Cooperative Networking:

A method of promoting understanding in the sciences

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Les étudiants comprennent difficilement les sciences. Ils confondent "retenir par coeur" avec "comprendre". D'où leurs difficultés à appliquer des concepts et principes scientifiques au monde réel et à établir des liens entre les idées. De plus, ils apprennent les sciences de façon passive. Tout ceci entraîne à un faible taux d'assiduité et par conséquent un manque de scientifiques compétents.

Nous pensons que les étudiants peuvent prendre une part plus active dans leurs études. D'un point de vue constructiviste, l'étudiant comprend les idées en établissant des liens avec ses connaissances antérieures et en générant de nouvelles. Ce processus donne du sens à leurs connaissances scientifiques et y établit une cohérence.

Nous proposons deux stratégies pour aider les étudiants à participer activement à leur apprentissage: l'apprentissage coopératif et la formation de réseaux. La première stratégie est un outil pédagogique qui permet aux étudiants de diverses capacités de discuter des idées en petits groupes. C'est donc un moyen d'arriver au but académique commun. Les recherches ont jusque ici démontré que l'apprentissage coopératif contribue à améliorer la performance et entraîne une attitude plus positive ainsi qu'une meilleure estime de soi.

L'apprentissage en réseaux, appelé aussi représentation graphique conceptuelle, est une autre stratégie pédagogique qui met l'accent sur l'organisation des idées et sur la nature des rapports entre ces idées, ce qui aide l'étudiant à échafauder des éléments de connaissance en une structure significative. Ceci est mis en évidence par des recherches dans un bon nombre de domaines scientifiques (Holley & Dansereau, 1984; Holley, Dansereau, McDonald, Garland, & Collins, 1979; Rewey, Dansereau, & Peel, 1991; De Simone, 1993; Lambiotte, Peel, & Dansereau, 1992).

Les deux stratégies dont il est question ayant chacune leurs mérites, nous les regroupons sous le vocable "réseau coopératif". Bien que les étudiants aient en général construit des réseaux différents, ils ont participé à des groupes de travail dans lesquels ils s'interrogeaient les uns les autres sur leur degré de compréhension. Leur compréhension du sujet s'en trouvait ainsi approfondie et leurs idées plus riches de sens.

Dans notre recherche, nous avons étudié les effets des représentations graphiques conceptuelles coopératives sur la performance et sur la manière de structurer les idées des étudiants en sciences. Reconnaissant que l'apprentissage est influencé non

seulement par les notes, mais également par un tas d'autres facteurs, nous avons examiné l'impact des représentations graphiques conceptuelles coopératives sur l'attitude des étudiants face au sujet étudié, les stratégies et objectifs utilisés, leur motivation et leur mode d'apprentissage.

De plus, nous savons bien qu'il ne suffit pas de dôter nos étudiants d'une stratégie comme celle des représentation graphique conceptuelle coopératives; aussi faut-il qu'ils apprennent à les utiliser dans leur apprentissage quotidien. C'est pourquoi il est indispensable que le professeur reconnaisse l'importance de ces stratégies en tant qu'éléments essentiels de sa pédagogie. Pour cette raison, nous avons collaboré étroitement avec les enseignants pour les familiariser avec ces stratégies et pour les aider à les appliquer dans leurs classes.

Professeurs et étudiants peuvent apprendre à utiliser en classe ces stratégies de plusieurs façons (Prawat, 1990). Dans notre étude, nous avons adopté un mélange des deux dernières, en misant sur les points forts de chacune selon les exigences pédagogiques du moment.

Plan d'expérience et participants

Notre plan d'expérience consiste en un "non-equivalent pre-test and post-test control group design". La variable indépendante est l'enseignement: traditionnel ou réseau coopératif. Les variables dépendantes sont le succès tel que mesuré par les examens en classe ainsi que par les examens communs finaux, le degré de compréhension, les structures conceptuelles, l'attitude face au sujet étudié, les objectifs et les attributs. La covariable est le sexe.

Les participants étaient des professeurs et étudiants de biologie, physique et méthodes quantitatives. En méthodes quantitatives, il y avait deux groupes ayant le même enseignant, un groupe soumis aux méthodes traditionnelles, l'autre aux représentations graphiques conceptuelles coopératives. En physique, il y avait deux groupes menés par deux professeurs, un groupe témoin et un autre expérimental. Ce même plan fut appliqué en biologie.

Observations

Dans ce projet, nous avons mené trois études: en hiver 1992, en automne 1992 et en hiver 1993. En cours de ce projet, la stratégie, les recherches et les mesures ont évolué. Une question a persisté: "Est-ce que les représentations graphiques conceptuelles coopératives améliorent la performance telle que mesurée par des examens portant sur la matière enseignée?". Résultats: mixtes. Dans la première étude, en méthodes quantitatives, le taux de succès était plus élevé parmi les garçons du groupe expérimental ainsi que parmi les filles du groupe témoin. Dans la deuxième étude, dans les classes de physique, nous n'avons pas pu démontrer une différence dans la performance des deux groupes. Dans la troisième étude, dans les classes de biologie, les étudiants du groupe expérimental réussissaient significativement mieux que les autres. Dans cette troisième étude, nous avons aussi mesuré l'organisation des structures conceptuelles des étudiants par l'analyse de leurs protocoles écrits. Les étudiants des représentations graphiques conceptuelles coopératives avaient des structures conceptuelles plus approfondies et mieux organisées.

Une autre question qui a fut adressée dans chacune des trois études est la suivante: "Est ce que l'enseignement par représentations graphiques conceptuelles coopératives contribue à mieux orienter les étudiants vers une fin commune et améliore leurs attributions causales ainsi que leur attitude face à la matière étudiée?"

Au sujet de l'orientation vers une fin commune, dans les classes de méthodes quantitatives et de physique nous n'avons pas pu montrer de différences significatives dans la maîtrise des objectifs; par contre, dans les classes de biologie les étudiants du groupe expérimental avaient beaucoup plus tendance à maîtriser leurs connaissances que ceux du groupe témoin.

Quant aux attributions causales, nous n'avons demandé qu'aux étudiants de méthodes quantitatives s'ils attribuaient leurs succès ou échecs à l'aide fournie par leurs camarades de classe. Au cours de cette étude, les étudiants du groupe expérimental ont eu plus tendance à attribuer leurs succès ou échecs à l'aide de leurs camarades de classe que ceux dans les classes traditionnelles. De plus, dans les études menées dans les classes de physique et de biologie, nous avons demandé aux étudiants s'ils attribuaient leurs succès ou échecs à leur professeur. Il a paru que la méthode d'enseignement n'avait pas un effet significatif sur les attributions causales dans ces classes.

Notre méthode d'enseignement a également eu des effets mixtes sur la réaction des étudiants par rapport à l'apprentissage de la discipline dans les trois études. Quant aux réactions par rapport à l'apprentissage des méthodes quantitatives, la stratégie pédagogique semble n'avoir eu aucun effet significatif. Cependant en physique, la méthode par représentations graphiques conceptuelles coopératives a augmenté les réactions négatives des étudiants comparativement aux étudiantes. Le contraire s'est produit en biologie: la méthode par représentations graphiques conceptuelles coopératives a augmenté les réactions positives des étudiantes par rapport à l'apprentissage en comparaison avec les étudiants.

Nous avons soulevé une troisième question "Est-ce-que l'enseignement par représentations graphiques conceptuelles coopératives a augmenté l'utilisation par les étudiants des stratégies d'apprentissage?" dans l'étude des classes de méthodes quantitatives seulement. Dans cette étude, les étudiants du groupe expérimental ont indiqué plus fréquemment que ceux du groupe témoin l'utilisation des stratégies qui font appel à un choix d'idées essentielles.

Dans les classes de physique et biologie nous avons adressé la quatrième question, "Est-ce-que l'enseignement par représentations graphiques conceptuelles coopératives a augmenté la motivation des étudiants et leur tendance à apprendre de façon réfléchie?" Quoique rien de significatif n'ait été détecté dans les classes de physique, les étudiants du groupe expérimental de biologie se sont montrés beaucoup plus motivés pour réussir et mieux orientés vers une façon réfléchie d'apprendre.

Nous avons posé une dernière question "Comment les professeurs diffèrent-ils dans leur façon d'implanter l'enseignement par représentation graphique conceptuelle coopérative?" Nous avons naturellement trouvé des similitudes et des différences. Similitude: les trois professeurs ont tous utilisé le réseau comme structure de base pour leurs présentations et discussions en classe. Différences: en méthode quantitatives et en physique, les professeurs ont utilisé la construction de représentations pour modeler le raisonnement, alors qu'en biologie le professeur a fourni des systèmes complets d'expertise comme un moyen de transmission d'un ensemble structuré de connaissances. Dans les trois classes expérimentales, les étudiants se sont construit des représentations et ont discuté en groupes de leur compréhension individuelle telle que rendue par les réseaux. En méthodes quantitatives, les étudiants ont aussi construit ces représentations lors d'activités de groupes. Le professeur de biologie a perçu les deux composantes de la stratégie (Réseaux et Apprentissage Coopératif) comme distinctes et a formulé différents objectifs pour ces deux composantes. Par contre, les professeurs de méthodes quantitatives et de physique ont perçu les deux composantes comme inséparables. En somme, le professeur de biologie a utilisé les réseaux pour l'organisation des idées des étudiants et l'apprentissage coopératif de deux façons: 1) pour développer une relations plus intime avec ses étudiants, ce qui, d'après elle, constitue une partie intégrante de son enseignement; 2) et pour encourager les étudiants à mieux se connaître. D'autre part, les professeurs de méthodes quantitatives et de physique ont encouragé leurs étudiants à utiliser les représentations comme outil dans le développement de stratégies et procédures de résolution de problèmes. En méthodes quantitatives, le professeur a modelé une méthode de création de représentations conceptuelles, méthode qui spécifie les stratégies de résolution de problèmes à appliquer par la suite. Elle a maintenu cette application de deux façons: implicitement, en continuant d'utiliser des représentations comme structure de ses présentations, et explicitement en se référant aux représentations d'étudiants quand elle leur donnait son point de vue sur leurs solutions. La manière par laquelle une interdépendance positive et une responsabilité individuelle qui sont des aspects clefs de l'apprentissage coopératif, ont été implantées ont varié d'un professeur à l'autre.

Discussion

Nous avons souligné ci-haut à la fois la présence et l'absence de faits significatifs. Comme notre étude s'est déroulée dans des classes, cet environnement riche comportait des variables qui ont affecté l'utilisation de stratégies ainsi que la réussite. Dans la discussion qui suit, nous allons noter quelques unes des variables contextuelles et spéculer quant à la nature des mécanismes impliqués.

