elaboration) which the student usually would not acquire alone. Still, the focus is on the group providing a setting for the development of <u>individual success.</u> In contrast, GPS objectives are for individuals to

---

1. Group collaboration is used as a broad, inclusive term and may refer to: cooperative learning, group problem solving, distributed decision making, computer-supported cooperative work, and multi-crew interaction. The term not only denotes the people composing the group but represents the underlying support technology and the particular situational context within which it occurs.

assume specified roles (i.e., separate performance tasks which may be coordinated in certain ways) which bring about success for the group. The group performs tasks and accomplishes purposes which the individual could not do alone. The focus of the group is the development of group success.

In the process of fulfilling these different objectives, CL and GPS have moved in separate directions. For example, some typical contrasts are: different settings (i.e., the everyday world versus the lab), different reward structures (cooperative versus competitive), and different types of relationships among group members (long term versus short term). A large amount of research in CL has become isolated from its inherited theoretical foundation in GPS. Many studies in GPS (e.g., Bender, 1985; Laughlin & McGlynn, 1986; Wilson, McNeese, & Brown 1987) still fail to be acceptable in CL circles. This is due -in part- to different orientations in what counts as success (i.e., CL uses measures of memory recall but GPS uses measures of performance-accuracy and speed), different task requirements (GPS is evaluated in terms of performance tasks whereas CL is evaluated in terms of learning tasks), and in part to different research paradigms (which vary within and between each area).

Dansereau (1988) indicates that the CL research lacks sufficient experimental controls, as well as, fails to use current theories associated with cognitive approaches to learning. Slavin (1987) believes that research on CL has developed so rapidly that it may have outrun its theoretical underpinnings. As a consequence, there are a wide range of results that suggest different contingencies for determining when group collaboration results in success or failure.

The quest for a sound integration of CL and GPS is unlikely. This lack of integration is reflected by the lack of acknowledgement of each literature by the other. Hill's (1982) review of group versus individual performance is comprehensive but devotes approximately 1 paragraph to CL. The review concluded at the time that there was not enough research within CL to justify its inclusion in this GPS review. McGrath's (1984) recent review of group performance is comprehensive but virtually ignores the contributions from CL. Hence, the mention of CL and GPS within the same paper is relatively infrequent. Yet, there remain similarities in that each area uses group collaboration as a means to bring about success, albeit through different perspectives. This review is primarily directed at CL, but it does not exclude the heritage of GPS. GPS contributions are used appropriately to facilitate both insight and understanding of CL.

WHAT COUNTS FOR SUCCESS IN GROUP COLLABORATION?

Collective wisdom has suggested that in some cases "too many cooks spoil the broth", while in others, "many hands make light work". These adages capture the major problem within group collaboration. It is that of trying to define the conditions/measures which determine group success or failure. Steiner's (1972) theoretical orientation (taken from the GPS literature) proposes a reasonable scheme to conceptually classify and understand this dichotomy within collaborative behavior. He suggests that groups often have many more resources (and thereby greater potential productivity) to perform tasks than individuals. However, GP may fail due to conditions of process loss (members are not motivated to contribute to group product and/or their efforts are not well coordinated). Hence, the actual productivity of a task equals the potential productivity minus process losses depending on the nature of the task.

The demands of the task are important as they determine the ways in which team members combine resources. Steiner suggests that a task can provide three ways to combine resources: 1.) disjunctive, 2.) conjunctive, and 3.) additive. Disjunctive tasks are ones in which one member can do the task and it is solved. Conjunctive type tasks are contingent upon all group member's success in order for the group to prevail on a problem. Thus, disjunctive tasks are connected to the group's best performer, whereas conjunctive tasks are connected to the group's weakest performer. The other type of task, additive, is based on a summation of member resources and is dependent upon the average group member.

Process losses in combination with task type act to determine whether a group engages in successful or flawed decision making. What makes a task difficult is the simultaneous or sequential performance of several different activities. Steiner believes that when a complex task is divisible (i.e., the task can be decomposed into smaller parts wherein each part may be performed by an individual or subset of individuals), the condition may be set for the group to excel as no single member is required to perform all phases of the job and one person's strengths can complement another's weaknesses.

Hill's (1982) review of the GPS literature show mixed evidence of process loss and gain in groups. McGrath (1984) notes that Steiner's classification points out that some members of the group do one set of things while others do other things; and that task performance is related to their coordination of efforts rather than just the the ability of the best, worst, or average member. The field of CL may also look to this scheme to address the conditions which count for success and failure, given the demands of group learning tasks. Thus, one must be attentive to the variables, techniques, and task structures which impact potential resource productivity in learning groups, as well as be on the lookout for what counts for process loss (motivational and coordinational breakdowns).

The basis for success in CL suggests that when students[2] cooperate as a group (within a variety of contexts), many positive benefits can often accrue (e.g., Dansereau, 1988; Fletcher, 1985; Gabbert, Johnson, & Johnson, 1986; Johnson & Johnson, 1975, 1985a; Johnson, Johnson, & Stanne, 1986; Johnson, Maruyama, Johnson, Nelson, & Skon, 1981; Sharon, 1980; Slavin 1983a, 1983b, 1985; Webb, 1982a,b, 1985a). Success is often prevalent in research as well as educational settings. Many educators (Damon, 1984; Stodolsky, 1984; Webb, 1985) support and advocate CL in classrooms as well.

Specific models of CL used in classrooms are: Jigsaw (see Aronson, 1978); Student Team Learning: Student Teams-Achievement Divisions

2. Note that this paper uses the concept of student in the very global sense. A student represents a person trying to acquire new knowledge or strategies within a specific context. Student may be synonymous with user, learner, or performer. For example, a designer may also be a student if that person is trying to learn about some process which effects the practice of design. The author believes that anyone may become a student at anytime. Also, the concept of teacher is very broadly used. A teacher may be an associate, a mentor, an advisor, a co-worker, an expert, a squadron leader, or another student. A teacher may take the form of non-human intervention via the role of technological interfaces. Intelligent tutoring systems, embedded training, and expert systems are all examples of non-human teachers although these teachers usually have derived their knowledge from humans. Hence, when we observe the student-teacher interface in a global way, we actually are addressing user-system interfaces or human computer interfaces. For instance, the designer as student may be exposed to the perceptual aspects of design by interacting with an intelligent tutoring system specialized with such knowledge. When there are more than one student and/or teacher, then we may state that we are concerned with a "**Cooperative System**".

(STAD), Teams-Games-Tournament (TGT), and Jigsaw II (see Slavin, 1980c); Learning Together (see Johnson & Johnson, 1975); Group-Investigation (see Sharon & Sharon, 1976); and Co-op Co-op (see Kagan, 1985). Others have taken general approaches to CL and tailored them for specific educational settings (e.g., engineering education, see Smith, Johnson, & Johnson, 1981; English composition, see Meeks, 1987; home economics education, see Way, 1985; nutrition, see Johnson & Johnson, 1985b). In some instances CL is being applied at the college level as well (Bouton & Garth, 1983; Spear, 1988).

There are also researchers who have developed elaborate research paradigms to study CL strategies (e.g., the First Degree MURDER strategy, see Hythecker, Dansereau, & Rocklin, 1988; and giving and receiving explanations in small groups; see Webb, 1985b). Applications of CL to the classroom are often for the purpose of conducting an experimental evaluation rather than being an integrated part of the curriculum.

Yet, there remains a disjunction in the classroom[3] as many teachers fail to put CL groups into everyday practice (Goodlad, 1984; Graybeal & Stodolsky, 1985). This may be due to attitudes or teacher-student preferences as what constitutes "appropriate learning structures" for certain subject matter. The apparent complexity of tasks, goals, group arrangements and their application to different study domains (e.g., math versus social studies) acts to bring different demands on curriculum planning (see Graybeal & Stodolsky, 1985). The level of cognitive skill required for a given subject matter tends to be facilitated by different kinds of reward-task structures experienced in different CL programs. This may be the first indication that the CL success story is much more complex than initially envisioned. This complexity may be contingent upon the conditions which act to facilitate higher-order cognitive skills. This points to understanding CL at a level which addresses both cognitive and group process.

---

1. Classroom refers to traditional and non-traditional understanding of 'where' the classroom exists. In the traditional sense, the classroom may be a room in a building set aside for learning. However, for a good portion of this review, the non-traditional sense of classroom is used. By this we mean that the classroom may be the real-world context of learning, a kind of "learning at the interface". The classroom becomes any naturalistic domain in which a person can experience learning/problem solving. For example, the designer may learn something new from a human factors engineer during the course of working on the drawing board at the engineering facility.

Research within CL has compared cooperative interaction with more traditional types of learning structures, such as competitive and individualistic interaction (Deutsch, 1962; Johnson & Johnson, 1975). Thus, the nature of success is ascertained in relation to other learning structures. These structures serve as the control groups which the cooperative group's success is compared against. Slavin (1980a) points out that this research typically demonstrates success in two categories: 1.) academic achievement and 2.) social relationships. More definitively, Slavin (1985) defines social outcomes to include intergroup relations, mainstreaming, and self esteem.

Although, CL research has diverged in many different directions, it still does not have the wealth of history or the breadth generated within GPS. Consequently, the research tends to be less fragmented and still generally produces shared purposes across various studies. The gist of CL research has traditionally:

1.) focused on how the group contributes or facilitates individual learning by accomplishing a group goal (see Damon, 1984; Johnson et al., 1981; Murray, 1982; Sharon & Sharon, 1976; Slavin, 1980a, 1983a, 1987),

2.) considered such factors as learning group mixture (see Webb, 1982b, 1984); achievement-recall (see Johnson et al., 1981; Sharon, 1980); and learning strategies (see Dansereau, 1988; Fletcher, 1985),

3.) produced studies which emphasize learning rather than performing activities, and

4.) utilized task and reward structures based on the group rather than individuals (see Graybeal & Stodolsky, 1985; Slavin, 1983a).

Within this context, a plethora of variables, parameters, and factors have been studied to see how they influence the success of CL (and thereby the potential group productivity) . For example, recent studies have investigated group mixture (Good & Marshall, 1984; Webb, 1985), metacognitive learning strategies in groups (Larson, Dansereau, O'Donnell, Hythecker, Lambiotte, & Rocklin, 1985; McDonald, Larson, Dansereau, & Spurlin, 1985;), group-to-individual transfer (Lambiotte, Dansereau, Rocklin, Fletcher, Hythecker Larson, & O'Donnell, 1987; Yager, Johnson, Johnson, & Snider, 1986), cooperative procedural learning (O'Donnell, Dansereau, Hythecker, Hall, Skaggs, Lambiotte, & Young, 1988) and computer-assisted CL (Fletcher, 1985; Johnson, Johnson, & Stanne, 1986; Trowbridge, 1987) to name just a few. CL has become an encompassing enterprise that often includes other juxtapositioned areas (i.e., peer response groups, peer tutoring, reciprocal teaching, group work in education). Hence, it is evident that CL is theoretically in vogue in educational research today.

In a review of the effects of CL on student learning (i.e., the measurement of success), Slavin (1983b) found that out of 46 field studies, 29 showed favorable effects, 15 showed no differences, and 2 favored the control group. Yet, Slavin (1983b) brings forth an important point that needs further understanding. He observed that group collaboration in and of itself would not facilitate student achievement. Perhaps this claim signals impending failures within CL. Some studies have shown that experimental groups who simply work together do not facilitate achievement (e.g., Johnson, Johnson, Johnson, & Anderson, 1976; Johnson, Johnson, & Scott, 1978; Slavin, 1980b; Vedder, 1985). These are instances wherein process loss has significantly reduced the potential productivity of the learning group. Slavin points out that the two critical elements that make CL more effective than traditional instruction are: group reward and individual accountability. Without these factors, process loss may occur.

In effect, Slavin is proposing that simply bringing a group to learn together is not a sufficient condition for successful collaboration. As Steiner (1976) suggests, success seldom depends on the availability of resources, as they must first be employed and then employed in a strategic manner. Just bringing a group together does not guarantee strategic utilization of the potential resources within the group. This introduces a major issue to consider in collaboration. It is understanding the conditions which precipitate strategic utilization of group resources. However, one must first understand what comes to be measured as learning and/or performance in such situations.

Success is based more on how group members are motivated to contribute rather than on what group members know. Of the 29 studies citing favorable effects, 25 used group reward structures (i.e. the group is rewarded as a unit to motivate member's performance) that facilitated significant achievement beyond the control. Hence, a basic question is whether CL success is inextricably bound to group reward. Slavin's point reveals that there are many complexities inherent in understanding cooperative learning and problem solving.

Slavin's observation must be held in contrast with some reviews stated in Johnson & Johnson (1985a). First, they indicate that of the 26 studies they have conducted regarding the effects of CL on achievement, 21 studies yield favorable results, 3 found no differences, and 2 had mixed results. Their studies have ranged across a wide variation of variables, group compositions, individual differences, curriculum subject matter, and study durations. Additionally, Johnson, Maruyama, Johnson, Nelson, & Skon (1981) report a meta-analysis that reviewed 122 studies from 1924 to 1981 which focused on CL effects on achievement and social interdependence. Their findings indicate that CL provides advantages which hold for all age levels, subject areas, and for tasks that involve concept attainment, verbal problem solving, categorizing, spatial problem solving, retention and memory, motor performance, and guessing-judgement-predicting. Surely, this is one of the most quoted and respected reviews in CL.

Furthermore, Johnson, Johnson, & Maruyama (1983) conducted another review on the relative merits of CL compared with competitive and individualistic learning. Of the 98 studies reviewed (using three types of meta-analysis), results indicated a strong validation of the proposition that CL facilitates greater interpersonal attraction among: homogeneous students, students from different ethnic groups, and handicapped and non-handicapped students.

The point is that the Johnson & Johnson reviews seem to paint the picture that CL's positive results occur across a wide diversity of conditions. This result seems to suggest an important, general issue when compared with the Slavin (1983b) review. That is, what are the limitations/capabilities of cooperation, performance, and learning in group interaction? Slavin suggests that success is dependent upon group and reward structure. Johnson & Johnson suggest that success is a more general phenomena with the only restrictive condition being cooperation of group members. All of these reviews suggest positive benefits for CL, but the Slavin paper puts forth the restriction that these benefits only occur with group rewards and individual accountability.

Deep Structures of Success

Again we must reemphasize that the "general versus restrictive success" issue has only been addressed by looking at surface level variables. In order to determine the underlying cause of success or failure, CL interpretation must proceed at a deeper structure (i.e., by addressing the cognitive processes and the information distribution in group collaboration). When an evaluation of CL studies proceeds from this perspective, different interpretations may be possible that go beyond the Slavin and Johnson & Johnson orientations.

Hertz-Lazarowitz (1985) summarizes 11 dynamic variables, suggested by Johnson & Johnson (1985a) as mediators of cooperation and social and/or academic gains, as 3 clusters: cognitive process variables, social variables, and instructional variables. As Johnson & Johnson (1985a) interject, many variables in CL have been studied but the processes that mediate or moderate the relationship between cooperation and productivity have been relatively ignored. This reflects what we meant by surface versus deep structures of CL. Process in this sense is a deep structure because it relates group collaboration to cognitive variables which are contingent on deep knowledge structures.

Very few studies in group collaboration have identified the cognitive component as being influential in any of the results stated. Hill (1982) concluded her review by stating that process gain may occur when: a.) there was member capacity to learn, and b.) cognitive stimulation was present. Hill's (1982) review signals a return to CL but requests that learning be evaluated from a cognitive viewpoint.

Only recently have efforts been made to understand the cognitive process underlying GPS and CL (e.g. O' Donnell et al., 1988; Laughlin & Ellis, 1986; Yager, Johnson, Johnson & Snider, 1986). Hill (1982) and Laughlin & Barth (1981) realized that the bridge between cognition and GPS must be constructed. Fletcher (1985) suggests that group superiority effects may be due to cognitive information processing, independent of the presence of other factors. The Johnson & Johnson (1985a) reference to cognitive process variables (i.e., oral elaboration, quality of learning strategy, and controversy/disagreement among group members) forms the cornerstone for interpreting why CL (and GPS) may be beneficial or detrimental, general or restrictive.

UNDERSTANDING GROUPS THAT COOPERATIVELY LEARN

As mentioned, there is much complexity in determining the nature of cooperative problem solving. Indeed, there have been various reviews (Dyer, 1984, Hackman & Morris, 1975, Hill, 1982, and McGrath, 1984) that look at a variety of group variables to conceptualize successful performance. To understand CL it is first necessary to address the goals and composition of learning groups. This section reviews these considerations and develops additional comprehension by comparing/contrasting some of the differences between CL and GPS. Finally, examples of successful CL are given to show the transition from theory to actual practice.

Goals

The goals inherent within GPS represent situations which are often focused on 'individual efforts' to support the group. In contrast, CL group goals focus on how the 'group efforts' can support the individual. As a consequence, GPS goals tend to be actively pursued in an immediate time window; whereas CL goals pertain to helping an individual in some future endeavor. A more critical question of goal orientation which will be addressed later is the extent to which the group-to-individual and individual-to-group subprocesses act to formulate group and individual success. Looked at another way, these subprocesses formulate how the group effects its members' future endeavors and how the individual members effect the future endeavors of the group.

There is also the perspective which looks at "who" demands the group to begin with. If I am a manager responsible for completing a project, I am interested in composing a group with efficient performance characteristics. My goal is to get the job done according to some defined criteria. Contrast this with the teacher who is responsible more to the student. In either case, group process transpires but the goals of the process are different. Given your own role in a group, you want to both contribute to the process to increase group performance, as well as consume from the process to increase learning, if you are motivated to do so. However, if you are not concerned with the group process, then individual and group failure may be forthcoming (e.g. social loafing, see Latane, Williams, & Harkins, 1979). Thus the goals when evaluated from the perspective of who they pertain to, justify different directions for the research. Research in terms of these goal perspectives creates conditional understanding of group process. Many of the conditions of group collaboration are direct derivations of the specific goal perspective selected.

Traditionally, CL studies have put forth goals of classroom instruction in the sense that the teacher is the facilitator of knowledge acquisition for students. Knowledge acquisition may take the form of remembering target materials (e.g., the Jigsaw II problem, see Slavin, 1980c) or may take the form of teaching the student general skills that facilitate the learning of new material (e.g. the MURDER strategy, see Dansereau, 1988). In either case, CL prevails but what varies is the measurement of learning. Instead of requiring a group member to engage in problem solving skills, it is more likely that the CL situation requires the member to engage in memory and comprehension skills. Although memory, comprehension, and problem solving are all interrelated -and dependent- cognitive skills, CL studies tend to focus on recall rather than the others. Hence, within CL we have studies that look at student recall but rarely look at how students might use recall of knowledge to perform a subsequent task. Yet, the goal of CL is to acquire knowledge for future use. Perhaps this is a normative description. Most CL research serves the goal of knowledge acquisition for the student in the present context without thought to future endeavors.

The Composition of Cooperative Learning

Although there can be various configurations of learning groups, the group basically is a set of students who are encouraged to work together and give and ask other students for help when needed (Webb, 1985a). Within CL, group-task structures are highly integrated; and concomitantly, exert influences upon each other which in turn makes it difficult to separate them. In many cases, the natural setting of a classroom also serves as the experimental setting. Also, in CL, there is much more reliance upon the factor of reward structure, whereas in GPS, reward structure is usually only mentioned as a passing comment in describing dependent variable measures for experimental tasks. Thus, in CL, rewards are usually explicit, but in GPS they are transparent, although this need not be the case.

The definition of the group in CL may take the form of the variables under study. Groups may be defined in terms of gender, intelligence of members, durational stability, size, cooperative method used, subject matter, age, race, abilities; to name just a few factors studied. Groups can vary according to a variety of constructs and these constructs act to effect the group's productivity. Without some form of systematic decomposition of such factors in CL, the generalization of results remains impossible. Some researchers have begun to make such an effort (e.g., Kagan, 1985; Graybeal & Stodolsky, 1985; Slavin, Sharon, Kagan, Lazarowitz, Webb, & Schmuck, 1985). For example, Stodolsky (1984) differentiates peer-work groups from teacher-led groups. She suggests that there are five types of peer-work groups: completely cooperative, cooperative, helping obligatory, helping permitted, and peer tutoring. Each of these groups poses differential involvement on the part of teachers and students. Furthermore, each group requires certain investments to bring about the proper training in a given method of CL.

It is at this point that it becomes inefficient to try to separate the group definition from task typologies and theoretical orientations. Therein, the remainder of this section looks at how various group, goal, task, and reward structures are conditioned to produce CL. Bossert, Barnett, & Filby (1984) contend that a more dynamic view of grouping is needed- one that considers the interactions between task and group structures. They suggest that the linkage between group assignment, resource allocation, and task characteristics becomes a critical variable to understand effects upon learning and development. In their matrix development of group activity configurations, they create nine different classifications of activities based on the factorial combination of task interdependence and task differentiation. Table 1 shows examples of these activities.

A basic question in CL is how to orchestrate the group to accomplish goals? This involves task structure and reward structure (see Slavin, 1983a). Slavin (1983b) defines cooperative *task structure* as situations in which two or more individuals are allowed, encouraged, or required to work together on the same task while coordinating their efforts to complete the task. Graybeal & Stodolsky (1985) summarize that *reward structure* refers to the way in which students are evaluated within and between groups, and *task structure* is the way in which work is organized in the group. In fact, Steiner's breakdown of tasks as disjunctive, conjunctive, or additive readily fits into CL structures. Slavin goes on to dichotomize task structures as either involving task specialization (whereby each student has a unique subtask which the group requires to complete the task) or group study (whereby all group members study together and do not have unique tasks). Slavin defines reward structures (or incentive structures) or goal structures (see Johnson et al., 1981) along lines originally postulated by Deutsch (1949) as cooperative, competitive, or individualistic structures.

Table 1

Activity Configurations Within Classroom Groupings (taken from Bossert, Barnett, & Filby, 1984)

Task Independence	None	Between Groups	Within Groups
Independent	(1) Whole-class worksheet	(2) Separate reading groups	(3) Separate individualized program
Interactive	(4) Whole-class with cooperation	(5) Separate reading groups with cooperative tasks	(6) Common individualized program
Interdependent	(7) Common group projects	(8) Group product	(9) Coordinative group task

The Deutsch (1985) research provides support for showing that the effects of different systems of distributive rewards within a group are contingent upon the type of task confronting the group. Deutsch (1985, 1987) has currently extended this thinking to determine reward structure based on the following modes: equity (each receives reward according to their contribution), equality (reward is distributed equally to members), need (each receives reward according to their needs), or winner (reward is given to the best performer). Deutsch's research reveals that equality is the best modality when cooperation is present, and that equality may create a reward structure that leads to greater cooperation. If studies make equity the primary modality for reward, it is likely that more competition (rather than cooperation) will transpire for tasks involving much interaction. When competition reigns, the likelihood of process loss becomes greater which could spiral into conflict. Because most CL studies utilize cooperation vis-a-vis the equality modality there is less chance for process loss.

CL incentives reflect the distribution of rewards. Rewards may be given to groups on the basis of: 1.) individual performance or 2.) a single group product. Rewards may also be given individually. Slavin (1983b) thus creates a 2 (task structure) x 3 (incentive structure) to classify all methods of CL. As was mentioned previously in this review, Slavin believes that CL is only productive (for those groups that do not use task specialization) when the group is rewarded and when each member is individually accountable to contribute to the product. He notes that in group study where there is group reward (i.e., where groups are evaluated on the basis of a single worksheet, test, or project), it is possible for a single group member to do all the work. This can set up instances of social loafing. In contrast, when groups are rewarded on the basis of an average or a sum of individual learning performances, whereby each member's own rewards depend on other member's learning, CL shows substantial gains.

The Difference Between CL and GPS Conditions

Many of the differences within CL groups have been elaborated. Even with these differences prevalent, there is much evidence to demonstrate the success of this learning strategy. At this point, a comparison between CL and GPS groups can provide some differences between the two areas, which might elicit some of the conditions underlying process gain and process loss.

One of the basic differences between CL and GPS is the focus of the activity that they are engaged in. CL proposes to use reward and task structures to promote learning, achievement, and social integration; whereas, GPS coordinates member resources to perform together to accomplish particular requirements. Both groups use knowledge and information, but in variant ways and for different purposes. However, many of the group processes that underlie purpose and form may actually be very similar. For example, discussion may be a group process that ensues regardless of whether a group intends to perform or intends to learn. In either case, a group of the individual members and their thoughts get combined into agreement or disagreement. One of the artificial distinctions between CL and GPS groups may lie in separating performance from learning.

Another critical difference lies in the temporal duration and frequency of interaction. Kelley & Thibaut (1969) originally identified these as requirements related to response distributions over time such as sequencing, cuing, alternation between members, and other temporal patterns. If these requirements become an end in themselves then they consume group processes which may result in losses. Usually, GPS studies are short term and are typified by a group meeting for a practice session and then perhaps several more experimental sessions and then the group is debriefed and disbanded. The overall duration of the group is probably 1 week to 4 weeks. Often, their collaboration may take place in a concentrated, tactical manner over the course of an hour session. Member relationships are solely for the purpose of accomplishing the task at hand and usually nothing more. One must note that the subjects are usually college freshmen randomly selected to be representative of the population under question. Experiments within the actual operational target environment however are sparse.

In contrast, the CL time window is vastly different. In many studies, the researchers conduct their study within the operational environment, wherein subjects are usually involved in a stable long term relationship Although, the task may be foremost in the study, the group's members may interact frequently for reasons other than the CL task as they participate in other class activities. Because they come to know one another much more than GPS subjects, their social perceptions and knowledge of each other may lead them to experience greater cooperation than GPS groups.

The studies involving CL use groups which are already organized whereas GPS studies use ad hoc groups for study. Thereby, another source for loss in GPS groups is the investment in organization to identify or solve a problem. When groups are compared with individuals, organization also becomes a factor which might artificially suggest that the group fails more frequently. Note that some of these organizational lulls can be offset by specific training procedures embedded into the experimental procedure for studying CL or GPS. A study by Amaria, Biran, & Leith (1969) reveals that a child's history of experience with certain curricular practices can come to influence experimental studies of groups in the classroom.

CL studies use a wide range of students, but, in general, subjects are often children with various levels of cognitive and social capabilities still in development. Necessarily the role of rewards is historically tied into the educational experience, whereas the reward for GPS studies usually ties into a college freshman obtaining experimental credit to pass his/her intro psychology class. Thus, the reasons and motivations for participating in the study may be at odds. Students are in school with the purpose to learn but GPS subjects are in an experiment as a requirement, not necessarily because they want to perform (or learn).