La taille de la classe et l'horaire du cours ont tous deux un impact sur l'efficacité du travail d'équipe. De grandes classes nuisent au travail de groupe, en rendant difficile une communication constante entre le professeur et chaque équipe et entraînant un délai trop important lors de la formation des équipes. Les classes qui se rencontrent tôt le matin, se voient plus perturbées par les retards d'étudiants quant au travail en équipes, que lors d'un enseignement magistral.

Les disciplines soumises à cette étude ont des traditions différentes selon la nature du curriculum et cela se reflète dans l'organisation des manuels de cours respectifs à chacune des disciplines. Les manuels de physique sont proceduraux et sont exempts d'une organisation explicite. Les manuels de biologie sont structurés de façon hiérarchique et leur structure est explicite. Les manuels de méthodes quantitatives se placent entre les deux types précédents, en se rapprochant une peu plus des manuels de biologie. L'implémentation par le professeur de Biologie comprend des modes de représentation par systèmes d'expertise, modes qui augmentent encore plus l'organisation déjà explicite du domaine. Voila donc pourquoi les étudiants en biologie étaient plus réceptifs à notre méthode. Par contre, les professeurs de physique et des méthodes quantitatives ont forcé leurs étudiants à créer leurs propres structures d'organisation, tâche que les étudiants ont jugé nouvelle et difficile. Ces étudiants étaient donc moins réceptifs à notre méthode.

En outre, nous avons remarqué que lors de l'apprentissage, les étudiants passent par des stages d'accumulation du savoir, d'ajustement et de restructuration. Une stratégie implantée pour aider l'étudiant dans ses principales activités de l'acquisition du savoir s'avère la plus efficace. Peut-être les représentations en systèmes d'expertise du professeur de biologie sont celles qui s'adaptent le mieux à l'apprentissage de ses étudiants.

De plus, la stratégie a évolué lors de ces trois implémentations, tout comme son interprétation, et l'expérience de l'enseignant. Ainsi, le professeur de biologie qui a mené la troisième (et dernière) étude avait plus d'expérience que les autres.

Nous suggérons l'idée selon laquelle la stratégie affecte la réussite de l'étudiant de deux façons: directement, par l'utilisation de la stratégie par l'étudiant, ce qui mène à l'organisation ou même à la ré-organisation de son savoir; et indirectement, par l'utilisation de la stratégie par l'enseignant, ce qui cause la ré-organisation du curriculum et affecte donc l'apprentissage. Dans le cas des méthodes quantitatives et de la physique, les classes expérimentales et témoins ont reçu des curriculums structurés de façons similaires. Cependant, en biologie, l'enseignant du groupe témoin n'a pas utilisé les réseaux est n'a donc pas réorganisé son curriculum comme dans le groupe expérimental. Ainsi, seul un effet indirect des réseaux peut être perçu dans l'étude en biologie.

Finalement, les étudiants participant aux études se trouvaient à des étapes différentes dans leurs études au CÉGEP et prenaient ces cours pour des raisons différentes. Ces facteurs suscitaient des attentes différentes chez ces étudiants. Nous sommes convaincus que le professeur de biologie du groupe expérimental a très bien su adapter l'utilisation de la stratégie aux attentes de l'étudiant.

Recommandations

Notre expérience dans l'implémentation d'un enseignement coopératif en réseaux nous a mené à donner les recommandations suivantes aux enseignants et chercheurs.

Comment utiliser les représentations graphiques conceptuelles coopératives en classe

1. Expérimenter la stratégie comme un outil pédagogique d'abord sur une petite portion du cours.
2. Avant d'introduire la stratégie, prendre en considération les croyances et attentes des étudiants.
3. Choisir des tâches appropriées pour illustrer les bénéfices des représentations graphiques conceptuelles coopératives et entraîner les étudiants à l'usage de cette méthode.
4. Vérifier que les étudiants ont bien les savoir et savoir faire prérequis avant de vouloir reconstruire leur connaissance d'une matière.
5. Surveiller avec beaucoup d'attention les étudiants alors qu'ils travaillent en équipes et être prêts à intervenir dès que les étudiants montrent un manque d'efficacité ou encore développent une conception erronée.
6. Laisser assez de temps aux étudiants pour leur permettre d'approfondir leur compréhension du sujet.
7. Associer les méthodes d'évaluation aux objectifs de l'apprentissage.

Comment continuer la recherche en représentations graphiques conceptuelles coopératives

1. Considérer les études en classe comme du travail exploratoire.
2. Développer plus de scénarios de représentations graphiques conceptuelles coopératives et engager des enseignants dans le développement de la stratégie, de la création de documentation et des outils.
3. Cueillir des données sur les structures conceptuelles de l'enseignant et rechercher l'impact de ses présentations sur la compréhension conceptuelle des étudiants.
4. Évaluer les processus et ses résultats.
5. Analyser les relations entre les variables.
6. Poursuivre la recherche par des tests spécifiques d'hypothèses dans des scénarios contrôlés expérimentalement.

SUMMARY

Learners have difficulty understanding science. They often equate memorizing with understanding. Consequently, they are unable to apply scientific concepts and principles to the real world, cannot forge connections between ideas. Moreover, they generally take a passive approach to learning science. In turn, these difficulties lead to a high rate of withdrawal from scientific studies and a subsequent shortage of competent science workers.

We believe that learners can become active participants in their own learning. From a constructivist perspective, learners come to understand ideas through a process in which they attempt to relate ideas to what they already know and to actively generate new ideas. From such struggle learners construct a coherent body of scientific knowledge, and so learn meaningfully.

In order to assist learners in becoming active constructors of their own learning we offer them two strategies: cooperative learning and networking. Cooperative learning is both a learning strategy and an instructional strategy. It creates a forum for learners to come together to work and discuss ideas in small groups. The purpose of these cooperative groups is to accomplish some common goal (e.g., an academic goal). Research conducted thus far on cooperative learning has shown it to be an effective tool for increasing achievement, positive attitudes to learning, and self-esteem.

Networking (also referred to as concept mapping) is a learning strategy which emphasizes the organization of ideas and the nature of the relationships between ideas. Knowing how ideas are related helps learners treat ideas as parts of a meaningful structure instead of discrete bits and isolated facts. Empirical evidence indicates that the use of the networking strategy facilitates the construction of meaningful knowledge in a number of science domains (Holley & Dansereau, 1984; Holley & Dansereau, McDonald, Garland, & Collins, 1979; Rewey, Dansereau, & Peel, 1991; De Simone, 1993; Lambiotte, Peel, & Dansereau, 1992).

Recognizing the merits of both strategies, we have fused them under the label cooperative networking. Although, for the most part students constructed their own networks, they also participated in cooperative groups in which they questioned each other's understanding and their networks. These activities encouraged students to clarify their understanding of the topic under discussion and so, to learn ideas in a meaningful manner.

In this study, we have tested the effects of cooperative networking in science classrooms on student achievement and on the way they structure ideas. Learning is influenced not only by grades on tests, but also by a multitude of other factors. Hence, we examined the impact of cooperative networking on students' feelings towards the subject, the strategies that they employ, their goals in learning, their motivation, and their learning styles.

Moreover, we recognize that equipping students with strategies such as cooperative networking requires that they learn to use these strategies as an integral part of their classroom learning. Therefore, teachers need to indicate that they believe that these strategies are a worthwhile component of their pedagogy. For this reason, we adopted a collaborative partnership with classroom teachers by initially instructing teachers in cooperative networking and then guiding them in the implementation of this strategy in their classrooms.

There are several ways in which teachers and students can be taught to use strategies in their classrooms (Prawat, 1990). In this study, we have espoused a mixture of the embedded and immersion approaches drawing upon the strengths of both, depending on the pedagogical demands at the time.

Design and Participants

The design of our study was a non-equivalent pre-test and post-test control group design. The independent measure was instruction: traditional or cooperative networking. The dependent measures were achievement as measured by class tests and common finals, comprehension monitoring, conceptual structures, affect (feelings about learning the subject), goals, and attributions. The moderator variable was gender.

The participants in this study were biology, physics, and quantitative methods teachers and their students. The quantitative methods course was taught by one teacher teaching two sections of the course, using cooperative networking in one section, and traditional methods in the other. There were two physics and two biology sections, taught by four teachers. Each course was taught by two different teachers, one using cooperative networking and one using traditional means.

Findings

In this project, we conducted three studies over the winter 1992, the fall 1992, and the winter 1993 semesters. The strategy, research question, and measures evolved over that period. One question that was addressed in all three studies was "Does cooperative networking enhance learning as measured by an achievement test of the material so taught?". We obtained mixed results. In the first study, in quantitative methods, male students taught using cooperative networking did better than did male students taught traditionally. On the other hand, female students taught traditionally, did better than did female students taught by cooperative networking. In the second study, in physics classes, we were not able to show any significant differences on achievement between cooperative networking and traditional instruction. In the third study, in the biology classes, students taught using cooperative networking did significantly better than did students taught traditionally. In this third study, we also measured the organization of the students' conceptual structures by analyzing their written protocols. Students taught by cooperative networking had both more extensive and more organized conceptual structures.

A second question that was addressed in all three studies was "Does cooperative networking enhance students' goal orientation, causal attributions, and affect?" With respect to goal orientation, although in the quantitative methods and physics classes we were not able to show any significant differences in mastery goals, in the biology classes students taught using cooperative networking were found to be significantly more mastery oriented than were students taught with traditional instruction.

With respect to causal attributions, only the quantitative methods students were asked whether they attributed success and failure to help from their peers. In this study, students who were taught using cooperative networking attributed success and failure to help from their peers significantly more than did students taught traditionally. In the studies carried out in the physics and biology classes, students were asked whether they attributed success and failure to help from their teacher. There were no significant effects of instructional treatment on causal attributions in these classes.

The instructional treatment also had mixed effects on students' feelings towards learning the subject in the three studies. There were no significant effects of the instructional strategy on feelings towards learning in the quantitative methods class. However, in the physics study, cooperative networking increased male students' negative feelings to learning compared to those of female students. In the biology class, cooperative networking increased female students' positive feelings toward learning compared to those of male students.

We addressed a third question, "Does cooperative networking enhance students' uses of learning strategies?' only in the quantitative methodology study. In this study, students taught using cooperative networking reported using strategies involving the selection of main ideas significantly more than did students taught by traditional instruction.

We addressed the fourth question, "Does cooperative networking enhance students' motivation and their orientation to learn meaningfully?' in the physics and biology classes. While there were no significant findings for the physics classes, biology students taught using the cooperative networking strategy had significantly greater achievement motivation and meaning orientation than did students taught by traditional methods.