Also, there is a confound between speed-accuracy tradeoffs. When one compares a CL task with a GPS task, the question must be asked if the group was given more time would the solution improve? Often times success is solely defined as speed in GPS and as accuracy in CL without any attention to these tradeoffs. This is another example of the measures of success leading to a particular research result. Research must be conducted with the proper control groups in order to assess such tradeoffs to make comparisons and generalizations in GP. Not only are such temporal factors critical for understanding differences between CL and GPS, they are necessary to understand differences in comparing group with individual problem solving. Groups may be slower and much more uncoordinated than individuals (see Kelley & Thibaut, 1969) in performing a task if they get involved in response distributions. If success only counts as speed and not accuracy, a false impression could be obtained for groups when compared to individuals. This would be especially so if the task was one which allowed greater quality of solution as a function of time on task.

Thus taken together these different temporal patterns may bias more positive responces in the CL community but cause more inconsistencies in GPS due to more possibilities of process loss. Perhaps insight would be gained if GPS tasks were utilized in the classroom and CL tasks were designed to be utilized by college freshmen for partial fulfillment of their intro-psychology class.

The training and retesting issues are ones that impact differences between GPS and CL. Usually, the GPS studies train subjects to be able to perform at a certain standard, then introduce new twists to the study. Studies may be within-subject or between-subject designs. But in CL studies, the training in essence is the reason for the study, without any concern for performance. Also, preparation for their CL may be minimal. Some of the formalized programs (e.g.. the Jigsaw method) may provide adequate preparation but as Stodolsky (1984) notes, many small group studies incorporate very *little preparation* of learners for helping, cooperative, or tutorial roles. Training usually implies some sort of evaluation that involves paper-and-pencil testing although it would certainly be possible to use more sophisticated measures.

In GPS, performance typically involves dependent variables that reflect accuracy, judgment, speed, or time-stress measures. Often these measures reflect the use of sophisticated technology and the measures are sampled periodically over a given time unit. This portrays a task that is often based upon fast responses by the subjects and may artificially create time pressures to demonstrate distinct differences in group abilities. CL groups usually take some form of summary response for the group and are not constantly monitored for sequential responses that compose the final product. Their time pressure and stress may not be as concentrated as that of GPS. Consequently, they may not show process loss as readily. Some new advances might be made if some of the GPS dependent variables (and a reliance upon time pressure) were imported for use in CL. On the other hand, CL strategies involving slower responses (and reliance on more judgmental-assessment activities) might provide insights in GPS.

Another conditional factor related to training and views of success is the consideration of feedback in GPS and CL groups. Different reward structures not only influence what counts as success but they effect the type and distribution of feedback available to the group. In CL, success may be based on an average with other member's scores. But, success is often defined by the member's performance on a one-shot recall test. Thus, they may not receive any feedback on how well other members do. Kelley & Thibaut (1969) suggest that feedback like this effects a member's sense of responsibility in 2 ways. First, without much feedback there is no motivation for subjects to do well. Second, with feedback, blame-placing and deterioration of intergroup relations set in. However, CL usually has feedback in terms of what they think the correct information is but do not have actual verification on how well others know this for testing. Although they do have verbal feedback to assess whether another member knows the information required for the test. In all likelihood, this type of feedback results in the type of individual accountability which Slavin (1983b) identifies.

On the other hand, many GP tasks often contain performance which has timely, multiple feedback loops wherein blame placing can occur. GPS members may end up feeling more responsible for failure because they get feedback of failure more frequently than CL members. This may again be more evidence for greater probability of process loss in GPS.

A final issue that both areas need to address is the stability of group collaboration patterns over time. Webb (1985a) has addressed this issue initially but her results are conflicting (Webb & Cullian, 1983; Webb, 1984). This is a much more important issue than is indicated within either area. To only evaluate achievement after the CL group accomplishes its task, is to ignore the effect of CL upon the individual's access of material at a much later date. If CL evaluations are not stable over a given time period, then one may question the utility of the strategy to impart knowledge to students for future use. Likewise, in GPS, if the performance of members varies across time, then the stability of the variables evaluated would also be invalid. This factor of instability may illuminate why there are inconsistencies within and between each area. Part of the problem of evaluating a student's performance from $time_1$ to $time_2$ is not knowing what took place in between evaluations. This relates to the students developing social perceptions of one another as well. Hence, this variable is difficult to tie down, but weighs heavily in ascertaining the effects of CL.

A picture begins to emerge (based on the previous comparisons) that CL has evolved into an area that has major differences in variables within studies, as well as major differences with GPS studies. It seems that GPS studies have been designed in ways that present more opportunities for process loss. CL studies seem to be designed in ways that emphasize process gain. One must ask the question as to whether there are any means to reconcile these directions. The directions are not opposite or antagonistic to one another, but rather they seem mismatched in terms of measures, methods, temporality, cooperation, and context. To the extent that each would use more of these factors from the other area, insights would begin to ensue.

Examples of Successful Cooperative Learning

Earlier, this review provided evidence that cooperative learning, in general, seems to be very successful in fulfilling its goals. There are many techniques which demonstrate how cooperative learning increases student learning but we will only look at Jigsaw II (Slavin, 1980c) as being representative of such techniques. In Jigsaw II, students are assigned to four- to five-member teams; whereupon they read narrative materials (e.g., a text on perception in man-machine interfaces). Each team member is given a special topic (e.g., a section consisting of several chapters in which to become an expert). The students then discuss their topics in "expert groups" and return to their team to teach their teammates what they have learned. Students then take a quiz on the material, and the quiz scores are used to form individual and team profiles.

For example, Andrew may be a member of the "Designers" team and be assigned to the "Spatial Disorientation" expert group who would gather to learn the section of the book which relates pilot performance with spatial disorientation. When the "Spatial Disorientation" group is through discussing aspects of disorientation on pilot performance, Andrew would then return to his "Designers" team to teach his teammates this knowledge. Likewise, his teammates would teach him about their group's area of expertise. For instance, Fred (another "Designers" member) taught Andrew about the role of perceptual learning for discriminating contours and shapes. In this way, all team members are exposed to all parts of the "perception in man-machine interface" text. In conclusion, Andrew and his fellow members would take tests on the text. Their results are tabulated individually, but perhaps more importantly for group process, they are tabulated as a team for comparisons with the other teams.

Jigsaw II provides cooperation among and within teams. It is worth noting that individual members are given incentive to learn and cooperate as the group's success is contingent upon individual scores. The group with the highest scores receives various forms of recognition. Although, other CL tasks differ in defining group success, Jigsaw II is representative of the type of cooperative activities students engage in. As students participate in these types of CL tasks, there seems to be a substantial process gain experienced in learning. In this CL example, the adage "two (or more) heads are better than one" is true.

Examples of less than successful cooperative learning (without looking at group-to-individual transfer) are too few to mention in that replication has not been successful. However, in order to understand when failures do occur it is necessary to progress to the deeper structure of group collaboration.

UNDERSTANDING GROUP-to-INDIVIUDAL TRANSFER OF LEARNING

At the heart of many issues involving collaboration is the effect the group has upon its members in their own subsequent individual transfer tasks. As Laughlin & Barth (1981) surmise, many educational and training systems assume that individuals who successfully solve problems in cooperative groups will subsequently perform better than individuals who have previously solved problems alone. In order to derive a deeper understanding of group collaboration, we must examine the conditions which precipitate Group-to-Individual Transfer (GIT). So the true emphasis is not on performance or learning within the group but rather how the group can provide greater transfer of knowledge or metacognitive strategies for an individual. A related sub-problem is determining not only the presence of transfer but asking the question of "What is transferred?" Subsequent process gain or loss hypotheses must be understood in terms of lasting effects on individuals rather than temporary effects on the group. Success or failure cannot be determined solely on the basis of the performance of the group without subsequent evaluation of individual members in comparison with other people who were not exposed to the original group processes. Because so much of CL and GPS studies fail to: 1.) evaluate transfer, and 2.) use proper control groups; a clear-cut answer cannot be provided.

The Role of Learning Strategies

CL may approach the effects of collaboration on individual problem solving from two interrelated fronts: 1.) *learning strategies* that are developed during the course of group collaboration, and 2.) *group-to-individual transfer paradigms*. Weber, Chen, & Weinstein (1989) define learning strategies as general, goal-directed procedures which can be used to acquire information and expertise in any domain. They point out that in order to effectively learn, people must know about and be able to use learning strategies. The goals of GIT are based on the group providing some form of collective induction for its individual members which they can subsequently use in their own problem solving endeavors. Laughlin (1989) defines collective induction as the cooperative search for descriptive, predictive, and expanatory generalizations, rules, and principles. Collective induction (see Laughlin &

McGlynn, 1986) might be thought of as a group process which acts to develop particular learning strategies. However, Slavin (1983b), initially takes a position that GP emerges only because members share their answers, and not because of any property of group collaboration (e.g., a learning strategy). He goes on to state, "School achievement bears little relationship to GPS. Learning is a completely individual success that may or may not be improved by cooperation, but it clearly is not obviously improved by cooperation in the same way GPS is superior to individual problem solving." This suggests that there is not a role for collective induction within CL. Unfortunately, this chasm between group performance and learning process may explain the presence of inconsistencies (regarding process loss and gain) within both fields.

Slavin (1983b) may take his position because he views achievement in a limited way (i.e., extrinsically tied to rewards to coordinate work to obtain an average group score on a test). However, he does recognize the need for paradigms that measure individual learning rather than GP. Because CL studies have traditionally only measured the performance of the group on the task rather than seeing how the group subsequently facilitated individual performance, CL is put in a compromising position.

Slavin (1987) later recognized that in addition to a motivational perspective in CL, there also is a 'developmental' perspective. This perspective takes the position that cooperative task structures determine learning (rather than reward structures) wherein students are given the opportunity to discuss, argue, present, and hear one another's viewpoints. We would just note that the characteristics underlying Slavin's description of a 'developmental' perspective span across the entire spectrum of human problem solving and are certainly not only identified with younger students. Vygotsky's (1978) statements are exemplary of this alternative way of conceptualizing CL and may also be food for thought for conceptualizing GPS. He saw socio-cultural factors influencing higher level cognitive development. He suggested that collaborative activity would effect learning as follows: "Functions are first formed in the collective in the form of relations among children and then become mental functions for the individual....... Research shows that reflection is spawned by argument." Intelligence is reinterpreted as a collective activity (which is jointly accomplished between the problem solver and others) before the problem solver can intelligently function alone. This view is being substantiated by current approaches that emphasize 1.) everyday problem solving in culture (often termed situated cognition); see Rogoff & Lave (1984), and Sinnott (1989) 2.) the role of mentor and tutor; see Palincsar & Brown (1984), and 3.) the social construction of knowledge through cognitive apprenticeship; see Brown, Collins, & Duguid (1989). Obviously, this provides a theoretical cornerstone for CL and GIT.

The influence of argument is an extremely pertinent variable for addressing learning strategies and group-to-individual transfer. Argument, in essence, is a learning strategy (see Perkins, 1986). This brings the discussion to a new plateau, as it can now make a distinction in CL classification as a function of the level of cognitive activity involved in particular strategies of learning. For instance, if argument is a basis for using knowledge which in term produces higher levels of individual transfer of learning, then there is a solid basis for: 1.) properties of the group collaboration facilitating learning beyond which an individual could generate individually, and 2.) the transfer of this knowledge to successive tasks wherein the individual performs but not in the group context (i.e., the individual has learned to *learn to perform*).

Indeed, some of the most recent research in CL has created designs that try to assess the effects of learning strategies. If collaboration brings about more learning than non-collaboration, then this can be tested empirically. Skon, Johnson, & Johnson (1981) found that, "the academic discussion within CL groups promotes the discovery of higher quality reasoning strategies". Similarly, Barnes & Todd (1977) found young adolescents solving problems through discussion facilitated problem solution because it required multiple contributions. Foreman (1981) found that argument and social exchange facilitated higher cognitive processes.

This relates highly to the work of Webb and her associates (1982b, 1985a). They conceptualize CL as the giving and/or receiving of help. When students provide explanations rather than brief responses, the helper is aided in learning the material. With brief responses, this aid diminishes. Webb (1985a) suggests that explanations are verbal interactions that allows the helper to elaborate material and allows him/her to reorganize or clarify the material in their own mind. Winograd & Hare (1988) state that explanation may be the most significant component of direct instruction. Weinstein, Underwood, Wicker, & Cubberly (1979) show that training the student on elaboration activities leads to better comprehension and recall.

Of even greater interest is research (Smith, Johnson, & Johnson, 1981) which shows that discussion which promotes controversy promotes greater learning, compared to discussion without controversy. Nijhof & Kommers (1985) interject that, "Controversy is a process of perceiving and reasoning.........highly cognitive in nature; oriented around conclusions formed from arguments, information experiences, and other data. It is a process of convincing other people of a particular cognitive perspective." One must ask what controversy affords for a collaboration group? Bender (1985) believes that groups usually talk or concurrently verbalize the reasons behind their decisions; whereas individuals do not. Individuals who do concurrently verbalize their reasons for decisions in a problem solving task, show superior levels of performance when compared to silent individuals (Berry & Broadbent, 1984; Fletcher & Perman, 1982). Indeed, Fletcher applied these principles to groups interacting on a microcomputer-based task and found that group superiority effects are partially due to cognitive facilitation associated with talking aloud.

Furthermore, Bargh & Schul (1980) conclude that teachers helping others are enabled to see the issue from new perspectives which blossom new, previously unthinkable relationships between discrete elements. These researchers have evolved CL into an area that places promise on the learning strategy component. As learners get involved to teach others, their knowledge becomes organized in much more complex and efficient ways (see Allen, 1976; Annis, 1983; Murray, 1983).