In addressing the last question 'How do teachers differ in their implementation of cooperative networking, we found similarities and differences in approaches. All three teachers used networking as the structure for their lectures and class discussions. While the quantitative methodology and physics teachers used the construction of maps to model reasoning about quantitative methods or physics, the biology teacher provided completed expert maps as a way of transmitting a structured body of knowledge. In all three classes, students constructed maps and discussed in groups their individual understanding and their networks. In the quantitative methods class students also constructed maps as a group activity. The biology teacher viewed the two components of the strategy (networking and cooperative learning) as separate and had different objectives for each component. In contrast, the quantitative methodology and physics teachers viewed the two components as inseparable. Consequently, the biology teacher used networking to organize ideas for her students and used cooperative learning in two ways: 1) to develop a close rapport with her students which she reported as being integral to her teaching; 2) and, to encourage students to become acquainted with one another. On the other hand, the quantitative methodology and physics teachers encouraged their students to used maps as a tool in the development of problem solving strategies and procedures. The quantitative methodology teacher modelled a method of developing concept maps that would specify problem-solving strategies which students were expected to apply in subsequent work in the course. She supported this application in two ways: implicitly by continuing to use mapping to structure her presentations; and explicitly by referring to the students' maps when she provided students with feedback on their problem-solving. The manner in which positive interdependence and individual accountability, key aspects of cooperative learning, were implemented varied from teacher to teacher.

Discussion

Above we have noted the presence and absence of significant outcomes. Because this research was carried out in a classroom setting, the rich environment was filled with variables which moderate strategy use and achievement. In this discussion we will note some of these contextual variables and speculate on the nature of their involvement.

Class size and scheduling both had an impact on the effectiveness of group work. Large classes mitigated against group work in that it was difficult to provide sufficient teacher response to every group and the transition between whole class format and group work was time consuming. Classes with early morning schedules had a large number of late arrivals which disturbed group work more than whole class work did.

The domains involved in the studies have different traditions concerning the nature of the curriculum as reflected in the organization of their texts. Physics texts are procedurally driven and lack explicit organization. Biology texts are hierarchically structured and the structure is explicit. Quantitative methods texts fall somewhere in between these two, but closer to the biology texts than those of Physics. The biology teacher's implementation involved presenting students with "expert" maps that further enhanced the already explicit organization of the knowledge domain. Thus, the biology students readily accepted the value of networking. In contrast, the physics and quantitative methods teachers required students to create the organizational structures on their own, a task that students found novel and difficult. These students were less accepting of the networking strategy.

In addition, we note that learners cycle through various stages as they acquire knowledge. A strategy that is implemented so as to aid the principal activities of a student's current stage of learning is most effective. Perhaps the biologist's expert maps most closely matched her students' learning stage. Therefore, cooperative networking enhanced students' learning more in biology than it did in the other disciplines.

Not only did the strategy evolve over the three implementations, so did teacher experience and understanding of the strategy. Thus, the biology teacher, who carried out the third and final study had more experience than the others.

We propose that the strategy impacts student achievement in two ways: directly, through student use of the strategy, encouraging them to organize and/or re-organize their knowledge; and, indirectly through teacher use of the strategy, causing the teacher to re-organize the curriculum, and so indirectly affecting student learning. In the case of quantitative methods and physics, the experimental and control classes were exposed to similarly structured curricula. However, in biology the control class teacher did not herself use networking and so did not re-organize her curriculum in a manner similar to that of the experimental class teacher. Thus, the indirect effect of networking could only be examined in the biology study.

Finally, students in the three studies were at different stages of different CEGEP programs and were taking the courses studied for different reasons. These factors caused the students in each study to have different expectations. It is our belief that in biology the teacher of the experimental class matched her use of the strategy closely to student expectation. Therefore, this enhanced the effectiveness of cooperative networking in biology more than it did in the other disciplines.

Recommendations

Our experiences with implementing cooperative networking have lead us to make the following recommendations for teachers and researchers.

Using cooperative networking in the classroom

1. Experiment with the strategy by using it initially as an instructional tool over small portions of the course.
2. Take the students' beliefs and expectations about learning into consideration before introducing the strategy.
3. Select appropriate tasks to illustrate the benefits of cooperative networking and to train the students in its use.
4. Make sure that students have the appropriate prerequisite skills and knowledge before they attempt to reconstruct their understanding of a topic.
5. Monitor the students carefully while they are working in their groups and be prepared to intervene when students are either experiencing problems working effectively or are developing misconceptions about the topic.
6. Make enough time available for students to develop a deeper understanding of the topic.
7. Match the evaluation methods to the learning objectives.

Extending the research on cooperative networking

1. Consider classroom studies to be exploratory in nature.
2. Develop cooperative networking over more settings and engage teachers in the development of the strategy, materials and instruments.
3. Collect data on the teachers' conceptual structures and investigate the impact of the teachers' presentations on students' conceptual understanding.
4. Include process measures as well as product measures.
5. Analyze the relationships among variables (systemic research).
6. Follow up systemic research by testing specific hypotheses in experimentally controlled settings.

GENERAL INTRODUCTION

Science education in North America is in crisis. The diminishing enrolment in science (Tobias, 1990), high rate of attrition (Conseil des Colleges, 1988) and poor performance in science classrooms as well as scientific ignorance in the general population (Culliton, 1989; Lewin, 1989; Grant, 1990) are all indicators of the crisis. These deficiencies need to be addressed, since lack of basic science literacy in the population has negative effects not only on the scientific community but also on the pace of technological development (Roger, 1983) and on the economic survival of our society (Brooks, 1989; Walberg, 1991).

The inability of students to acquire a meaningful understanding of science concepts is considered by many researchers to be the underlying cause of the crisis (Eylon & Linn, 1988; Cavallo, 1991; Alexander & Kulikowich, 1992). Many students rely on memorizing isolated facts rather than on relating ideas together and building a structured body of scientific knowledge. This problem is similar to the problem that students face in abstracting key ideas, discerning relationships between ideas, and integrating these ideas to their prior knowledge to form a coherent framework (Bransford, 1979; Novak & Gowin, 1984; Dansereau, 1989; 1990).

Poor comprehension monitoring skills, i.e., the ability to detect gaps and contradictions in one's understanding and the ability to fix them (Zabrucky, Moore, & Shultz, 1987) contributes to the difficulties students have in learning meaningfully. Investigators in the area of meta-comprehension have found that the problem appears to be in students' abilities to integrate meaning across text, to detect errors in the relationships between ideas, and to detect inconsistencies between the text and prior knowledge (Englert, Hiebert, & Stewart, 1988; Baker, 1979) and in their ability to apply appropriate "fix-up" strategies (Garner, 1987). These problems in comprehension and meta-comprehension are aggravated by the fact that information in expository texts, such as those found in the sciences, is densely packed and the students may not have any prior knowledge in the domain (Kirby & Cantwell, 1985).

Inappropriate attitudinal and motivational behaviours can also hinder meaningful learning (Ausubel, 1963). That is, learners may believe that learning meaningfully is not worth while and so not want to learn meaningfully.

These problems challenge us to conceive new and better ways of promoting comprehension and thinking skills in students. Three broad areas in educational research have informed our study: constructivist views of knowledge and knowledge construction, b) research on meaningful learning, and c), research on classroom instructional interventions.

Constructivist perspectives

Most educational researchers currently take constructivist approaches to knowledge and learning. These posit that learning is an active process during which learners question, manipulate, select, elaborate, organize, and revise ideas so as to construct an understanding that makes sense to them (Novak, 1988; Wittrock, 1990). Thus, in these approaches, learners play an important role in constructing their own learning. Learners are not viewed as "absorbing" someone else's ideas; rather they interpret ideas and impose meaning according to their prior knowledge and experiences.

Proponents of constructivist perspectives, e.g., Piaget, 1954, Wittrock, 1990, ..., hold that the construction of meaning is a continuous process of change. Learners modify their understandings as they gain more and different knowledge and experiences. Therefore, the construction of meaning not only involves incorporating new ideas into existing ones, a process referred to by Piaget as assimilation, but also includes the disassembly, reexamination, and rearrangement of ideas so that misconceptions are clarified or new perspectives are adopted. Piaget refers to this process of re-structuring and modifying ideas as accommodation. In the constructivist view, meaning is constructed and understanding develops not only by adding more ideas but also by changing and re-structuring previously acquired ideas and learning strategies.

According to constructivist perspectives, students are not the only constructors of knowledge. Teachers also construct meaning by making sense both of the domain and of the learning strategies used by themselves and by their students. In order to understand and use strategies effectively, teachers need to make them personally meaningful. Their experiences influence the way in which the strategy is incorporated into the curriculum and the way in which it is used in the classroom (Kagan, 1992).

While it is common for researchers to assess students' construction of meaning and strategies in reaction to some intervention, teachers' experiences have gone virtually unrecognized (Brody, 1991). This is despite the fact that researchers often ask teachers to participate in classroom intervention studies. In this study, we took the position that the teachers play a vital role in classroom strategy training and that they, like their students, make varying attempts at constructing their own interpretation of the strategy (Garner, 1988). Ultimately, it is the teacher who decides whether a strategy becomes an integral part of classroom life or whether it is merely an "academic frill" (Berieter, 1984). Their choice determines how the strategy is used and generalized. Thus, we sought to describe teachers' experiences with cooperative networking in order to understand how they conceptualize and make use of it. Drawing on the richness of the teachers' experiences would allow us to develop better instructional interventions, to conduct better classroom research, and to interpret more accurately students' responses.

Meaningful Verbal Learning

Most classroom learning involves the mastery of concepts and propositions which are presented either in textbooks or in lectures. Meaningful learning is an active process whereby learners actively wrestle with new ideas and incorporate them into existing conceptual structures (Ausubel, 1963; 1968; Novak, 1988; Roth, 1990). Conceptual structures are organized clusters of information stored in long-term memory (Klauseimer, 1990). If students are going to learn meaningfully, they must a) attend to new information; b) consider the relational meaning of the new information relative to their existing conceptual structures; c) incorporate the new information into a new conceptual structure by subsuming it under more inclusive concepts and/or by reorganizing the conceptual structure; and, d) communicate their conceptual understanding in some verbal form (Ausubel, 1963; Roth, 1990).

Viewing students as active constructors of knowledge has lead to an interest in identifying the variables which mediate meaningful learning . These variables can be clustered into three groups of factors. Firstly, the learner must have a predisposition towards meaningful learning, e.g., appropriate attitudinal, motivational and cognitive behaviours (Ausubel, 1963; Wittrock, 1986; Novak, 1988). Secondly, the learner must have appropriate existing conceptual structures (e.g., prior knowledge) (Ausubel, 1963; Roth, 1990). Finally, the instructional setting (task, materials, and classroom climate) must be potentially meaningful. When any one factor is lacking, meaningful learning does not take place. Traditionally, researchers have isolated variables and investigated their influence on learning, more or less independently of the other variables (Salomon, 1991). However, educational researchers, especially in the area of self-regulated learning, are beginning to consider the interdependence among cognitive, motivational, affective, and classroom variables and to explain meaningful learning in terms of these interactions (Corno & Mandinach, 1983; Zimmerman &

Schunk, 1989; Pintrich & De Groot, 1990; McCombs & Marzano, 1990; Pintrich, Marx, & Boyle, 1993). We will discuss the first two clusters under this heading of Meaningful Verbal learning and leave the discussion of the third (instructional setting) for the section headed Classroom Instructional Interventions.