In particular, the Palincsar & Brown (1984) approach used "reciprocal teaching" whereby students weak in reading comprehension skills cooperatively worked together to interpret text. The students alternated in posing questions, summarizing, clarifying, and predicting subsequent portions of text, which was initially modeled for them by the teacher. Other group members would comment and enhance these activities. The Palincsar & Brown (1984) study obtained evidence for continued improvement in reading test performance (i.e., individual skill at answering questions about passages which were read privately) which was maintained even without continued participation in the reciprocal teaching practice. When compared with other groups of students who engaged in intensive reading practices, the reciprocal teaching group showed significantly better comprehension skills.

This study is noteworthy as it: 1.) demonstrates proper use of control group comparisons in a form of cooperative learning, 2.) it assesses the effects of GIT on the individual reader, and 3.) it insures retention of these effects over a specific time duration. The study is exemplary in requiring the proper experimental procedure necessary to make comparisons across studies and from CL to GPS. Finally, the study emphasizes the importance that self-monitoring training has in the context of CL and its role in GIT. Other studies (Bereiter & Bird, 1985; Collins, Gentner, & Rubin, 1981; Day, 1980) also demonstrate self-monitoring learning in a social setting to facilitate text comprehension.

The Group-to-Individual Transfer Paradigm

The most recent advances that focus on learning strategies (in combination with group-to-individual problem solving transfer) have been taken in a paper by Gabbert, Johnson, & Johnson (1986) and have been pioneered by Dansereau and colleagues (see Dansereau, 1988 for a review of their work). A primary consideration in the GIT paradigm is the use of proper control groups. This usually takes the form of comparing group-to-individual transfer with individual-to-individual transfer, to ascertain the effect of group collaboration upon the individual performing in a general problem solving transfer task.

More specifically, a group performs on an acquisition task at time1. Then individual members of this group perform on a transfer task (similar or analogous in nature to the acquisition task) at time2. In order to properly assess transfer, this first situation is compared with the control. The control has individuals -not groups- perform on the acquisition task at time[1]. Then, these individuals participate in the transfer task at time[2]. Hence, the paradigm allows comparison to see whether the individuals exposed to group collaboration (on the acquisition task) do better on the transfer task than those individuals who worked alone on the acquisition. If the transfer task performance of those subjects exposed to group collaboration is better than the individual control group, then we have produced the condition of group-to-individual transfer. Other controls might compare several group-to-individual transfer conditions, wherein the incidence of type of learning strategy involvement per group is varied.

The Gabbert et al (1986) study revealed that the higher achievement of students in the cooperative condition transferred to individual testing conditions for three higher level reasoning tasks (taken from Bloom's taxonomy of cognitive objectives, 1956). Hence, this is a particular example of successful GIT, but it places the condition of task complexity as being crucial for demonstration. They state that this is positive evidence for process gain and collective induction. This is a line of research that corresponds to Hill's (1982) request to do studies that investigate cognitive stimulation in order to obtain process gain in group collaboration. This research also reestablishes connections with the GPS area as it provides evidence of what Laughlin & Barth (1981) posit as the fundamental issue for a theory of group-to-individual problem solving transfer (i.e., collection induction: group induction of general principles that none of the group members could induce alone). Gabbert et al. (1986) point out that more evidence is needed to examine group-to-individual transfer.

The research studies investigating GIT have been sparse. Consequently, the lack of replications (inconsistencies) are prevalent. Some research suggests that this transfer is not obtained (e.g., Beane & Lemke, 1971; Bender, 1985; Johnson & Johnson, & Scott, 1978; Klausmeier, Wiersma, & Harris, 1963; Laughlin & Barth, 1981; Laughlin & Sweeney, 1977; Lemke, Randle, & Robertshaw, 1969; McClintock & Sonquist, 1976; Perlmutter & de Montmollin, 1952; Taylor & Faust, 1952). Positive group-to-individual transfer studies; however, make conclusions difficult (e.g., Johnson, Brooker, Stutzman, Hultman, & Johnson, 1985; Johnson, Johnson, Roy, & Zaidman, 1985; Smith, et al., 1981; Yager, Johnson, Johnson & Snider, 1985). It is also interesting to highlight the lack of studies which investigated the individual-to-group transfer (see Laughlin & Barth, 1981). These studies use the reverse procedure for testing transfer.

There are two interrelated processes which underlie process gain within successful GIT. One is what Laughlin & Barth (1981) refer to as *social learning*. "By this they mean to what extent the group serves as the setting for individual learning (much like a book, a television program, or a museum). Concomitantly, the second process, *collective induction*, accounts for an individual's use of their knowledge collectively to induce general principles for subsequent acquisition by other individual members. Hence, we begin to see the reciprocal and complex nature of learning strategies within group collaboration. Obviously, this is highly interactive with the particular type of task experienced (Laughlin & Ellis, 1986).

For transfer to occur from the individual to the group, the group must pickup knowledge from individuals to create general principles that the individuals could not create themselves. Members contribute different perspectives which may clarify knowledge for individuals. When a given member comprehends the group's current position, then they are free to expand, reciprocate, and to the group process. Hence, collective induction provides the environment for clarification, comprehension, and generation of knowledge which may not be operative when an individual acts alone. It is speculated that when collective induction occurs, there is a greater chance that an individual member will encounter more knowledge as compared to an individual in isolation. The opportunity for GIT may be large under these conditions.

Process gain in CL and GPS is not simple. Studies which confine social learning, may as a consequence inhibit cooperation, learning, and performance. As social learning is damaged, the effects may wash out subsequent collective induction, with the result being process loss. When researchers quote all the positive effects in CL studies they are usually only obtaining evidence of a particular social combination process (e.g. truth wins, truth-support wins, majority rules) induced by the task without looking at how knowledge was compiled by the group in a transfer paradigm. Thus, the issues of how well the individual has learned and the social and cognitive process factors that predicated learning, are often masked.

The new tact of research taken by Dansereau and colleagues has reconciled this crippled state of affairs by conducting studies that systematically address the learning strategies that underlie CL situations within a group-to-individual transfer paradigm (see Dansereau, 1988; Hythecker, Dansereau, & Rocklin, 1988; Larson et al., 1985; McDonald et al., 1985; Spurlin, Dansereau, Larson, & Brooks, 1984). These studies provide additional cases of success within the GIT paradigm. They have extended the idea of argumentation and elaboration by incorporating a specific mechanism (within their CL dyad technique entitled First Degree MURDER) that specifically develops cognitive learning strategies for members. This technique was developed to study CL strategies for acquisition of knowledge from text material (see Dansereau, McDonald, Collins, Garland, Holley, Diekhoff, & Evans, 1979). They propose that learning fosters two types of activities: 1.) active processing of information and 2.) cross modelling/imitation.

Within their CL strategy, the dyad is required to engage in alternating rounds of reading and summarization; whereupon, a positive Mind-set, Understanding, Recall, Detection, Elaboration, and Review are established. More specifically, there are a number of cognitive process gains introduced by the cooperative dyad that utilizes the MURDER script. For an extensive examination of this script refer to Dansereau (1988). The processes that the dyad participates in are representative of a structured implementation of CL. A summarization of these activities is taken from the Hythecker et al. (1988) and Lambiotte, et al. (1987) papers.

The MURDER script allows a variety of cognitive, metacognitive, affective, and social skills to be shared in the cooperative setting (Hythecker et al., 1988). The method relates to the Rosenshine (1983) definition of direct instruction, which is comprised of presenting material in small steps, focusing on one aspect at a time, sequential organization for task mastery, skill modelling, presenting many examples, providing detailed explanations, and monitoring process.

Metacognition in group collaboration. The key in these methods is to find the activities/conditions which make CL effective for subsequent transfer. These activities may be classified as *metacognitive* characteristics common to individual learning. Note that Weber, Chen, & Weinstein (1989) differentiate metacognitive from cognitive strategies. They indicate that metacognitive strategies enable people to plan and assess their cognitive behavior, set performance standards, take remedial action, and determine their own rewards for effective cognitive behavior. In comparison, cognitive strategies (used conjunctively with metacognition) help people focus their attention on to-be-learned information, understand new material, reason, and remember. Paris (1988) metaphorically compares metacognitive strategies to executive managers, rule-of-thumb tactics, or general heuristics. They become problem solving aids when they become designated as metastrategies (Chi, 1981), metacomponents (Sternberg, 1979), metacognitive skills (Brown, Bransford, Ferrara, & Campione, 1983), and metamemory (Wegner, 1987). Note that Paris (1988) characterizes CL and reciprocal teaching (Palincsar & Brown, 1984) by use of a "town council meeting" metaphor in which reciprocity and equality provoke reflection, debate, and shared discovery.

Metacognitive learning strategies facilitated by CL are a conduit through which individual learning is connected with group processes. The group process facilitates the acquisition of certain strategies which the individual may use in successive learning contexts. A critical issue is whether metacognitive strategies generate access of knowledge for problem finding and problem solving. The next section addresses this issue in more depth. Mayer (1988) notes that learning strategy research desires to understand how to help learners improve their ability to learn, to think, and to remember. We would add to this, how to help learners improve their ability to perform and how to help performers improve their ability to learn. Zuboff (1988) exemplifies this approach in her quote:

> "Learning is not something that requires time out from being engaged in productive activity; learning is the heart of productive activity. To put it simply, learning is the new form of labor."

Another focus, the teaching of thinking and problem solving, has recently been the foundation for much research in metacognition (see Baron & Sternberg, 1987; Beyer, 1987; Bransford, Sherwood, Vye, & Rieser, 1986; Heiman & Slomianko, 1987; Perkins & Salomon, 1989; Vye, Delclos, Burns, & Bransford, 1988; Weinstein, Goetz, & Alexander, 1988). The usefulness of this area would be to see how collaboration facilitates the teaching of problem solving for the individual, and consequently, how the individual problem-solves to teach the group.

Group metacognitive actions given proper coordination may lead to process gain, given a group-to-individual transfer paradigm. One must assume that a general strategy of metacognition is transferred to the individual. It is particularly important to note that one study (Larson et al., 1985) examined the relative contributions of metacognitive and elaborative activities on cooperative performance. They found that metacognition facilitates initial acquisition of materials, but elaboration activities facilitate transfer. This is pertinent as it shows that <u>differential learning activities experienced within CL act to effect knowledge acquisition and access in variant ways.</u>

Brown, Campione, & Day (1981) interject that unless students become conscious of their own thinking, keep track of what they are doing when they engage in thinking, and assess the effectiveness of what they do, they cannot control their own thinking and become self-directed thinkers. Even more significant, if they fail to take conscious control of their thinking, the possibility of transfer of thinking skills from one setting to another diminishes. Given reciprocal teaching/CL or even GPS situations, this may become even more salient. GIT may not be a reality unless problems can be understood in terms of <u>metacognitive</u>, <u>cognitive</u>, and <u>specific knowledge access</u> activities. These activities form the deep structure underlying learning and performance. Unless they are activated initially within the group, the probability of collection induction is remote. Without collection induction, there is little hope that an individual will pick up strategies or knowledge which would be beneficial for transfer to subsequent problem solving involving similar types of problems.

In concluding this section, it brings up a question regarding the use of *specific knowledge* and cognitive processing in such transfer paradigms. Indeed, Dansereau (1988) mentions that some dyads appear to focus on content at the expense of the strategy, while other groups do the opposite. These studies show that CL groups can facilitate social learning of strategies, and this provides insight into understanding notions of process gain. But, there is still the remaining question as to whether learning groups can facilitate transfer of specific contextual knowledge to the individual members on subsequent tasks. For if one retains metacognitive strategies to apply to knowledge but fails to retain the knowledge itself, what has one gained? A broader issue is whether metacognitive strategies are separate from cognitive strategies, and whether they are independent from specific knowledge itself (see Perkins & Salomon, 1989 for a review of such issues). There also is the question of whether acquisition of specific knowledge can facilitate metacognitve strategies which can be transferred.

Spontaneous Access of Knowledge

In this section, we will begin to focus more upon individual problem solving/learning within the GIT paradigm. What remains is to understand how individuals (in group collaboration) come to experience a problem through acquisition of specific knowledge, which can subsequently be accessed to solve similar types of problems (see Bransford, Sherwood, Hasselbring, Kinzer, & Williams, in press). This view corresponds to everything we have suggested in GIT but places emphasis on an individual spontaneously accessing previously acquired knowledge. By spontaneous access we mean that the individual comes to access knowledge without being told or prompted to do so (i.e., uninformed access). This really gets to the heart of the issue as it rekindles our discussions about what counts for success in CL and GPS.

There is a difference between knowing something and spontaneously accessing what you know during performance. As we have indicated, a majority of the research studies in CL often measure what problem solvers know (i.e., their recall measures) but fail to assess the process and extent to which a person uses knowledge during the course of problem solving (i.e., spontaneous access). Within group collaboration, members may have salient knowledge to bear upon the activity at hand but if they fail to spontaneously access this knowledge it has no usefulness. Whitehead (1929) termed such a predicament "inert knowledge". It is knowledge accessed only under restricted contexts even though it is applicable to a variety of contexts.

For example, with military operations there is much reliance and collaboration among group and individual problem solving, intelligent computer sytems, and group support technologies. Together these elements are often referred to as cooperative systems. Yet, given our forthcoming definition, one would have to question whether these groups possess situational understanding. Although crew problem solving exists as a possibility, there are often *catastrophic lapses* which occur both individually and collectively. The recent *Vincennes* incident is an example of the failure to integrate individual with group problem solving within an ill-defined, stressful situation (see Klein, 1989). Other collaborative incidents such as *Three Mile Island* and the *Discovery* shuttle launch decision process also contained these catastrophic lapses.

Many of these crew coordination breakdowns have been glibly labelled or attributed to human error. They have been indicative of what experts term a lack of "situational awareness." Unfortunately these terms are often only descriptive and fail to address the real cause of the lapses encountered. The approach presented in this report defines catastrophic lapses as simply the inability to use or retrieve knowledge under stress, complexity, and uncertainty (i.e., knowledge remains inert). Hence, one facet of group collaboration which has not been properly addressed is the extent to which an individual or group of individuals can spontaneously access prior knowledge for their current problem solving focus.

If spontaneous access of knowledge is central to understanding GIT, then a prime hypothesis to ask is: "What are the conditions in group collaboration that lead to a group member's use of knowledge as an individual?" Or put another way, "How can collaboration prevent the formation of inert knowledge in its individual members?" To answer these questions we must look at some of the research which determines how individuals come to use knowledge in future endeavors. Bransford et al (in press) suggest that the use of knowledge is contingent upon the way it is acquired originally. A summary of the key points which are required for knowledge acquisition are as follows:

1.) problem oriented rather than fact-based acquisition
2.) conditioned knowledge
3.) perceptual learning and the noticing of features

Bransford and his colleagues suggest that when individuals learn to acquire knowledge as perceptual problems, rather than facts, they learn to notice patterns and encode knowledge that is useful. This position allows problem solvers to first experience what a problem is and then see how information provides a solution to the problem. When acquisitions get subgoaled together in a naturalistic context, the knowledge can be accessed for future use. The key idea here is that a problem orientation primes the processes of problem identification and definition. Too often, problem solvers just try to generate solutions/actions without knowing the problem/conditions that occur.

Problem-oriented acquisition. Put in the context of GIT then, this places strong emphasis upon how *the group facilitates knowledge* acquisition among its members. Perfetto, Bransford, & Franks (1983) and Adams, Kasserman, Yearwood, Perfetto, Bransford, & Franks (1988) show in their experiments that problem-oriented knowledge acquisition can lead to enhanced spontaneous access during later problem solving. The studies demonstrate that facts can be transformed into conceptual tools by acquiring information in a way that spawns the problem solving process (i.e., identifying and defining problems). Their studies term this type of acquisition as a "problem orientation". When students are given information in this form they can spontaneously access it for use in new problem solving settings; whereas fact acquisitions result in inert knowledge. Furthermore, their results are interpreted within a "transfer appropriate processing" framework that basically holds that latter problems share content and processes that are similar to the acquisition experiences.

Conditioned knowledge. The problem orientation studies relate nicely to work by Simon (1980), wherein, he states that the knowledge representation that underlies competent performance is based upon productions. Production-based representations are condition-action pairs that let a human associate a pattern/context with a specific action to be taken. Such pairs are mediated by a human's goal hierarchy structure. Simon (1980) points out that much of the difficulty in learning and instruction is brought about because of the lack of conditioned knowledge that students receive. Thus we see that some of the products of problem finding would enhance understanding of patterns (pattern recognition) which precede actions. Hence, by experiencing the problem, students could then know how to use new information to form a solution. One of the keys that precipitates conditioning knowledge is the role of noticing features.

Noticing of perceptual features. Bransford, Sherwood, Vye, & Rieser (1986) point to the role of perceptual learning and the development of contrasting features as underlying acquisition of the problem orientation. Garner (1974) suggests that an expert has internal contexts that enable noticing features that novices can miss. Bransford et al (1986) believe that perceptual learning occurs via experiences with a set of contrasts so that features of particular events become salient by virtue of their differentiation from other possible events. The specific knowledge which one comes to perceptually differentiate in a naturalistic context (i.e., a semantically rich context which affords problem solving and discovery) can be useful for transfer to new situations and can induce natural metacognitive functions.

Bransford, Franks, Vye, & Sherwood (1986) claim, "Wisdom arises from the opportunity to experience changes in our own beliefs and assumptions- changes that help us realize that the ideas and priorities which seem so clear today will probably be modified as a function of new experiences. " Hence, "wisdom cannot simply be told" but must be perceptually learned. This is a very pertinent insight. Knowledge acquisition within strictly verbal contexts may only provide the output of another expert's pattern recognition process, which may have a low probability to induce conditioned knowledge. Whereas, perceptual learning allows a person to experience changes in his/her own perception (i.e., develop their own pattern recognition ability), which does induce conditioned knowledge. In these contexts, the student is encouraged to actively define their own problems. This "generation effect" is a natural activity that is a general stage of Bransford & Stein's (1984) model (i.e., the *identification and defining problem* stage).

By reviewing these key precipitators of individual knowledge acquisition-access, the stage has been set for establishing a framework for generating the conditions within a collaborative setting which would facilitate spontaneous access of knowledge. Consequently, the projected role of specific knowledge in GIT has been elaborated. The doors have been opened to approach CL as a cognitive system which exchanges metacognitive strategies and specific knowledge (in collaborative settings) in certain ways which come to impact individual learning.

DISCUSSION

The remainder of this paper discusses a cooperative systems perspective as a new approach for CL. Finally, a research paradigm to begin the systematic study of cooperative systems will be developed. The discussion section is provided as a response to the problems and issues identified within CL and GPS in the preceding sections.

A Cooperative Systems Alternative

A COoperative SYStems (hereafter, COSYS) approach is one which places emphasis on how the group uses different metacognitive strategies and specific knowledge in problem solving and learning. The meaning of cooperative systems is predicated upon two major concepts: *situational understanding* and *group replication.* Together, these concepts define cooperative problem solving systems in a new way that makes their ecological boundaries different from traditional views of GPS and CL.

Situational understanding. This concept implies settings in which the group is aware of it's own resources to adapt to changes in task, knowledge, context, and technology. Inherently, situational understanding incorporates situation assessment and information assimilation (Wellens & Ergener, 1988), and problem finding (Bransford & Stein, 1984; Brown & Walter, 1983; Perkins, 1986; Sternberg & Caruso, 1985). Today, one would find this concept within medical diagnosis, battlefield management, and corporate status assessment, as well as many other areas wherein members must notice and understand the patterns inherent in the situation they are attending to. Ben-Bassat & Freedy (1982) identify situational assessment tasks as a general family of problem solving tasks characterized as a multiperspective, multimembership hierarchical pattern recognition. Situation understanding implies that the adaptation and experience associated with problem finding (as utilized in the collaborative setting) acts to generate gain beyond which the best members could provide by themselves.

A COSYS alternative is in line with Hill's (1982) suggestion that process gain may be demonstrated via member capacity to learn and through cognitive stimulation. In each case, specific knowledge becomes the fuel to feed the fire. Maier & Solem (1962) explain that if groups were "problem-minded" rather than "solution-minded", group product might be improved. Hill (1982) outlines that problem-minded means: the group questions its current approach to the problem, considers other aspects of the problem, the group analyzes problem facets as subtasks, members separate and recombine problem-solving strategies, and groups may consider two different solutions. Likewise, Pea (1982) emphasizes the need for planning in advance of problem solving, and evaluating and checking progress in terms of goals to be ingredients of a reflective attitude about one's own mental activities. Necessarily these ideas involve cognitive and metacognitive strategies, in conjunction with specific knowledge. Brown, Collins, & Duguid (1989) propose that conceptual understanding develops through collaborative social interaction in the culture of a domain. They believe that the group offers the capacity to: 1.) produce insights and solutions that individuals could not obtain on their own, 2.) display multiple roles needed for carrying out any cognitive task, 3.) draw out, confront, and discuss ineffective strategies and misconceptions, and 4.) provide collaborative work skills. Capacity for a member's contribution to the group may very well rest on the developmental reciprocation of group and individual knowledge.

As alluded to in the previous section, an individual's understanding of a task or problem will be contingent upon: 1.) the prior knowledge which they can access or be cued to access by the group, and 2.) additional knowledge supplied to the individual by the ecology of the group. Additional knowledge may be picked up from other group members, by performing a certain role in a task, by observing/interacting with others in other roles, by external presentation of additional material (e.g., text, visual, or audio media), or by the differentiation of the domain itself. A key to determine whether additional knowledge is merely attended to or whether it is picked up, integrated to prior knowledge, and available for future access is the extent to which it is anchored as a "problem".

One way to generate situation understanding within cooperative systems is through the use of *anchoring*. Anchoring has been primarily invoked in individual learning but its application in group collaboration has not been formally suggested, nor researched. Bransford, Sherwood, Hasselbring, Kinser, & Willliams (in press) introduce anchored instruction as a way to help students think for themselves and transfer knowledge content to new problem situations. The anchor allows a student to pursue problem finding, exploration, and discovery. It is a "focus" which generates interest and enables students to identify and define problems and to pay attention to their own perception and comprehension of these problems. The goal of the anchor is to allow the student to experience changes in their own perception and understanding as they view a situation from new perspectives.

Dewey (1933) and Hanson (1970) note that experts in a discipline commonly experience changes in perceiving and understanding. In contrast, novices are often unable to experience how new information can change their thinking. Vye, Bransford, & Franks (1988) found that an anchor can serve to integrate compartmentalized information around rich themes. When perspectives are related to a common ground, students were more likely to spontaneously use this knowledge to flexibly think about subsequent problems. These results reinforce the view that the anchor is designed to develop useful knowledge rather than inert knowledge. Perceptual learning, spontaneous knowledge access, and problem oriented acquisition are all brought about with the use of anchored instruction. The role of anchors may be extended to cooperative system settings to facilitate problem identification, definition, and solution.

Anchors often begin by presenting a focal event or problem situation in which there is a general goal with associated subgoals and subproblems. The anchor should help a problem solver notice features of the event which make particular actions relevant (i.e., the anchor should help produce conditioned knowledge). Because the noticing of features is an important role of the anchor, Bransford and his colleagues emphasize the use of video-based anchors which afford a rich macro-context beyond which the printed media provides. Video-based anchors present dynamic moving scenes which can easily be contrasted to trigger pattern recognition skills.

Simon's (1980) concept of *conditioned knowledge* (i.e., to acquire knowledge as condition-action pairs rather than isolated facts) is very strategic for generating situational understanding in collaboration. In response to Winograd & Hare's (1988) proclamation that students are not taught when and where to use strategies; Paris, Lipson, & Wixson (1983) also export the idea of conditionalized knowledge into the learning strategy arena. They propose that knowing why, where, and when to apply strategies is a prerequisite for the selective use and transfer of knowledge. Thus, we see that in this case specific knowledge, cognitive, and metacognitive strategies are integrated for maximum gain within an instructional context. Pressley, Borkowski, & O' Sullivan (1984) reinforce these views by noting that specific strategy knowledge includes knowledge about: 1.) appropriate goals and objectives, 2.) appropriate tasks, 3.) range of applicability, 4.) expected performance gains, 5.) effort required, and 6.) enjoyment value.

Often group collaboration may exist but without the presence of anchors. Groups of individuals may coexist in space and time, yet may not cooperate and share knowledge in a way that is meaningful. These are *unanchored groups* as they have failed to integrate members' perspectives through a common ground. Unanchored groups tend to fragment and lose control of the group process. We suggest that groups are: 1.) in the process of acting on an anchor provided, 2.) searching for an anchor to provide a common ground of understanding, or 3.) in a state of debilitating conflict. Rather than limiting our discussion to these discrete states of groups, it may be appropriate to speak of anchoring in terms of a continuum. Necessarily, this requires an evaluation of the characteristics of anchors. Anchors must be evaluated by the extent to which they allow a person to generate problem finding and problem experience. Bransford & Stein (1984) suggest that an anchor should be an "advance disorganizer" that stimulates questions and puzzlement rather than an "advance organizer."

The position taken by Bransford and others places power in the ability to differentiate perceptual features by successive activities of contrast/comparison. Wisdom may be told but unless it develops in conjunction with perceptual differentiation, it may remain inert and never be applied to future endeavors.

This principle is so very relevant for group process as it exposes the notion that the individual must be totally integrated into the group's ecology in order to receive - and in turn- distribute intelligence and understanding. We have talked about spontaneous access of knowledge for an individual based on various conditions in the collaborative acquisition setting. Now, however, we are also emphasizing that once an individual is primed to use knowledge, that knowledge can fold back into the collaborative group process, given the chance. Laughlin (1989) suggests that groups externalize the internal cognitive processes of individuals. When this occurs for various members of the group, group and individual process become very symbiotic. This is the stuff collective induction and group-to-individual transfer are made of.

Group replication. Group replication (i.e. defining the members and support systems of a group) is a new way of visualizing what a particular group consists of. Traditionally, groups have involved the cooperation of human problem solvers and their support systems. Now, however, society is entering an age that includes the advent of intelligent systems. Thus, cooperative systems are a collaboration between human and artificial intelligence, within a cooperative interaction setting. In particular, artificial intelligence technology has allowed designers to implement individual expert systems which emulate experts in particular domains (see Buchannon & Shortliffe, 1984). Other efforts have used principles in behavioral decision theory and other decision heuristics to create adaptive decision aids for users (Morris & Rouse, 1986). These intelligent entities foster new levels of group collaboration and problem finding; and lead to unforeseen combinations of decision control and task allocation (see Fraser, Hipel, Kilgore, McNeese, & Snyder, in press; Snyder & McNeese, 1987). Thus, a new ecology must entertain the concept that collaboration will consist of interactions among human problem solvers, artificial intelligence systems, and other support systems. This might be termed the "distributed intelligence" of cooperative systems.