The student's disposition to learn in a meaningful rather than rote fashion is a major prerequisite for meaningful learning (Ausubel, 1963). Several researchers (Entwistle & Ramsden, 1983; Anderson & Roth, 1989; Donn, 1992; Cavallo, 1991) have found that some students approach a learning task by integrating information and searching for understanding, while others approach learning using rote techniques.

Moreover, their learning approach is often predicated on their beliefs about the nature of scientific knowledge (Edmonson, 1989 in Cavallo, 1991; Eylon & Linn, 1988). For example, students must believe that a coherent body of knowledge exists and that understanding this body constitutes the learning task.

In addition, students consider the nature of subsequent testing when studying. For example, students reduce their self-testing behaviours when studying for multiple-choice tests, as opposed to studying for short-answer tests (Pressley & Ghatala, 1990). This presents a problem if students have been in a learning environment which rewards rote learning and/or evaluates learning by grading the product rather than the process, i.e., multiple-choice examinations.

Motivation plays an important role in students' attention and persistence at a learning task. Therefore, motivational variables need to be considered when investigating meaningful learning. However, motivation is a multifaceted construct. Four of these facets are presented below.

Achievement motivation is the drive to excel and overcome obstacles (Weiner,1992). Research has indicated that achievement motivation is positively correlated to science achievement as measured by performance on school examinations (Uguroglu & Walberg, 1979; Kremer & Walberg, 1981; Oliver & Simpson, 1988). However, achievement motivation does not necessarily correlate with meaningful learning, since science achievement, as measured by grades, is not necessarily an indicator of meaningful learning (Tobin & Fraser, 1989).

A second facet of motivation which influences meaningful learning is the student's academic goal orientation. Several researchers (Dweck, 1986; Ames & Archer, 1988; Meece, Blumenfeld, & Hoyle, 1988) have shown that students have a variety of academic goals: to master or understand the material (mastery goals); to achieve favourable judgements (ego or performance goals); to work with friends (affiliative goals); and, to avoid work (work-avoidance goals). Research has indicated that mastery goals promote understanding while performance goals discourage it (Ames & Archer, 1988; Dweck & Leggett, 1988).

A third facet of motivation is its source, i.e., intrinsic or extrinsic motivation (Lepper & Greene Nisbett, 1973). Students who are intrinsically motivated are motivated to master the task because it is intrinsically satisfying. On the other hand, students who are extrinsically motivated require a "reward" (grades, praise, etc.). Research suggests that students who are intrinsically motivated are more likely to use cognitive strategies (Pintrich & Groot, 1990) and have a meaningful learning orientation while students who are extrinsically motivated are more likely to have a preference for learning by rote (Entwistle and Ramsden, 1983; Biggs, 1985; EQS reference).

Finally, students attribute success or failure to different factors e.g., ability, effort, task difficulty, luck, help. These attributions mediate academic achievement (Weiner, 1979; Skinner, Wellborn, & Connell, 1990). Students who attribute their success or failure to causes which are controllable and internal, e.g., effort (Weiner, 1979), who believe they are able (Stipek, 1980), and are capable of producing the behaviours causing learning (Bandura, 1977) have positive attitudes to learning, are cognitively engaged, use learning strategies, and are academically successful (Dweck & Leggett, 1988; Pintrich & DeGroot, 1990). On the other hand, attributions of success and failure to causes that are uncontrollable or external, e.g., help from others, diminish cognitive engagement and subsequent learning.

Research has indicated that causal attributions (Weiner, 1985), perceptions of competence and personal control (Harter, 1986), goal orientation (Meece, Blumenfeld, & Hoyle, 1988), differentially influence affect (emotional experience). For example, students who have a mastery orientation also have positive feelings towards learning. Positive affect, in turn, enhances the use of learning strategies, which, in turn, enhances meaningful learning (McCombs & Whistler, 1989).

Researchers have also begun to examine the cognitive and meta-cognitive strategies which students employ during learning. If students are to construct meaningful conceptual structures they need to question their understanding and the adequacy of the information they are apprehending. Thus, they need to monitor their understanding, detect errors and misconceptions both in the new information and in their prior knowledge, and rectify these problems. To accomplish this students should be able to use several learning strategies, such as using appropriate study aids, selecting important information, relating ideas and trying to understand the underlying principles and relationships. However, being able to use a strategy is not enough to ensure that meaningful learning takes place. For example, although students often know about these strategies, they do not necessarily choose to use them, given a complex task (Zimmerman, 1989; McComb, 1989; Garner, 1990).

Garner (1990) has suggested that students fail to use strategies because they may lack the necessary knowledge and meta-cognitive skills, make inappropriate causal attributions, have inappropriate learning goals, or be in inappropriate learning settings. She emphasizes that learning is situated within a classroom context and cannot be understood separate from that context.

Most researchers, in the area of meaningful learning, consider that the conceptual structures held by learners determine subsequent learning (Ausubel, 1963; Roth, 1990; Bransford, Vye, Kinzer, & Risko, 1990). However, the cognitive strategies available to a learner (as mentioned above) impact on the nature of any learning. Moreover, researchers recognize that there are developmental aspects to these cognitive strategies, and hence to meaningful learning. However, they differ in *what* developmental aspects they highlight. Some, interested in cognitive development, emphasize the development of mental processes and/or the resulting mental representation of knowledge that results from maturation (Piaget, 1954; Vygotsky, 1978). Others, interested in cognitive skill development, emphasize the development of mental processes and/or the resulting mental representations of knowledge that result from developing expertise or learning (Anderson, 1982; deKleer & Brown, 1983; Royer, Cisero, & Carlo, 1993). Cognitive skills, in this tradition, refer both to lower-level skills (or tactics) which become automated with expertise and higher skills (or strategies) which become used to plan, monitor and accomplish complex tasks with expertise (Royer, Cisero, & Carlo, 1993). Although learners, especially adolescents, develop cognitively as a result of both maturation and learning [1], these two traditions have remained largely distinct. The stages and therefore the mental processes and mental representations that are investigated in the two traditions differ in underlying metaphors, assumptions, operational definitions, and assessment techniques.

As educational researchers we are interested in cognitive development due to learning, we chose to follow the second of the two traditions. The following summary of this research tradition, especially as it relates to assessment, is taken in part from Royer, Cisero, and Carlo (1993). According to Glaser and his colleagues (Glaser *et al.*, 1985) cognitive skill development can be characterized along seven dimensions, four of which, (knowledge acquisition, knowledge organization and structure, depth of representation, and quality of mental model), are useful in assessing students' conceptual structures. Below we describe these four dimensions

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[1] Klausmeier (Klausmeier, 1990) has developed a theory of concept learning and development which integrates maturation with skill acquisition during learning. It is based on both longitudinal studies as students mature and cross-sectional studies between novices and experts.

and the nature of measures used to assess them.

Knowledge acquisition describes the degree to which learners have acquired the declarative knowledge necessary to function within a specific domain. Although it is a prerequisite to meaningful learning, this characteristic does not distinguish between novices and experts nor between meaningful learners and rote learners. Knowledge acquisition can be (and usually is) assessed by traditional short-answer, true-false, multiple-choice tests.

Knowledge organization and structure describes the manner in which knowledge is conceptualized, related, structured, and stored in long term memory. Novices, and presumably rote learners, store verbatim, unrelated and loosely structured information as opposed to experts, and presumably meaningful learners, who store highly interrelated and structured information. There are two broad categories of assessment techniques, indirect measures and measures based on assumptions about the associative nature of memory. Although the former appear promising, we based our investigation on the latter category. Written or oral protocols can be collected from students, subjected to a propositional analysis (Frederiksen, 1975; Kintsch & van Dijk, 1978), and transformed into node-link structures (concept maps). The degree of organization and structure in the concept map can subsequently be assessed (Chi, Glaser, & Rees, 1982; Frederiksen & Breuleux, 1990; Novak & Musonada, 1991).

Depth of representation describes the extent to which learners subsume specific information under more general and superordinate categories. Novices, and presumably rote learners, represent their knowledge in terms of surface features while experts, and presumably meaningful learners, subsume the surface features by making inferences to general principles.

Mental models are mental analogies of the events or situations along with procedural rules to mentally manipulate the event or situation (Johnson-Laird, 1983; *cf* Gentner & Stevens, 1983). Learners can use these models to predict future events, answer comprehension questions, or solve problems. Initially learners construct conceptual structures that are primarily descriptive in nature and correspond more closely to the propositional structure of text (propositional models) (McNamara, Miller, & Bransford, 1991). However, learners can downplay these text features and construct mental models of the situation, by encoding procedures, goals, and relationships (causal, spatial, temporal, etc.) (McNamara, Miller, & Bransford, 1991). Whether a learner opts to encode text propositionally or construct a mental model appears to be a function of text features, task difficulty, expertise, and knowledge of subsequent testing (McNamara, Miller, & Bransford, 1991). Quality of mental models refers to the degree to which the non-propositional learner constructed models faithfully represent and generalize the original.

Novices, and presumably rote learners, construct conceptual structures that are specific to the event or situation to be learned and have few references to "extra-propositional" ideas. They may relate some features of the event or situation to be learned with features of familiar events or situations. Experts, and presumably meaningful learners, construct mental representations that are a generalization of similar events or situations, identify salient features of the generalized event or situation that respond to manipulation, and include rules for manipulating the model. This implies that learners need to have been exposed to enough instances of the event or situation to make the generalization (Klausmeier, 1990). The same techniques (protocol analysis) that are used to assess knowledge organization and structure can be used to assess the quality of mental models. The only differences are the nature of the task (recall versus application) and the nature of the propositions being assessed (declarative versus procedural). Mosenthal and his colleagues (Mosenthal & Kirsch, 199?; *cf* Cavallo, 1991) developed a method of scoring written or verbal protocols into microstructure (propositional conceptual structure) and macrostructure (mental model) components.

Classroom Instructional Interventions

Many classroom interventions have been developed to enhance meaningful learning in science (Eylon & Linn, 1988; Walberg, 1991;*cf* Weinstein, Goetz, & Alexander, 1988). Two which we found promising and chose to focus on are networking and cooperative learning.

Networking

Understanding the relationships among ideas is an important aspect of meaningful learning for college students who are faced with a large body of information (Cavallo, 1991). Networking is a cognitive strategy that is particularly suited to identifying the relationships among ideas. Networking falls under a broader class of strategies called visual-spatial strategies. Like other learning strategies, visual strategies facilitate thinking and learning about the information by condensing, reorganizing, elaborating, and representing the information externally (Holley & Dansereau, 1984; Schmeck, 1988b). They differ from other learning strategies in that they are graphical illustrations of verbal statements. A distinctive characteristic of the networking strategy is that it uses named relationships to link ideas. This enables the learners to think not only in terms of the fact that ideas are related, but also that they are related in some particular way. In turn, this leads to a more synthesized and coherent body of knowledge (van Patten, Chao, Reigeluth, 1986).

The construction of a network requires that a student identify the important information, discern the relationships between units of information, and represent them in the form of a two-dimensional node-link-node visual representation. Concepts are displayed in nodes (boxes or circles) which are connected by particular links (lines with arrowheads) which specify the nature of the relationships between concepts. These concept maps are often hierarchical (general,inclusive concepts at the top of the map and specific, less inclusive concepts arranged beneath them). According to Novak (1988) this is a structural feature of most science knowledge. This hierarchical structure is familiar to most students (Minsky, 1975) as many science texts already use this format to represent information. For example, Figure 1, on the page below, is a network depicting information about the relationship between work and the transfer of energy in the Physics domain of Classical Mechanics.

Thus, the above three features of networking (selecting and summarizing main ideas, relating ideas, and organizing them in a hierarchical structure) may be implicated in enhancing meaningful learning. Firstly, networking may help students construct meaning because it focuses the learner's attention on important concepts. For example, networking has been found to be particularly useful for the recall of main ideas in geology (Holley & Dansereau, 1984; Holley, Dansereau, McDonald, Garland, & Collins, 1979), the human circulatory and renal systems (Rewey, Dansereau, & Peel, 1991), biology (Lambiotte, Skaggs, & Dansereau, personal communication), health sciences (De Simone, 1993), and psychology (Lambiotte, Peel, & Dansereau, 1992). Furthermore, knowing what is important helps reduce the amount of information that needs to be remembered, thus minimizing the cognitive load (Breuker, 1984). Both young students (Brown, 1983) and college students (Holley & Dansereau, 1984; Mikulecky, Clark, & McIntyre-Adams, 1989) have difficulties selecting more important from less important ideas, especially when the content is unfamiliar and when there is much to learn. One could infer that students are likely to have difficulty with networking for this reason. On the other hand, focusing student attention on the necessity of the selection process may contribute to increased effort in that area and hence promote meaningful learning.

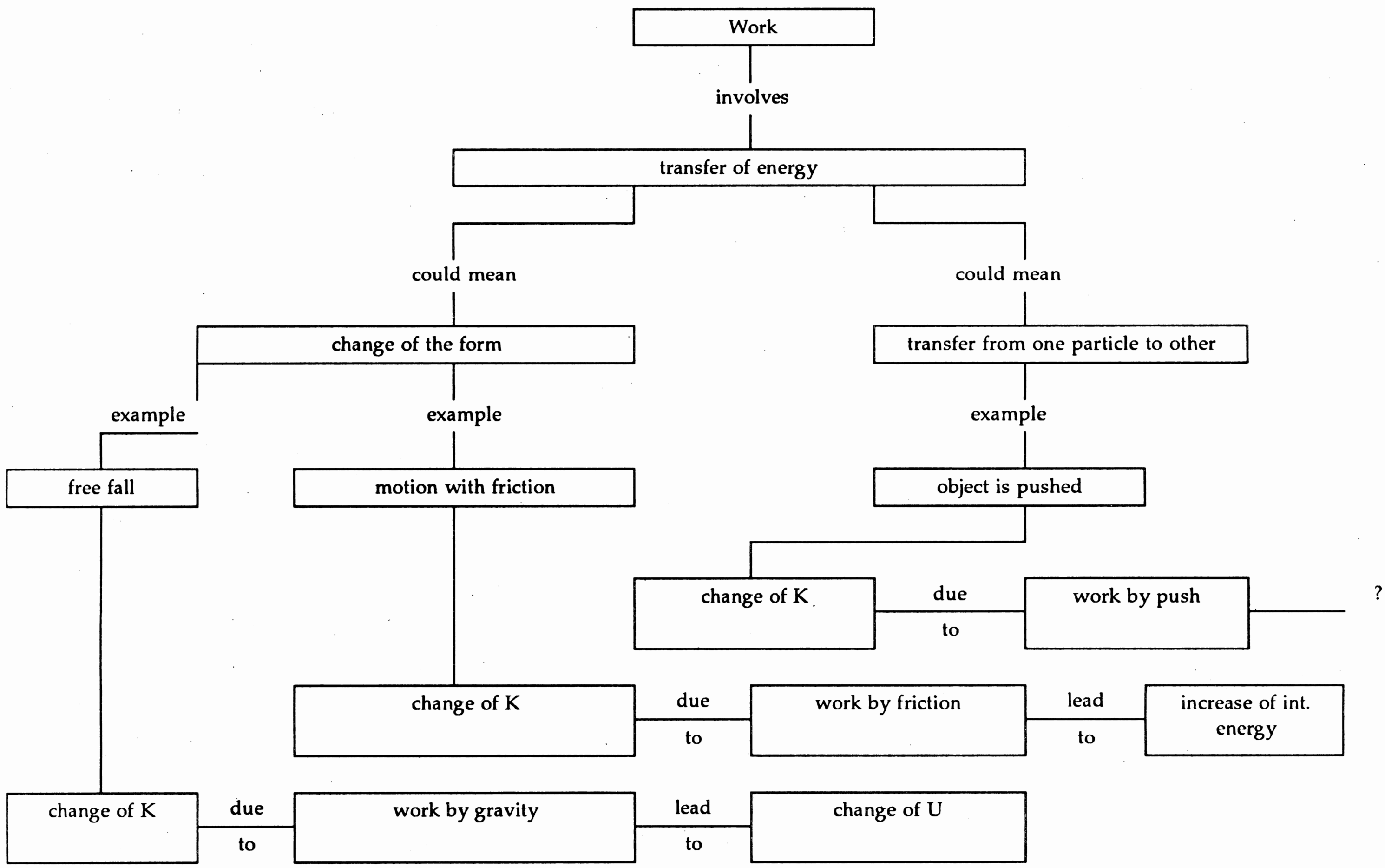

Figure 1: Network of Work and Transfer of Energy

Secondly, networking may help students construct meaning by requiring them to not only recognize the important ideas, but also to look for relationships between them (Bransford, 1979). Networking emphasizes the relating of ideas. Learners are taught to ask themselves questions such as 'How are these ideas related?', 'Is this an example?', 'How does this idea fit with what I already know?', and 'What other characteristics do I know?'. As students ask themselves these questions, they elaborate on their knowledge. They enrich their knowledge by adding more ideas, by revising them, and by generating new relationships among the ideas. Consequently, the more ideas that are integrated and the more new relationships formed, the richer and more coherent is the body of knowledge that is constructed (Derry, 1990).

Finally, networking requires students to organize their ideas and thus may facilitate their understanding (Derry, 1990). Organizing ideas hierarchically in a network facilitates students' understanding (van Patten, Chao, & Reigeluth, 1986) by encouraging learners to think of ideas as integrated systems rather than as discrete units of information. Consequently, more meaningful learning and achievement should result from the combination of thinking about important concepts, determining their relationships, and organizing the information into networks.

Cooperative Learning

Cooperative learning is a set of instructional strategies in which students work in small, usually heterogeneous, groups to accomplish shared academic goals (Abrami *et al.*, 1993). Cooperative learning, unlike simple group work, requires a learning environment that is explicitly structured to promote positive interdependence and individual accountability. Positive interdependence and individual accountability are complementary processes with the former focusing on promoting positive relationships among group members and the latter focusing on the individual's role in those relationships. Slavin (1983, 1989) investigated the characteristics of successful group learning implementations and found that those that promoted both positive interdependence and individual accountability (i.e., cooperative learning methods) were superior.

A number of specific techniques for implementing cooperative learning have been developed (e.g., Aronson *et al.*, 1978; Slavin, 1987, Johnson & Johnson, 1987; Sharan & Sharan, 1976; Davidson, 1985, and Kagan, 1989). These differ primarily in the manner in which they foster positive interdependence and individual accountability. We decided to adopt Kagan's "multi-structured" approach because it offers a repertoire of content-free structures which teachers select, integrate with their course content to create learning activities, and sequence to create lessons. This flexibility allows teachers to foster the specific skills that are required by a student for a given learning task. Thus, the teacher's role changes from solely delivering information to also structuring effective learning opportunities and guiding cooperative work so that students construct and communicate a coherent body of knowledge (i.e., conceptual structures of the domain).

Most researchers who have studied the effectiveness of cooperative learning have concluded that, in general, it enhances achievement, motivation, and affect (Johnson, Maruyama, Johnson, Nelson & Skon, 1981; Johnson & Johnson, 1989; Sherman, 1986). Research on the effectiveness of cooperative learning in post-secondary classrooms (Dansereau, 1988; Cooper *et al.*, 1990; Johnson, Johnson, & Smith, 1991; d'Apollonia & Glashan, 1992) has indicated that it is effective in developing higher-level thinking skills, promoting academic achievement, enhancing positive attitudes toward the subject matter, and promoting positive gender and race relations. A prior study funded by PAREA (d'Apollonia & Glashan, 1992), found that students taught via cooperative learning, learned more than did students taught by traditional means and that low and medium-ability students also perceived that they had learned more. Cooperative learning also enhanced low-ability students' academic self esteem. Observations of students' verbal interactions indicated that students became more cooperative with time and that they spent most of their time giving or getting task-related information, or asking for and giving academic help (d'Apollonia & Glashan, 1992; d'Apollonia et al., 1992; Kouros et al., 1993).

Researchers differ in their causal explanations for the benefits of cooperative learning. According to one perspective, the Vygotskian developmental perspective (Vygotsky, 1962), children learn to think critically and become self-regulated problem solvers within a social-context. Within this perspective, verbal interaction, initially with parents and subsequently with peers, is the basis of both meaningful learning and metacognition (Harris, 1990).

Cooperative Networking

There is a growing awareness that classroom instruction occurs within a social context influencing both motivational and cognitive outcomes (Weiner, 1990; Pearson & Fielding, 1991). There have been a few studies which have investigated the effectiveness of combining cooperative learning with some form of text comprehension strategies (Darch, Carnine, & Kameenui, 1986; Rewey, Dansereau, Skaggs, Hall, & Petrie, 1989; Palincsar, Brown & Martin, 1987; Okebukola, & Jegede, 1988). While some of these strategies approach networking, they focus more on the extraction of main ideas and not the relationships among the ideas. Some researchers have recommended that students be trained to network in small groups to provide scaffolding, discussion, and peer modelling (Schmid & Telaro, 1990; De Simone, 1993). Working with others constructing networks may provide students with a forum in which they can exchange information about the content while providing each other with feedback. Consequently, they may encourage one another to become more sensitive to errors and contradictions in knowledge (Palincsar & Brown, 1984). The combination of networking, which emphasizes the internal reconstruction of knowledge, and cooperative learning, which facilitates the communication of this knowledge, should compliment each other.