Examples of Successful COSYS Research-Development

Traditional group studies typically are not dependent on advanced technology and often do not attend to situation understanding. However, we are experiencing active changes in the way groups can experience problems. Note that most of these changes are taking place in natural settings but they still lag behind in experimental research evaluation.

Currently, several cooperative system research and design projects are underway. These projects either fall under the heading of *computer supported cooperative work* or *group decision-support systems.* They are often found in business and corporate cultures (see Gray, 1986; Kraemer & King, 1986 for reviews). They partially fulfill our definition of a cooperative system as they demonstrate group replication. However, we want to emphasize that often they do not conform to the "situation understanding" component of our cooperative systems definition.

In this sense, most of these new systems fail to take into consideration the *distributive intelligence* (i.e., the intelligence derived from the holistic, synergistic interaction of knowledge and understanding among agents; whereby the "group mind" is greater than that of any single member) inherit in group collaboration. We agree with Chandrasekaran, Goel, & Allemang (1988); the power of this kind of intelligence derives from the cooperation between different mechanisms and representations at different levels of description. In spite of these new systems' lack of distributive intelligence, they are contemporary embodiments of GPS and do represent current state of the art techniques.

When process loss is solely a function of time and effort spent in group coordination/communication, it is very plausible that the use of communication, computer, and other group technologies would be advantageous for learning and performance activities. However, other factors which contribute to process loss may not be offset by group decision-support systems. The question whether these systems actually help GIT is currently an empirical one. Although many of these systems claim to produce significant success in GPS, the research base to substantiate this conjecture is small (Kraemer & King, 1986).

One exception to this is the Wellens & Ergener (1988) computer-based situation assessment task (termed CITIES) for studying distributed decision making. This simulation has recently been developed for the purpose of empirical study of interactive teams (which include expert systems) performing situation assessment activities.

Although it still is too early to obtain useful results from CITIES, this research is indicative of the kind which must evaluate distributive intelligence. Most of the research studies involving computer usage in CL revolve around several students cooperatively sharing a computer (e.g. Johnson, Johnson & Stanne, 1986; Sheingold, 1987; Trowbridge, 1987) and as such fail to evaluate new groupware techniques in education. Certainly, the use of group decision-support systems could be imported to create new ways to anchor problems in CL.

Most of the new group decision-support systems are variants of what could be called "electronic meetings" (see Johansen, Vallee, and Spangler, 1979 for an initial review). The electronic meetings concept focuses on the implementation of audio/video teleconferencing systems or electronic mail systems, whereupon group members may interact remotely by having their audio/video signatures transmitted electronically in real or delayed time. More exotic technologies provide ideas of groups interacting in "virtual worlds" (see Furness & Kocian, 1986) that allow members to interact with computers through human touch voice, and gesture (Bolt, 1984). Hence, groups can coordinate/communicate activities without being physically present with one another.

The next generation of change for group decision-support systems was brought about by "groupware" or *computer-supported cooperative work* which provides computer support for group collaboration (see Johansen, 1988). Additionally the use of hypermedia software in the group setting allows group collaboration to proceed on new levels of awareness. Some state of the art examples of computer-based group aiding are group authoring software, COLAB (a team network designed at Xerox PARC which integrates individual workstations with a shared large screen display, see Stefik, Foster, Bobrow, Kahn, Lanning, & Suchman, 1987), group PC screen sharing, text filtering (see the *information lens* as presented in Malone, Grant, Turbak, Brobst, & Cohen, 1987, which allows a team to reach out and find information that matches rules created by its individual members), conversational structuring software, group memory management (hypertext linkages between team member interactions), and the electronic hallway (which allows interactive drop-in capability upon various electronic media formats, see Goodman & Abel, 1987). These group technologies have been taken from the

Johansen (1988) review wherein he provides a significant amount of pitfalls associated with each one. For additional review of groupware initiatives see the *Proceedings of the Conference on Computer-Supported Cooperative Work* (1986, 1988).

In particular, we are interested in the use of artificial intelligence technologies as they allow new forms of group replication (see Shaw, 1988; Winograd & Flores, 1986). The Wellens & Ergener (1988) group simulation research includes effects of electronic team members. Snyder, Wellens, Brown, & McNeese (1989) present three paradigms for studying multi-person interaction which include consideration for intelligent system components. The concepts presented in McNeese (1986) and Snyder & McNeese (1987) also allude to a "humane intelligence" comprising human and computer interaction. Their work focuses on the potential cognitive conflicts which may arise in cooperative systems. Pea (1987) also provides an integration of human and computer intelligence which is directed towards learning and an educational development emphasis. His work reveals the role that intelligent tutoring systems (see Sleeman & Brown, 1982 for review) and different developmental levels play in this symbiosis. The books by Polson & Richardson (1988) and Psotka, Massey, & Mutter (1988) provide current theoretical and practical information on intelligent tutoring systems.

The Participant Construct System, PCS, (Shaw, 1988) is an extremely useful example of group aiding as it supplies GPS with an interactive knowledge-base and makes an attempt to address cognitive and distributive intelligence. This system has merged work in personal construct theory and participant systems (see Chang, 1986) that enables a number of individuals to interact through networked personal computers (i.e., the *Apple Macintosh*) to develop mutual understanding of a problem domain.

Another more theoretical example of a current view of distributed intelligence is provided by Wegner (1987) in his elaboration on transactive memory systems. His theory generates useful ways of understanding how people think together. Transactive memory describes a social network of individual minds that transcends notions of uniform agreement. Memory here is defined as a *group property* that connects disparate minds. Wegner believes: "transactive memory incorporates a system of interconnections that exists in individuals' communications of information, and hence, places direct emphasis on the social organization of diversity rather than on the social destruction of diversity." Expanding this idea further, Wegner proposes that individuals become external storage reservoirs for other people. Through communication the memories transactively become enlivened. The interdependent knowledge storage that results is larger and more complex than an individuals own memory system. Through the use of external memory components (i.e., optical videodisc technology, computers, hypermedia, and artificial intelligence); a transactive memory can be facilitated in ways that act to enhance individual knowledge and power.

This theory breaks distributed intelligence down into interdependent and transactive systems of distributing and refining memory. Distributed intelligence is manifest as a process wherein knowledge is encoded, retrieved, and picked up both internally in individuals and externally from other group members and technological storage and support. Transactive memory is very relevant for GIT as Wegner (1987) suggests that it derives from individuals to form a group information-processing system that eventually may return to have profound influence upon its individual participants. The core principle of this system is that *expertise* may be afforded us by every person we interact with in the group. For additional review of transactive memory as applied to organizational management and instruction please refer to Wegner's (1987) intriguing paper.

A Research Agenda for Cooperative Systems

Within this review we have proposed: 1.) what counts for success in group collaboration, 2.) understanding the conditions for successful CL/GPS, and 3.) understanding the degree of transfer from the group to the individual setting. In conclusion, we have seen that there are many possible reasons (based on both surface and deep structures) that account for success/failure. There are many differences in task structure, reward structure, group definition and other details between CL and GPS. Given that there are multiple differences between these two areas on a variety of levels, there is one similarity in approach that tends to occur. It is the relative absence of analyzing group collaboration in terms of cognitive, metacognitive, and specific knowledge transfer from the group to the individual. A cooperative systems viewpoint suggests that groups can be analyzed by the extent to which individual members realize a change in their perception by experiencing a problem. In spite of all the differences between CL and GPS, we propose that looking at the group as a cooperative system (to determine the extent to which a problem is anchored) could lead to both practical and theoretical reconciliation. By using this approach, a more systematic trend of research can ensue wherein learning, performance, knowledge, and group process are properly defined and integrated from the beginning.

A research agenda would begin by having groups of individuals and individuals learn and perform in different acquisition task types which would vary the social combination process required, the cognitive complexity, and whether the task required generative-planning, problem solution, or decision-making activities. For each task type, each condition would have a certain degree of anchoring (i.e., they would vary to the extent which perceptual features could be noticed). Subsequent transfer tasks would involve conditions including individuals and groups in order to assess extent of transfer. These transfer tasks would also vary in the extent to which they were anchored. This would compose the basic research paradigm to test the use of anchors in collaborative learning and process. The paradigm could be extended to also include various group replications such as the use of intelligent systems as a learning or performance aid in certain individual and group conditions. By involving technology and group enactment variables, a research paradigm would be established to assess the distribution of knowledge and intelligence across individuals, groups, and technologies; under variant naturalistic situations.

This paradigm would begin by testing college freshmen as a baseline but could be generalized to other "groups" as required. For example, an experimenter might want to test the effects of anchors upon teaching a group collaborative of human factors practitioners to teach human factor principles in systems design (e.g. perceptual organization in visual display). In this case, the basic paradigm would change the group definition from college freshmen to human factors personnel (e.g. a human factors engineer). Another independent variable which might be useful to test would be whether the practitioners were novices or experts. Hence, one group would be further defined as recent graduates of a human factors program and the other group would consist of human factors engineers with more than 5 years of experience. The paradigm would still assess cooperative and individual performance and still utilize the appropriate control groups for transfer. Yet, the type of tasks could be transformed to more closely relate to a human factors domain but still incorporate the basic differences between generative and decision-making behavior.

This research paradigm objective is to understand the use of knowledge in group process so the dependent variables must reflect this. Ideally, this would involve assessment of learning, performance, and thinking levels as appropriate for the task types. It is at this point that our original concern for what counts as success must again be addressed. In order to preclude certain considerations of success, scores from recall tests or performance levels should be observed in a variety of ways. In many instances this can be driven by the domain or by conventional wisdom. Cooperative systems may benefit greatly by also analyzing group process in terms of protocol analyses. These analyses may contribute to understanding how thinking develops over the course of interaction and may detect differences between groups and individuals that would otherwise not be detected in recall or performance scores per se. Also, the use of qualitative research (e.g. socio-linguistic analyses) may be used to the same advantage. The work of Edwards & Middleton (1986) in conversational joint remembering is an example of how a group's account of shared experience can be analyzed through conversational discourse. The idea here is to assess subjects through a broad rather than limited means and to obtain dependent measures in accordance with the naturalistic conditions of study.

With this research paradigm, one would be able to track all the changes in groups in terms of their transfer of knowledge and understand how intelligence is distributed as a function of a number of variables. It is this systematic tracking which would allow generalization in the future, which is currently a risky business, given the state of affairs in CL and GPS.

The purpose of this paper has been to primarily explore issues and problems within CL. Although these problems are difficult, complex, and in some cases unsolvable, the time is ripe to begin a research agenda for investigating groups as cooperative systems. To obtain a deeper understanding of the distributive intelligence in cooperative systems, a major research effort is needed. It is our hope that the problems, issues, models, and approaches elaborated within this review will be a springboard upon which an effort can begin.

REFERENCES

Adams, L., Kasserman, J., Yearwood, A., Perfetto, G., Bransford, J. & Franks, J. (1988). The effects of facts versus problem-oriented acquisition. *Memory and Cognition, 16* (2), 167-175.

Allen, V. (1976). *Children as teachers: Theory and research on tutoring.* New York: Academic.

Amaria, R. P., Biran, L. A., & Leith G. O. M. (1969). Individual versus cooperative learning. *Educational Research, 11*, 95-103.

Annis, L. (1983). The processes and effects of peer tutoring. *Human Learning*, 2, 39-47.

Aronson, E. (1978). *The Jigsaw Classroom.* Beverly Hills, CA: Sage.

Bargh, J. A., & Shul, Y. (1980). On the cognitive benefits of teaching. *Journal of Educational Psychology, 72*, 593-604.

Barnes, D., & Todd, F. (1977). *Communication and learning in small groups.* London: Routledge & Kegan Paul.

Baron, J. B., & Sternberg, R. J. (1987). *Teaching thinking skills: Theory and practice.* New York: W. H. Freeman.

Beane, W. E., & Lemke, E. A. (1971). Group variables influencing the transfer of conceptual behavior. *Journal of Educational Psychology, 62*, 215-218.

Ben-Bassat, M. & Freedy, A. (1982). Knowledge requirements and management in expert decision support systems for (military) situation assessment. *IEEE Transactions on Systems, Man, and Cybernetics,12*, 479-490.

Bender, T. A. (1985). Paired versus individual learning in testing hypotheses. *Journal of General Psychology, 112* (1), 59-64.

Bereiter, C., & Bird, M. (1985). Use of thinking aloud in identification and teaching of reading comprehension strategies. *Cognition and Instruction*, 2, 131-156.

Berry, D. C., & Broadbent, D. E. (1984). On the relationship between task performance and associated verbalizable knowledge. *Quarterly Journal of Experimental Psychology, 36* (2), 209-233.

Beyer, B. K. (1987). *Practical strategies for the teaching of thinking.* Boston, MA: Allyn And Bacon.

Bloom, B. (1956). *Taxonomy of educational objectives.* New York: David McKay.

Bolt, R. A. (1984). *The human interface: Where people and computers meet.* Belmont, CA: Lifetime Learning.

Bossert, S. T., Barnett, B. G., & Filby, N. N. (1984). Grouping and instructional organization. In P. L. Peterson, L. C. Wilkinson, & M. Hallinan (Eds.), *The social context of instruction: Group organization and group processes.* Orlando, FL: Academic Press.