Strategy Training Interventions

There are different ways of teaching students learning strategies. Three basic approaches have been described in the literature and are summarized here: the stand-alone approach; the embedded approach; and the immersion approach (Prowat, 1991). The three approaches differ along two dimensions: integration with/separation from content; and, explicit/implicit strategy usage. While the stand-alone approach makes teaching learning strategies a discipline unto itself, the embedded and immersion approaches integrate teaching learning strategies with discipline specific course content. In the embedded approach the strategies are taught explicitly, while in the immersion approach they are taught implicitly.

The advantage of the stand-alone approach is that students do not need to understand discipline specific course content in order to learn strategies. The disadvantage of this approach is that students may not be able to transfer the use of strategies to learning either in or out of school.

The embedded approach requires the integration of learning strategies into the regular curriculum. Students learn about the strategies while applying them to discipline specific course content. In this case, both learning about strategies and learning about the discipline are perceived as being equally important. Advocates of this approach differ in the way in which they implement the embedded approach. Some prefer to teach students about the learning strategies first and then to show students how to use them to learn the discipline specific content. Others believe that students will appreciate and understand the learning strategies better after facing a situation that requires them. Therefore, the teacher would introduce the strategies on a need-to-know basis. The latter orientation leads to the third approach, the immersion approach.

The immersion approach is a relative newcomer. Proponents (Prawat, 1991) of this approach emphasize the learning of a carefully selected curriculum, through which students learn strategies. Strategies are not taught explicitly, but rather the discipline specific course content is modified and the learning environment is restructured so that students learn the use of selected strategies incidentally. Thus, an added requirement of the immersion approach is the revision of present day curricula and learning environments.

Despite the advantages of the immersion approach, adhering to it strictly has its limitations too. Because learning strategies are not explicitly taught, students may not know how to proceed when faced with problems in understanding. For example, it may be worthwhile to explicitly teach students "how to" think about issues that are relevant to their content area. In our study, we used a combination of the embedded and immersion approaches depending on the demands of the situation and learner needs.

Research Objectives

Our overall research objective was to investigate the effectiveness of cooperative networking in enhancing CEGEP students' learning of science in classroom contexts. With this objective in mind we addressed the following questions:

1. Does training students to use cooperative networking affect their goals, causal attributions, and motivation?
2. Does training students to use cooperative networking affect their use of learning strategies, including their ability to monitor their comprehension strategies?
3. Does training students to use cooperative networking affect their feelings towards learning?
4. Does training students to use cooperative networking affect their orientation concerning meaningful learning?
5. Does cooperative networking affect students' acquisition of knowledge, organization of knowledge, and depth of knowledge representation?
6. Does cooperative networking affect students' achievement?
7. Does the student's gender influence the effectiveness of cooperative networking?
8. How do teachers differ in their implementation of cooperative networking?

METHODOLOGY

Three studies were carried out over the winter 1992, fall 1992, and winter 1993 semesters. The characteristics of the studies are described below.

Subjects

The research project included the following classes:

winter 1992

a pilot Physics class (22 students);
a pilot Biology class (37 students);
two Quantitative Methodology classes taught by the same teacher
experimental (33 students) and control (34 students).

fall 1992

two pilot Biology classes (86 students) taught by the same teacher;
two Physics classes taught by two different teachers
experimental (38 students) and control (39 students).

winter 1993

two Biology classes taught by two teachers
experimental (30 students) and control (43 students).

Instructional Designs and Settings

Cooperative networking is an instructional strategy in which teachers' use networks as instructional aids and model networking to encourage students to construct their own mental and visual representations of knowledge. Cooperative networking is also a learning strategy in which students participate in cooperative groups to develop such skills as questioning, defining concepts, and summarising (pre-networking activities). Subsequently they individually construct networks on a specific topic or text passage. They finally again participate in cooperative groups to discuss, evaluate, and revise each others networks (post-networking activities). Cooperative networking interventions vary somewhat as teachers and students adapt the strategies to their particular goals.

Traditional instruction, in our studies, consists of an instructional strategy in which the teachers focus on the direct instruction of the declarative and procedural knowledge within the course content. Although the teachers may use a variety of instructional aids, in most cases the design is to teach the underlying structure of the domain implicitly rather than explicitly. Whole class discussion and individual practice are used in place of cooperative learning.

Below are specific descriptions of the experimental classes in each study.

Study 1: Quantitative methods

In 1992, two new compulsory courses were introduced into the Social Science program. One of them, Quantitative Methodology (360-001-88) was introduced at Vanier College in the winter of 1992. Many students were not aware of this requirement when they entered the Social Science Program, and resented taking the course. Furthermore, although there were no prerequisites for this course, many students had weak verbal and quantitative abilities. In comparison to grade 12 students, their percentile scores on verbal component ranged from 2 to 96 ($\underline{M}$ = 46); their percentile scores on the quantitative components ranged from less than 1 to 89 ($\underline{M}$ = 33). The overall objectives of the course were to teach students: to think critically about numerical information on social science presented in newspapers, textbooks, and introductory research articles; and, to understand and use the fundamental concepts of descriptive and inferential statistics. Because the above objectives require students to acquire an understanding of concepts and an ability to apply them to novel situations, we believed that Cooperative Networking would enhance instruction and therefore decided to implement the strategy in this course.

The strategy was integrated into all aspects of the course: materials; pedagogy; and, course requirements. Therefore, students were informed, in the course outline, that they would be expected to extract the basic concepts of quantitative methodology from the lectures and the textbook; connect these concepts to each other, to their experience, and to the resolution of research questions; and, to portray their understanding of the course content in concept maps. Students were informed that they would be working in small groups and that learning to work effectively in such groups was a course objective. These objectives were reflected in the method of evaluation. The final grade consisted of four class-tests (each worth 10%) each covering approximately a quarter of the course material; a summative final (worth 25%) given during the examination period; two laboratory assignments (each worth 10%); participation, i.e., performance on in-class group assignments, (worth 10%); and, homework and class quizzes (worth 5%). Achievement tests (both class tests and final) consisted of essay questions requiring students to apply definitions, concepts, procedures to new situations. For example, they were asked to interpret a National poll, categorize variables as having nominal, ordinal, interval or ratio scales, select the appropriate measure of central tendency in a given situation, etc. Thus, the evaluation tests measured application rather than rote learning.

The course was scheduled in two 2-hour sessions per week over 15 weeks. Cooperative-networking was not implemented in the six sessions scheduled in the computer lab. Five of the 33 students registered in the course dropped the course, of the remaining 28 students, 20 passed the course (pass grade = 60%). The course was scheduled at 8:00 AM. Consequently, students often arrived late and this tardiness caused problems for group work. There was a relatively high absenteeism rate (up to 20%). However, this did not differ from the other Quantitative Methodology sections. An observer attended approximately 50% of the classes and commented on the students' low attention span and disruptive behaviours.

During this implementation we had decided to distribute the training in cooperative-learning and concept mapping throughout the first ten weeks of the course. Consequently, we developed instructional objectives concerning the strategies in parallel to the instructional objectives concerning the content. Lesson plans were developed to encourage students to build team identity and cohesion, to become motivated to invest time in concept mapping, to build a precise vocabulary, to use questioning to guide reading, to connect concepts, to learn to network cooperatively, to practice cooperative networking, and to learn and practice meta-comprehension strategies.

The cooperative networking strategy was described to the students on the first day of class. At this time they were informed of why it was being used, of the quality and quantity of work they were expected to do, and were informed of the research project. Students were asked to sign a consent form to indicate that they were willing to participate. At this time students also completed sections of the Canadian Cognitive Abilities test, and the pretest questionnaire. On the third day of classes, students were assigned to groups of four (see Methods section) and were given time to discuss their background and academic goals and to exchange schedules and phone-numbers. They were supplied with group-binders in which they were to keep a copy of all course and training materials, concept maps, tests, handouts etc.

During each class, students were introduced to the content and strategy by the teacher, thinking aloud, posing questions to herself and the class, making connections to prior knowledge and daily experience, and constructing concept maps on the blackboard. This modelling took much more time than initially planned (e.g., 45 minutes rather than 20). Students subsequently worked in groups to do exercises, construct maps, solve problems, etc. Group work also took much more time than planned (45 minutes or more). Thus, cooperative networking was thoroughly integrated into the course curriculum and occupied a major portion of the class time. Consequently, students had little opportunity during class time to individually practice skills. Homework assignments consisted of reading and summarizing the text book.

Study 2: Physics

The thirty-eight students in physics were in their third or fifth semester of the CEGEP science program. For all students, this course entitled 'Waves and Modern Physics' was a required, terminal course. However, many students in the Health Science Program do not believe that this course is necessary for careers in medicine, biology, physiology, etc. For the Pure and Applied Science students in the class, physics is an integral component of further study in their field.

The instructor's objectives, as stated in the course outline, were: "to understand the basic concepts introduced in the course; to describe the relationships among these concepts; to relate your theoretical knowledge to your practical everyday experience; to be able to communicate this knowledge to others; to use your understanding of concepts and relationships among them to solve problems; to learn to develop problem solving strategies; and to be able to learn from the physics textbook".

The instructional method, as stated in the course outline, included lectures and whole-class discussions, the use of cooperative networking to summarize lectures and develop problem solving strategies, small group work to promote the communication of ideas, and homework reading and problem-solving assignments. Approximately 30% of the class time and 100% of the laboratory time was spent in group work.

Evaluation was based on the following set of tests, assignments, and lab reports. One, there were three class tests on material covered in lectures and in labs. These tests were worth 65% of the final grade. Two, there were six lab reports worth 15% of the final grade. Three, the homework and/or quizzes and/or assigned tasks in class were worth an additional 15%. The instructor retained the remaining 5% of the mark as discretionary.

Training materials were selected in collaboration with the classroom teacher and incorporated into the curriculum. Both the training and the cooperative networking strategy were integrated into the curriculum.

The initial training phase sought to address training on questioning and on cooperative group skills. Reinforcing these skills was deemed necessary for the successful acquisition and use of the networking strategy.

Training and practice in questioning took the following form. The teacher briefly outlined the importance of formulating probing questions. Probing questions are questions which inquire into the structure of concepts and require deeper processing as opposed to procedural questions of the type " How did you do that ?". Students were then asked to read a section of the text and to answer questions formulated by the teacher prior to listening to the teacher's lecture. Students' success at answering these questions was not important, rather they were to use them as guides while listening to the teacher's lecture. After the lecture, groups reviewed the answers and any remaining unanswered questions, modified, answered or reformulated the questions into new questions.

Subsequently, students were assigned another passage of text to read before listening to a lecture. As before, they were to attempt to answer questions formulated by the teacher. In addition, they were asked to formulate their own questions as a homework assignment. Again, questions served to focus their attention during the lecture. After the lecture, students examined the questions and answers in their groups and formulated a new set of questions. These exercises emphasising the use probing questions became a regular part of instruction.