Bouton C. & Garth, R. Y. (1983). *Learning in groups.* San Francisco, CA: Jossey-Bass.

Bransford, J. D., Franks, J. J., Vye, N. J., & Sherwood, R. D. (1986). New approaches to instruction: Because wisdom can't be told. Paper presented at a Conference on Similarity and Analogy, University of Illinois.

Bransford, J. D., Sherwood, R. D., Hasselbring, T. S., Kinzer, C. K. & Williams, S. M. (in press). Anchored instruction: Why we need it and how technology can help. To appear in a volume editied by D. Nix & R. Spiro. Hillsdale, N.J.

Bransford, J. D., Sherwood, R. D., Vye, N. J., & Rieser, J. (1986). Teaching thinking and problem solving. *American Psychologist* , 41 (10), 1078-1089.

Bransford, J. D., & Stein, B. S. (1984). *The IDEAL problem solver.* New York: W. H. Freeman.

Brown, A. L., Bransford, J. D., Ferrara, R. A.,& Campione, J. C. (1983). Learning, remembering, and understanding. In J. H. Flavell and E. M. Markman (Eds.), *Cognitive development* (Vol III). *Handbook of child psychology.* New York: Wiley.

Brown, A. L., Campione, J. C. & Day, J. D. (1981). Learning to learn: On training students to learn from texts. *Educational Researcher, 10,* 14-21.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher, 18* (1), 32-42.

Brown, S. I., & Walter, M.I. (1983). *The art of problem posing.* Hillsdale, NJ: Erlbaum.

Buchannon, B. G., & Shortliffe, E. H. (1984). *Rule-based expert systems.* Reading, MA: Addison-Wesley.

Chandrasekaran, B., Goel, A., & Allemang, D. (1988). Processing abstractions: The message still counts more than the medium. *AI Magazine*, Winter, 25-34.

Chang, E. (1986). Participant systems: Group human-computer interaction. In *Proceedings of the International Conference of IEEE Systems, Man and Cybernetics*, Atlanta, GA.

Chi, M. T. H. (1981). Knowledge development and memory performance. In M. Friedman, J. P. Das, & N. O'Connor (Eds.), *Intelligence and learning*. New York: Plenum.

Collins, A., Gentner, D., & Rubin, A. (1981). *Teaching study strategies.* (Rep. No. 4794). Cambridge, MA: Bolt Beranek and Newman Laboratories.

Damon, W. (1984). Peer education: The untapped potential. *Journal of Applied Development Psychology*, *8*, 331-343.

Dansereau, D. F. (1988). Cooperative learning strategies. In C. L. Weinstein, E. T. Goetz, & P. A. Alexander (Eds.) *Learning and study strategies: issues in assessment, instruction, and evaluation.* San Diego, CA: Academic Press.

Dansereau, D. F., McDonald, B. A., Collins, K. W., Garland, J. C., Holley, C. D., Diekhoff, G. M. & Evans, S. H. (1979). Evaluation of a learning strategy system. In H. F. O'Neil, Jr. & C. D. Spielberger (Eds.) *Cognitive and affective learning strategies.* New York: Academic Press.

Day, J. D. (1980). *Training summarization skills: A comparison of teaching methods.* Unpublished doctoral dissertation. University of Illinois, Champaign, IL.

Deutsch, M. (1949). An experimental study of the effects of cooperation and competition upon group process. *Human Relations*, *2*, 199-231.

Deutsch, M. (1962). Cooperation and trust: Some theoretical notes. In M. R. Jones (Ed.), *Nebraska symposium on motivation.* Lincoln: University of Nebraska Press.

Deutsch, M. (1985). *Distributive Justice*: A social psychological perspective. New Haven CT: Yale University Press.

Deutsch, M. (1987). Experimental studies of the effects of different systems of distributive justice. In J. C. Masters, & W. P. Smith (Eds.), *Social comparison, social justice, and relative deprivation: Theoretical, empirical, and policy perspectives.* Hillsdale, NJ: Erlbaum.

Dewey, J. (1933). *How we think.* (Revised Edition). Boston: D. C. Heath.

Dyer, J. L. (1984). Team research and team training: A state-of-the-art review, Chapter 8 in F. Muckler (Ed.), *Human factors review.* Santa Monica, CA: The Human Factors Society.

Edwards, D., & Middleton, D. (1986). Joint remembering: constructing an account of shared experience through conversational discourse. *Discourse Processes*, *9*, 423-459.

Fletcher, B. C. (1985). Group and individual learning of junior school children on a microcomputer-based task: social or cognitive facilitation. *Educational Review, 37* (3), 251-261.

Fletcher, B. C., & Perman, L. M. V. (1982). Knowing and doing: The relationship between verbal knowledge and systems-control ability. *Bulletin of British Psychological Society, 35*, A8.

Foreman, E. A. (1981) *The role of collaboration in problem solving in children.* Unpublished doctoral dissertation. Harvard University.

Fraser, N. M., Hipel, K. W., Kilgour, D. M., McNeese, M. D., & Snyder, D. E. (in press). An architecture for integrating expert systems. *Decision Support Systems.*

Furness, T., & Kocian, D. (1986). Putting humans into virtual space. *Proceedings, Society for Computer Simulation Aerospace Conference.* San Diego, CA.

Gabbert, B., Johnson, D. W., & Johnson, R. T. (1986). Group-to-individual transfer, process gain, and the acquisition of cognitive reasoning strategies in cooperative learning groups. *Journal of Psychology, 120* (3), 265-278.

Garner, W. R. (1974). *The processing and structure of information.* Hillsdale, NJ: Erlbaum.

Good, T. L., & Marshall, S. (1984). Do students learn more in heterogeneous or homogeneous groups? In In P. L. Peterson, L. C. Wilkinson, & M. Hallinan (Eds.), *The social context of instruction: Group organization and group processes.* Orlando, FL: Academic Press.

Goodlad, J. I. (1984). *A place called school.* New York: McGraw-Hill Book Co.

Goodman, G. O., & Abel, M. J. (1987). Communication and collaboration: Facilitating cooperative work through communications. *Office Technology and People, 3* (2), 129-146.

Gray, P. (1986). Group decision support systems. In E. R. McLean and H. G. Sol (Eds.), *Decision support systems: A decade in perspective.* Amsterdam: Elsevier.

Graybeal, S. S., & Stodolsky, S. S. (1985). Peer work groups in elementary schools. *American Journal of Education, 93*, 409-427.

Hackman, J. B. & Morris, C. G.(1975). Group tasks, group collaboration process, and group performance effectiveness: A review and proposed integration. In L. Berkowitz (Ed.), *Advances in experimental social psychology* (Vol. 8). New York: Academic Press.

Hansen, N. R. (1970). A picture theory of theory meaning. In R. G. Colodny (Ed.), *The nature and function of scientific theories.* Pittsburgh, PA: University of Pittsburgh Press.

Heiman, M. & Slomianko, J. (1987). *Thinking skills instruction: Concepts and techniques.* Washington, DC: National Education Association.

Hertz-Lazarowitz, R. (1985). Internal dynamics of cooperative learning. In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C. Webb, & R. Schmuck (Eds.), *Learning to cooperate, cooperating to learn.* New York: Plenum.

Hill, G. W. (1982). Group versus individual performance: Are N+1 heads better than one? *Psychological Bulletin, 91* , 517-539.

Hythecker, V. I., Dansereau, D. F. & Rocklin, T. R. (1988). An analysis of the processes influencing the structured dyadic learning environment. *Educational Psychologist*, 23 (1), 23-37.

Johansen, R., Vallee, J., & Spangler, K. (1979). *Electronic meetings: technical alternatives and social choices.* Menlo Park, CA: Addison-Wesley. Johansen, R. (1988). *Groupware: computer support for business teams.* New York The Free Press.

Johnson, D. W., & Johnson, R. T.(1975). *Learning together and alone: Cooperation, competition, and individualization.* Englewood Cliffs, NJ: Prentice-Hall.

Johnson, D. W. & Johnson, R. T. (1985a). The internal dynamics of cooperative learning groups. In In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C. Webb, & R. Schmuck (Eds.), *Learning to cooperate, cooperating to learn.* New York: Plenum.

Johnson, D. W., & Johnson, R. T. (1985b). Nutrition education: A model for effectiveness, a synthesis of research. *Journal of Nutrition Education, 17* (2), June supplement

Johnson, D. W., Johnson, R. T., Johnson, J. & Anderson, D. (1976). The effects of cooperative versus individualized instructions on student prosocial behavior, attitudes toward learning and achievement. *Journal of Educational Psychology, 104*, 446-452.

Johnson, D. W., Johnson, R. T. & Maruyama, G. (1983). Interdependence and interpersonal attraction among heterogeneous and homogeneous individuals: a theoretical formulation and a meta-analysis of the research. *Review of Educational Research, 53*, 5-54.

Johnson, D. W., Johnson, R. T., Roy, P., & Zaidman, B. (1985). Oral interaction in cooperative learning groups: Speaking, listening, and the nature of statements made by high-, medium-, and low-achieving students. *Journal of Psychology, 119*, 303-321.

Johnson, D. W., Johnson, R. T. & Scott, L. (1978). The effects of cooperative and individualized instruction on student attitudes and achievement. *Journal of Social Psychology, 104*, 207-216.

Johnson, D. W., Maruyama, G., Johnson, R. T., Nelson,D., & Skon, L. (1981). The effects of cooperative, competitive, and individualistic goal structures on achievement: A meta-analysis. *Psychological Bulletin, 89*, 47-62.

Johnson, R. T., Brooker, C., Stutzman, J., Hultman, D., & Johnson, D. W. (1985). The effects of controversy, concurrence seeking, and individualistic learning on achievement and attitude change. *Journal of Research in Science Teaching*, 22, 207-220.

Johnson, R. T., Johnson, D. W. & Stanne, M. B. (1986). Comparison of computer-assisted cooperative, competitive, and individualistic learning. *American Educational Research Journal, 23* (3), 382-392.

Kagan, S. (1985). Dimensions of cooperative classroom studies. In In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C. Webb, & R. Schmuck (Eds.), *Learning to cooperate, cooperating to learn.* New York: Plenum.

Kelly, H. H. & Thibaut, R. (1969). Group problem solving. In G. Lindsey and E. Aronson (Eds.), *Handbook of social psychology* (2nd ed.). Reading, MA: Addison-Wesley.

Klein, G. (1989). Do decision biases explain too much? *Human Factors Bulletin*, 32 (5), 1-3.

Klausmeier, H. J., Wiersma, W.,& Harris, C. W. (1963). Efficiency of initial learning and transfer by individuals, pairs, and quads. *Journal of Educational Psychology, 54*, 160-164.

Kraemer, K. L., & King, J. L. (1986). Computer-based systems for cooperative work and group decision making: Status of use and problems in development. *Proceedings of the Conference on Computer-supported Cooperative Work.* New York: ACM.

Lambiotte, J. G., Dansereau, D. F., Rocklin, T. R., Fletcher, B., Hythecker, V. I. Larson, C. O. & O'Donnell, A. M. (1987). Cooperative learning and test taking: Transfer of skills. *Contemporary Educational Psychology, 12*, 52-61.

Lanzetta, J. T., & Roby, T. B. (1957). Group learning and communication as a function of task and structure demands. *Journal of Abnormal and Social Psychology, 55*, 121-131.

Larson, C. O., Dansereau, D. F., O'Donnell, A. M., Hythecker, V. I., Lambiotte, J. G., & Rocklin, T. R. (1985). Verbal ability and cooperative learning: Transfer of effects. *Journal of Reading Behavior, 16*, 289-295.

Latane, B., Williams, K., Harkins, S. (1979). Many hands make light the work: The causes and consequences of social loafing. *Journal of Personality and Social Psychology, 37*, 822-832.

Laughlin, P. R. (1989). *A theory of collective induction: Final report.* Office of Naval Research, Arlington, VA.

Laughlin, P. R., & Barth, J. M. (1981). Group-to-individual and individual-to-group problem solving transfer. *Journal of Personality and Social Psychology, 41* (6), 1087-1093.

Laughlin, P. R., & Ellis, A. L. (1986). Demonstrability and social combination processes on mathematical intellective tasks. *Journal of Experimental Social Psychology, 22*, 177-189.

Laughlin, P. R., & McGlynn, R. P. (1986). Collective induction: Mutual group and individual influence by exchange of hypotheses and evidence. *Journal of experimental social psychology, 22*, 567-589.

Laughlin, P. R., & Sweeney, J. D. (1977). Individual-to-group and group-to-individual transfer in problem solving. *Journal of Experimental Psychology: Human Learning and Memory, 3*, 246-254.

Lemke, E., Randle, K., & Robertshaw, S. (1969). Effects of degree of initial acquisition, group size, and general mental ability on concept learning and transfer. *Journal of Educational Psychology, 60*, 75-78.

Lewin, K. (1935). *A dynamic theory of personality.* New York: McGraw-Hill.

Maier, N. R. F., & Solem, A. R. (1962). Improving solutions by turning choice situations into problems. *Personnel Psychology, 15*, 151-157.

Malone, T. W., Grant, K. R., Turbak, F. A., Brobst, S. A., & Cohen, M. D. (1987). Intelligent information sharing systems. *Communications of the ACM, 30* (5), 390-402.

Mayer, R .E. (1988). Learning strategies: An overview. In C. L. Weinstein, E. T. Goetz, & P. A. Alexander (Eds.) *Learning and study strategies: issues in assessment, instruction, and evaluation.* San Diego, CA: Academic Press, Inc.