Networking was explicitly introduced to students in one class period by one of the investigators (who was also one of the teachers participating in this study). The material used for training was selected on the basis of interest, relevance, brevity, and similarity in text structure to the regular classroom text.

Training included the modelling of network construction. Modelling included making one's thinking explicit about how to construct networks and how to use them in order to abstract meaning from the text or lecture. Subsequent to this training, students were provided with opportunities to practice the networking strategy. On two occasions students were asked to help each other in groups to summarize a lecture using networks. In addition, they were also required to construct two networks (on two different topics) at home and to discuss them subsequently in their groups. As well, they were asked to construct three networks in preparation for an examination. Moreover, the classroom teacher incorporated networks into her lectures wherever appropriate by constructing parts of networks with the class.

To address cooperative learning, students were provided with a 15 minute introduction to cooperative learning (Abrami et al., 1993). Two features of cooperative learning were emphasized: individual accountability and positive interdependence. In class work, the former was promoted by having students submit individually prepared homework assignments to their group for revision. The latter was promoted by having the teacher randomly select one revised assignment from each group for correction. In laboratory exercises, individual accountability was promoted by having individual students write up sub-sections of the lab report. Positive interdependence was promoted by having each group collate the sub-sections and write the abstract and conclusions for the submitted group lab report for a single group grade.

Students were assigned to either high scoring groups or low scoring groups on the basis of their scores on the Canadian Cognitive Abilities Test. Within each category, they were randomly assigned to four-member groups. Groups were assigned for the duration of the course. Throughout the semester, each four-member group was required to conduct laboratory experiments. Although these experiments were conducted in pairs, they were discussed and reported in the four member teams. Assessment of group performance took the form of a self-reflection questionnaire which groups were asked to complete. In addition, each group was observed for five minutes as they discussed a problem. The number of exchanges between group members was counted and the participation of individual members was assessed.

Study 3: Biology

The thirty students in introduction to biology were in their fourth semester of schooling at the college level. For the majority, this course was the first and only biology course required for the completion of the pure and applied science program. However, many students in the Pure and Applied Science Program do not see the relevance of this course is for careers in engineering, mathematics, and physics. For the few health science students in the class, biology is an integral component to further study in their chosen field.

The instructor's stated objective was to have students learn the essential concepts of biology; explore the relationships among these ideas; develop facility with their texts; communicate and apply biological information to practical exercises in the lab; and relate prior knowledge and everyday experiences to ideas in the course.

Instruction was delivered by interactive lectures in one and one half hour segments twice a week, and in a three hour lab once a week. Overheads were used extensively and supplemented with other media (e.g., films). Instructional aids included handouts on various topics in the form of maps, notes, and matrices. In the labs a brief lecture introducing the topic was followed by students working within their groups. The teacher and lab assistant went from group to group answering individual or group questions. Note that students were randomly assigned to groups within the first week of classes according to their verbal ability scores on the Canadian Cognitive Abilities Test.

Students were expected to spend a minimum of three hours per week reading the text and completing other homework assignments. Evaluation was based on tests which included multiple choice, matching and occasional essay/short answer questions. The final grade was comprised of two unit tests of 30%, two lab exams of 30%, and a final examination of 30%. The instructor retained 10% of the mark as discretionary. This percentage included lab quizzes, student journals, and her own evaluation of the student's performance.

Training took place in three parts: pre-networking skills training; training in cooperative learning; and, training in networking. Training materials were selected in collaboration with the classroom teacher and incorporated biological information and themes. Training in the uses of the cooperative networking strategy was designed as an integral part of the curriculum.

The initial training phase sought to address gaps in comprehension skills (e.g., information processing) as assessed by students responses to the LASSI. Reinforcing these skills was deemed necessary for successful acquisition of the networking strategy. Therefore, materials on elaboration, summarizing, selecting main ideas, and analyzing text structure were developed and used with the regular content. In addition to such skill training, students were exposed to teacher-generated networks and other graphical representations such as tables and flow charts.

Training in cooperative learning took advantage of the collaborative working relationships displayed by the classroom teacher, researchers, and lab assistant. For example, teacher and researchers worked together to design and present networking training; calling on each other during the workshop and utilizing common resources. This informal training of students in cooperative learning was supplemented by more explicit training such as an ice breaker and a group cohesion exercise.

Subsequently, networking was explicitly introduced to students in a one and one half hour workshop given by the teacher and the investigators. Training included direct instruction and student practice in constructing a network of their own from a short text on choline's impact on memory. Following this workshop, students were provided with guided practice where the teacher demonstrated her use of networking to help her and her students think about the domain.

Whereas networking was primarily used for presenting information to the class and as an aid for student recall of information, cooperative learning was used most often in the labs (i.e., fifty percent of the course was done using cooperative learning). Depending on the resources and the topic, every lab required students to work in two's or four's. Students were given opportunities to practice networking by constructing maps as part of assignments and exams. Therefore, students developed skill through teacher demonstrations, guided practice, and through receiving feedback in the form of comments from their teacher. A research assistant attended class approximately once every two weeks to assist the teacher and students in developing their use of the strategy.

In summary the lab/lecture format, nature of the domain, and the instructional interests of the teacher presented an ideal situation for exploring the possibilities of cooperative networking. Our approach to training emphasized integrating the strategy with the curriculum. We introduced the strategy in a developmental manner by moving from reviewing comprehension skills to demonstration and instruction, followed by practise and feedback. Therefore cooperative learning and networking were combined in this way in biology to foster the contemplation, relation, and meaningful discussion of ideas.

Research Design

Since students could not be randomly assigned to treatments, intact classes were used. For each study, the core design was a non-equivalent pre-test/post-test control group design. The design features and the independent, dependent and moderator variables used in each study are summarized in Tables 1 a), b) and c) below.

Table 1 a). Investigated variables and study features: Study 1. Winter 1992

Discipline:	Subjects:
Quantitative	1 instructor for both classes
Methodology	2 classes (experimental, control)
	67 consenting students
Independent and Moderator Variables	
Instructional Strategy:	cooperative networking vs traditional
Cognitive ability:	verbal and quantitative
Gender	
Dependent Variables:	
Achievement:	common summative final & class test on instructional unit
Affect:	negative and positive feelings about learning the subject
Goals:	mastery, performance, affiliative work-avoidant
Causal Beliefs:	ability, effort, task difficulty, luck, help from peers
Strategies:	information processing, motivational, use of study aids, self testing, selecting main ideas
Teacher Reactions:	interview

Table 1 b). Investigated variables and study features: Study 2. Autumn 1992

Discipline:	Subjects:
Physics	2 instructors
	2 classes (experimental, control)
	72 consenting students
Independent and Moderator Variables:	
Instructional Strategy:	cooperative networking vs traditional
Cognitive ability:	verbal and non-verbal
Gender	
Dependent Variables:	
Achievement:	equivalent class test on instructional unit
Affect:	negative and positive feelings about learning the subject
Goals:	mastery, performance, affiliative work-avoidant
Causal Beliefs:	ability, effort, task difficulty, luck, help from peers
Achievement motivation	
Motivational locus:	intrinsic vs extrinsic
Learning style:	meaning orientation vs reproducing orientation
Teacher Reactions:	interview

Table 1 c). Investigated variables and study features: Study 3. Winter 1993

Discipline:	Subjects:
Biology	2 instructors
	2 classes (experimental, control)
	64 consenting students
Independent and Moderator Variables:	
Instructional Strategy:	cooperative networking vs traditional
Cognitive ability:	verbal
Gender	
Dependent Variables:	
Achievement:	summative final & class test on instructional unit, near-transfer & far-transfer tasks, low-level & high-level questions, comprehension task (all common)
Meta-comprehension:	error detection/correction task
Conceptual structure:	number of: idea units; all combinations of accurate/inaccurate and relevant/irrelevant idea units; elaborations, and measure of structure
Affect:	negative and positive feelings about learning the subject
Goals:	mastery, performance, affiliative work-avoidant
Causal Beliefs:	ability, effort, task difficulty, luck, help from peers
Strategies:	information processing, motivational, use of study aids, self testing, selecting main ideas
Achievement motivation	
Motivational locus:	intrinsic vs extrinsic
Learning style:	meaning orientation vs reproducing orientation
Student Reactions:	journals, questionnaire
Teacher Reactions:	interview

Measures

Cognitive Abilities

Scores from the Canadian Cognitive Abilities Test (Thorndike & Hagen, 1988) were used to categorize students into either low or high ability strata for group assignment. These scores were also used as covariates for achievement, meta-comprehension, and conceptual structures measures. The Sentence Completion test of the Verbal Battery was used in all studies. In addition, the Quantitative Relations and Equation Building tests from the Quantitative Battery were used in Study 1, and the Figure Classification and Figure Analysis tests from the Nonverbal Battery were used in Study 2.

Achievement

In Study 1 (Quantitative Methodology), there were two achievement measures: a class test covering the course content that was taught using cooperative networking, and a summative final covering the entire semester. In addition to the Canadian Cognitive Abilities Test, two class tests (given prior to, and during the networking training) were used as covariates. The achievement tests were teacher-prepared and identical in both treatment and control conditions.

In Study 2 (Physics), there was one achievement measure, a class test covering the course content that was taught using cooperative networking. In addition to the Canadian Cognitive Abilities test, a class test (given prior to the training in networking) was used as a covariate. Class tests were prepared and scored by the teachers. The first class test was identical in both experimental and control classes. However, the second class tests were equivalent but not identical.

In Study 3 (Biology), there were two achievement measures: a class test covering the course content that was taught using cooperative networking, and a summative final covering the entire semester. In addition to the Canadian Cognitive Abilities Test, a pre-test, identical to the first test, was used as a covariate. The achievement tests were teacher-prepared and scored. The tests were identical in both treatment and control conditions. The multiple choice items, on the class test, were classified by researchers into questions assessing low-level knowledge (factual) and questions assessing high-level knowledge (requiring some transfer). In addition, the essay question in the class test, requiring students to compare and contrast biological concepts, was analyzed separately. The students responses to this essay question were also analyzed to determine the students' mental model of these concepts.

Meta-comprehension

An error detection and correction instrument consisting of 10 items covering the content taught during the experimental period was prepared by the teachers and researchers and administered during the common final exam. It was scored by one of the researchers. This was carried out only in Study 3 (Biology).

Conceptual Structure

This analysis was carried out only in Study 3 (Biology). Students were asked to compare and contrast two kingdoms (*Monera* and *Protista*). The compare and contrast protocols were coded in several stages. Firstly, students' protocols were segmented into propositions. A proposition represents the smallest unit of knowledge that can be true or false and is usually identified by the presence of a verb (McNamara, Miller, & Bransford, 1991). The propositions were then segmented into idea units. Idea units are propositional components such as subject, verb, etc. The reliability of the segmentation of protocols into idea units was determined by having two independent coders identify the idea units. Reliability in the form of percent agreement between the two coders was 95%. In cases of disagreement, the two coders reviewed the segmentation rules and came to a consensus.