McClintock, E., & Sonquist, J. A. (1976). Cooperative-task oriented groups in a college classroom: A field application. *Journal of Educational Psychology, 60*, 75-78.

McDonald, B. A., Larson,C. O., Dansereau, D. F., & Spurlin, J. E. (1985). Cooperative dyads Impact on text learning and transfer. *Contemporary Educational Psychology, 10*, 369-377.

McGrath, J. E. (1984). *Groups: interaction and performance.* Englewood Cliffs, NJ: Prentice-Hall.

McNeese, M. D. (1986). Humane Intelligence: A human factors perspective for developing intelligent cockpits. *IEEE Aerospace and Electronics Systems Magazine*, 1 (7), 6-12.

Meeks, L. L. (1987). Developing metacognition in composition with peer response groups. In M. Heiman & J. Slomianko (Eds.), *Thinking skills instruction: Concepts and techniques.* National Education Association.

Morris, N., & Rouse, W. B. (1986). *Adaptive aiding for human-computer control: Experimental studies of dynamic task allocation.* AAMRL-TR-86-005. Armstrong Aerospace Medical Research Laboratory. Wright-Patterson Air Force Base, OH.Murray, F. B. (1982). Teaching through social conflict. *Contemporary Educational Psychology*, 7, 257-271.

Murray, F. B. (1983). *Cognitive benefits of teaching on the teacher.* Paper presented at the American Educational Research Association Meeting, Montreal, Quebec.

Nighof, W., & Kommers, P. (1985). Cooperation in relation to cognitive controversy. In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C Webb, & R. Schmuck (Eds.), *Learning to cooperate, cooperating to learn*. New York: Plenum.

O'Donnell, A. M., Dansereau, D. F., Hythecker, V. I., Hall, R. H., Skaggs, L. P., Lambiotte, J. G., & Young, M. D. (1988). Cooperative procedural learning: effects of prompting and pre-versus distributed planning activities. *Journal of Educational Psychology, 80* (2), 167-171.

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and comprehension-monitoring activities. *Cognition and Instruction, 1*, 117-175.

Paris, S. G. (1988). Models and metaphors of learning strategies. In C. L. Weinstein, E. T. Goetz, & P. A. Alexander (Eds.) *Learning and study strategies: issues in assessment, instruction, and evaluation.* San Diego, CA: Academic Press, Inc.

Paris, S. G., Lipson, M. Y. & Wixson, K. K. (1983). Becoming a strategic reader. *Contemporary Educational Psychology, 8*, 293-316.

Pea, R. D. (1987). Integrating human and artificial intelligence. In R. D Pea, & K. Sheingold (Eds.), *Mirrors of the mind: Patterns of experience in educational computing*. Norwood, NJ: Ablex Publ.

Perkins, D. N. (1986). *Knowledge as design.* Hillsdale, NJ: Erlbaum.

Perkins, D. N. & Salomon, G. (1989). Are cognitive skills context-bound?, *Educational Researcher*, Jan-Feb, 16-25.

Perfetto, B. A., Bransford, J. D., & Franks, J. J. (1983). Constraints on access in a problem solving context. *Memory and Cognition, 11* , 24-31.

Perlmutter, H. V., & de Montmollin, G. (1952). Group learning of nonsense syllables. *Journal of Abnormal and Social Psychology, 47*, 762-769.

Polson, M. C., & Richardson, J. J. (1988). *Foundations of intelligent tutoring systems.* Hillsdale, NJ: Erlbaum.

Pressley, M., Borkowski, J. G., & O'Sullivan, J. T. (1984). Children's metamemory and the teaching of memory strategies. In D. L. Forrest-Pressley, G. E. MacKinnon, & T. G. Waller (Eds.), *Metacognition, cognition, and human performance.* New York: Academic Press.

Proceedings of the Conference on Computer-Supported Cooperative Work (1986). Austin, TX.

Proceedings of the Conference on Computer-Supported Cooperative Work (1988). Portland, OR.

Psotka, J., Massey, L. D., & Mutter, S. A. (1988). *Intelligent tutoring systems: Lessons learned.* Hillsdale, NJ: Erlbaum.

Rogoff, B. & Lave, J. (Eds.). (1984). *Everyday Cognition: Its development in social context.* Cambridge, MA: Harvard University Press.

Sharon, S. (1980). Cooperative learning in small group: Recent methods and effects on achievement, attitudes, and ethnic relations. *Review of Educational Research, 50,* 241-271.

Sharon, S., & Sharon, Y. (1976). *Small Group Teaching.* Englewood Cliffs, NJ: Educational Technology Publications.

Shaw, M. E. (1932). Comparison of individuals and groups in the rational solution of complex problems. *American Journal of Psychology, 44,* 491-504.

Shaw, M. L. G. (1988). An interactive knowledge-based system for group problem solving. *IEEE Systems, Man and Cybernetics, 18* (4), 610-617.

Sheingold, K. (1987). The microcomputer as a symbolic medium. In Pea, R. & K. Sheingold (Eds.), *Mirrors of the mind: Patterns of experience in educational computing.* Norwood, NJ: Ablex.

Simon, H. A. (1980). Problem solving and education. In D. T. Tuma and R.Reif (Eds.), *Problem solving and education: issues in teaching and research.* Hillsdale, NJ: Erlbaum.

Sinnott, J. D. (Ed.). (1989). *Everyday Problem Solving: Theory and application.* NY: Praeger.

Skon, L., Johnson, D. W.,& Johnson, R. T. (1981). Cooperative peer interaction versus individual competition and individualistic efforts: Effects on the acquisition of cognitive reasoning strategies. *Journal of Educational Psychology. 73,* 83-92.

Slavin, R. E. (1980a). Cooperative learning in teams: State of the art. *Educational Psychologist, 15* (2), 93-111.

Slavin, R. E. (1980b). Effects of student teams and peer tutoring on academic achievement and time on-task. *Journal of Experimental Education, 48,* 252-257.

Slavin, R. E. (1980c). *Using student team learning.* Baltimore: John Hopkins Team Learning Project.

Slavin, R. E. (1983a). *Cooperative Learning.* New York: Longman.

Slavin, R. E. (1983b). When does cooperative learning increase student achievement? *Psychological Bulletin* , 94, 429-445.

Slavin, R. E. (1985). An introduction to cooperative learning research. In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C. Webb, & R. Schmuck (Eds.), *Learning to cooperate, cooperating to learn.* New York: Plenum.

Slavin, R. E. (1987). Developmental and motivational perspectives on cooperative learning: A reconciliation. *Child Development, 58*, 1161-1167.

Slavin, R. E., Sharon, S., Kagan, S., Lazarowitz, R. H., Webb, C., & Schmuck, R. (1985). *Learning to cooperate, cooperating to learn.* New York: Plenum.

Sleeman, D. & Brown, J. S. (1982). *Intelligent tutoring systems.* New York: Academic Press.

Smith, K., Johnson, D. W., & Johnson, R. T. (1981). The use of cooperative learning groups in engineering education. In L. P. Grayson & J. M. Biedenbach (Eds), *Proceedings: Tenth annual frontiers in education conference,* Washington, DC: American Society for Engineering Education.

Snyder, D. E. & McNeese, M. D. (1987). *Conflict resolution in cooperative systems.* AAMRL-TR-87-066. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, OH.

Snyder, D. E., Wellens, A. R., Brown, C. E., & McNeese, M. D. (1989). Three paradigms for the study of multi-person and human-machine interaction. *Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics.* Cambridge, MA

Spear, K. (1988). *Sharing writing.* Portsmouth, NH: Boynton/Cook Publ.

Spurlin, J. E., Dansereau, D. F., Larson, C. O., & Brooks, L. W. (1984). Cooperative learning strategies in processing descriptive text: Effects of role and activity level of the learner. *Cognition and Instruction. 1*, 451-463.

Stefik, M. G., Foster, D., Bobrow, K., Kahn, S. Lanning, S. & Suchman, L. (1987). Beyond the chalkboard: computer support for collaboration and problem solving in meetings. *Communications of the ACM, 30* (1), 32-47.

Sternberg, R. J. (1979). The nature of mental abilities. *American Psychologist, 34*, 214-230.

Sternberg, R. J. & Caruso, D. R. (1985). Practical modes of knowing. In E. Eisner & K. J. Rehage (Eds.), *Learning and teaching: the ways of knowing*. Chicago: The University of Chicago Press.

Steiner, I. D. (1972). *Group process and productivity*. New York: Academic Press.

Steiner, I. D. (1976). Task-performing groups. In J. W. Thibaut, J. T. Spence, & R. C. Carson (Eds.), *Contemporary topics in social psychology*. Morristown, NJ: General Learning Press.

Stodolsky, S. S. (1984). Frameworks for studying instructional processes in peer work-groups. In P. L. Peterson, L. C. Wilkinson, & M. Hallinan (Eds.), *The social context of instruction: Group organization and group processes*. Orlando, FL: Academic Press.

Taylor, D. W., & Faust, W. L. (1952). Twenty questions: Efficiency in problem solving as a function of size of group. *Journal of Experimental Psychology*, *44*, 360-367.

Trowbridge, D. (1987). An investigation of groups working at the computer. In Berger, D. E., Pezdek, K, & Banks, W. (Eds.) *Applications of cognitive psychology: Problem solving, education, and computing*. Hillsdale, NJ: Erlbaum.

Vedder, P. H. (1985). *Cooperative learning: A study on processes and effects of cooperation between primary school children*. Granvenhage, The Netherlands: Stichting voor Onderzoek van het Onderwigs.

Vye, N. J., Bransford, J. D. & Franks, J. J. (1988). *Effects of multiple perspectives on access*. Personal Manuscript. Vanderbilt University.

Vye, N. J., Delclos, V. R., Burns, M. S., & Bransford, J. D. (1988). Teaching thinking and problem solving: illustrations and issues. In R. J. Sternberg & E. E. Smith (Eds.), *The psychology of human thought*. New York: Cambridge University Press.

Vygotsky, L. S. (1978). *Mind in society*. Cambridge, MA: Harvard University Press.

Way, W. (1985). *The role of the future homemakers of america student organization in facilitating the development of critical thinking skills*. Paper presented at the Meeting of the American Vocational Association, Atlanta, GA.

Weber, E. S., Chen, M., & Weinstein, C. E. (1989). Developing experts: designers who stimulate human learning. In G. R. Widmeyer (Ed.), *The 9th International Conference on Decision Support Systems.* San Diego, CA.

Webb, C. (1985). Cooperative learning in mathematics and science . In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C. Webb, & R. Schmuck (Eds.), *Learning to cooperate, cooperating to learn.* New York: Plenum.

Webb, N. M. (1982a). Peer Interaction and learning in small groups. *Journal of Educational Psychology, 74*, 642-655.

Webb, N. M. (1982b). Student interaction and learning in small groups. *Review of Educational Research, 52*, 421-445.

Webb, N. M. (1984). Stability of small group collaboration and achievement over time. *Journal of Educational Psychology, 76*, 211-224.

Webb, N. (1985a). Student interaction and learning in small groups: A research summary. In R. E. Slavin, S. Sharon, S. Kagan, R. H. Lazarowitz, C. Webb, & R. Schmuck (Eds.), *Learning to cooperate, cooperating to learn.* New York: Plenum.

Webb, N. M. (1985b). Verbal Interaction and learning in peer-directed groups. *Theory Into Practice, 24* (1), 32-39.

Webb, N. M., & Cullian, L. K. (1983). Group interaction and achievement in small groups: Stability over time. *American Education Research Journal, 29*, 411-424.

Wegner, D. M. (1987). Transactive memory: A contemporary analysis of group mind. In Mullen, B. & Goethals, G. R. (Eds.), *Theories of Group Behavior.* New York: Springer-Verlag.

Weinstein, C. L., Goetz, E. T., & Alexander, P. A. (1988). *Learning and study strategies: issues in assessment, instruction, and evaluation.* San Diego, CA: Academic Press, Inc.

Weinstein, C. L., Underwood, V. L., Wicker, F. W., & Cubberly, W. E. (1979). Cognitive learning strategies: Verbal and imaginal elaboration. In H. F. O'Neal & C. D. Spielberger (Eds.) *Cognitive and affective learning strategies.* New York: Academic Press.

Wellens, A. R. & Ergener, D. (1988). The C.I.T.I.E.S. game: a computer-based situation assessment task for studying distributed decision making. *Simulation and Games*, 19 (3), 304-327.

Whitehead, A. N. (1929). *The aims of education.* New York: MacMillan.

Wilson, D., McNeese, M. D., & Brown, C. E. (1987). Team performance of a dynamic resource allocation task: Comparison of shared versus isolated work setting. *Proceedings of the Human Factors Society*, 31st annual meeting, New York City.

Winograd, P. & Hare, V. C. (1988). Direct instruction of reading comprehension strategies: The nature of teacher explanation. In C. L. Weinstein, E. T. Goetz, & P. A. Alexander (Eds.) *Learning and study strategies: issues in assessment, instruction, and evaluation.* San Diego, CA: Academic Press.

Winograd, T., & Flores, F. (1986). *Understanding computers and cognition: A new foundation for design.* Norwood, NJ: Ablex.

Yager, S., Johnson, R. T., Johnson, D. W., & Snider, B. (1986). The impact of group processing on achievement in cooperative learning groups. *Journal of Social Psychology*, 126 (3), 389-397.

Zuboff, S. (1988). *In the age of the smart machine: The future of work and power.* New York: Basic.

U.S. Government Printing Office: 1990 — 748-002/00230