Secondly, the investigators prepared a template which was used to classify the idea units into categories. These categories were agent (subject of sentence), objects or states, qualifiers (elaborations, examples, etc.), actions (verb of sentence), and, links (conjunctions). They subsequently entered the idea units from the students' protocols under the appropriate category. The inter-rater reliability (calculated as the percent agreement between two coders over 20% of the student protocols) for this classification was 74%. There were two types of disagreement between the coders: 1) inappropriate application of the rules; and 2) insufficient content knowledge. Disagreements of the first type were resolved by referring back to the rules. Disagreements of the latter type were resolved by asking a content area expert in biology.

Thirdly, we were concerned that our coding schema did not distinguish between accurate/inaccurate propositions and between relevant/irrelevant propositions. We therefore asked the teachers to prepare a template of the relevant knowledge pertaining to the topic. The students' propositions were deemed to be relevant if they could be found in some form (accurate or inaccurate) on the teachers' templates. The students' proposition were deemed to be accurate if a verbatim or paraphrase match was found in the teachers' templates. The inter-rater reliability (calculated as the percent agreement between two coders over all the students' protocols) on the accuracy and relevancy of students' protocols was 90%.

Fourthly, the researchers assessed the organization of the students' conceptual structures. Very simple conceptual structures consist of unconnected propositions, each of which consists of an agent, an action, and an object/state. On the other hand, complex conceptual structures consist of propositions connected via conjunctions and containing qualifiers and often multiple objects. We assessed the organization of the students' conceptual structures by computing an index of conceptual complexity. This is the ratio of (total number of idea units-(3 × total number of propositions)) to total number of propositions. By subtracting three for each proposition, the score of a simple proposition becomes zero. Thus, the index of compactness for a simple conceptual structure will be zero. The larger the index, the more complex is the student's conceptual structure.

Finally, the depth of knowledge representation of the students' conceptual structures was assessed. Students can organize their ideas under general principles and supra-ordinate concepts. Depth of knowledge representation was defined as the number of general principles and supra-ordinate concepts present in the students' protocols. The inter-rater reliability was 83%.

To summarize, each student's compare and contrast protocol was scored for the following: number of relevant and accurate propositions (measure of knowledge acquisition), index of conceptual complexity (measure of knowledge organization) and number of general principles and supra-ordinate concepts (measure of depth of knowledge representation).

Affect

Student affect towards learning was measured using an instrument developed by the authors (d'Apollonia, & Glashan, 1992). Exploratory factor analysis[2] was carried out on pretest data collected from that study. EQS (Bently, 1989) was used for all exploratory and confirmatory factor analyses. Listwise deletion of missing data was used. Details of the structural models that were analyzed will be provided upon request. Twelve items that loaded highly on only one of the factors were retained. The structure of the instrument was confirmed (Comparative Fit Index = .87) on data collected from the pilot and experimental studies (approximately 370 students). The instrument measures two correlated (-.41) factors: positive affect (5 items) and

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[2] EQS (Bently, 1989) was used for all exploratory and confirmatory factor analyses. Listwise deletion of missing data was used. Details of the structural models that were analyzed will be provided upon request.

negative affect (7 items). The reliabilities (Cronbach's α) for the two factors are .79 and .88 respectively. Sub-scale scores were computed by calculating the mean across the relevant items.

Goals

Student goals were measured using an instrument developed by Meece et al (Meece, Blumenfeld, & Hoyle, 1988). Confirmatory factor analysis was carried out on pretest data collected from the pilot and experimental studies (approximately 370 students). The four factor model was confirmed (Comparative Fit Index = .85). The instrument measures four correlated goals: mastery (6 items), performance (3 items), affiliative (3 items), and work-avoidance (3 items). The reliabilities of the four goals (Cronbach's α) are .74, .56, .57, and .57 respectively. Sub-scale scores were computed by calculating the mean across the relevant items.

Causal Beliefs

In the study conducted in the winter of 1992, causal beliefs were assessed by five questions, one per causal attribution: effort, ability, task difficulty, luck, and help from peers (d'Apollonia & Glashan, 1992). In the two studies conducted in the fall and winter of 1993, an instrument adapted from Howard (Howard, 1989) was used. We used 15 items assessing causal attributions to success and failure across a number of academic situations. Each item has five response options, one assessing each of five causal attributions: effort, ability, task difficulty, help from teacher, and use of strategies. Sub-scale scores were computed by calculating the number of times each option was selected across all items.

Use of Learning Strategies

Students' use of strategies was measured using five sub-scales of the LASSI developed by Weinstein (Weinstein, 1987). The five sub-scales were Information Processing, Motivation, Study Aids, Self-Testing, and Selecting Main Ideas. Confirmatory factory analysis was carried out on pre-test data collected from the pilot and experimental studies (approximately 170 students). However, the factor structure suggested by the instrument developer was not a good fit (Comparative Fit Index = .35). We therefore eliminated 13 items which either did not load on any factor or loaded highly on multiple factors. We conducted an exploratory factor analysis on the same data and developed a model (Goodness of Fit Index = .85). Therefore we computed the following five sub-scale scores: information processing (9 items), motivation (6 items), study aids (4 items), self-testing (3 items), and selecting main ideas (3 items). The reliabilities of the five sub-scales (Cronbach's α) are .79, .71, .61, .78, and .65 respectively. Sub-scale scores were computed by calculating the mean across the relevant items.

Motivation and Learning Styles

Achievement motivation, motivational locus, and learning style were assessed using a 50 item instrument developed by Donn (Donn, 1990). Confirmatory factory analysis was carried out on pre-test data collected from the pilot and experimental studies (approximately 270 students). However, the model suggested by Donn (Donn, 1990, 1993) was a poor fit of the data (Comparative Goodness of Fit Index = .13). Since the instrument was adapted from an instrument originally developed by Entwhistle and Ramsden (Entwhistle & Ramsden, 1983) we subsequently analyzed the items from the three motivational sub-scales (intrinsic motivation (3 items), extrinsic motivation (3 items) and achievement motivation (3 items)) and from five strategies (deep approach (3 items), relating ideas (3 items), use of evidence (4 items), surface approach (5 items), and syllabus-boundness (3 items)). The reliabilities of the eight sub-scales (Cronbach's α) were .56, .30, .34, .34, .50, .29, .36, and .37. We grouped the strategies into two learning styles: meaning orientation, consisting of the first three strategies (10 items) and reproducing orientation, consisting of the last two strategies (8 items). The reliabilities of the two learning styles (Cronbach's α) were .63 and .45 respectively. Sub-scale scores were computed by calculating the mean across the relevant items.

Teacher interviews

The three teachers who used the cooperative networking strategy were interviewed. A questionnaire was developed and used in the interview process by non-teaching members of the team. The questionnaire consisted of 36 questions which asked teachers to describe their teaching, their use of the strategy, how they changed as a result of using the strategy, and how they dealt with the dual role of being a teacher and a researcher. Interviews were on average two and one-half hours. Teachers were encouraged to provide additional questions and comments which they felt were important to disclose, but were not tapped by the initial set of questions. All interviews were tape recorded and transcribed verbatim.

Although we asked teachers to respond to a number of questions, only those which pertained to teachers' use of the strategy are reported here. In order to obtain a clearer description of teachers' use of the strategy, we concept mapped their interviews. We intend to analyze the concept maps in future work.

Implementation Checks

The effectiveness of the cooperative networking training was assessed by examining students' concept maps, generated individually after the training. Three categories of networks were defined: Good, Acceptable, and Unacceptable.

The criteria were based on the following characteristics: appropriate number of nodes, presence of a hierarchical structure, number of labelled relationships, and ratio of node-link relationships to node-link-node relationships. The number of nodes depended on the domain or the topic in question. In the biology class students were asked to construct a map of a topic which included five major concepts. Therefore, for the biology students' maps, the appropriate number of nodes was five. In contrast, physics students were asked to summarize their knowledge of the concept 'Interference' which included three methods of dealing with interference, and seven variables. Therefore, for the physics students' maps, the appropriate number of nodes was ten. In the QM class, students were asked to construct a concept map of a text which contained four major concepts. Therefore, for the QM students' maps the appropriate number of nodes was four.

The information to be mapped was hierarchical and so at least one occurrence of a hierarchy was required for a map to be considered a good concept map.

Students were evaluated on the number of named relationships in their concept maps. Because different instructions were given to students, different cutoff scores were set for different subject areas. In physics and QM there were a number of repetitive relationships and therefore students were instructed to not explicitly label the same relationship each time. However, in biology repetitive relationships were rare and therefore explicit labelling of each relationship was emphasized. As a consequence of these different instructions, it became difficult to assess whether students had not labelled the relationship because they deemed it as repetitive or because the student in fact did not know the relationship between the concepts. As a result of the different instructions and, consequently, the researchers' inability to assess the reason behind the missing labels, it was decided that not all relationships need to be labelled in a good map. Therefore, in biology a good map must have 80% of relationships labelled. In quantitative methodology and physics it was 50%. All percentages were derived by taking the ratio of the number of named relationships over the total number of relationships.

The researchers examined the ratio of number of node-link relationships over number of node-link-node. In good maps the students had two or more nodes that were linked by a named relationships, i.e., node-link-node. Students who drew a node with a line extending outward from the node but not linked to another node or concept, ie.e, node-link, were presumed not to have an understanding of what constitutes a concept map. Therefore, in scoring the student maps, the researchers counted the number of node-link relationships over the number of node-link-node relationships. If the ratio was less than one, the map was considered to be a good map.

In all classes a good map satisfied all four above criteria, an acceptable map satisfied three out of four, and maps that satisfied two or less were rated non-acceptable.

The reliability of the implementation check was calculated on 20% of the protocols using the formula, $A/(A+D)$, where A = # of agreements and D = # of disagreements. Reliability in the form of percent agreement between the two coders was 82%. In cases of disagreements, the two coders reviewed the coding rules and came to a consensus.

We considered students to be "trained" in the networking component of the cooperative networking strategy if they were able to produce a "good" or "acceptable" map. In the quantitative methodology class 75% (9/12 students) were trained. In the physics class 87% (19/22 students) were trained. In the biology class 96% (21/22 students) were trained.

Data Analysis

Since there were some pre-existing differences between experimental and control classes, analysis of covariance (MANCOVA) was used to adjust post-test means for initial non-equivalence. The covariates in all cases were the appropriate pretest measures. In 12 out of 15 tests, the assumption that the variance-covariance matrices are homogeneous were not rejected at an α level of .05 (Box's M test). Therefore, the assumptions of MANCOVA were met. Multivariate tests on all the variables within a construct (e.g., mastery, performance, affiliative and work-avoidance goals within goal orientation) were first carried out. If the tests were at least marginally significant[3] ($\alpha < .10$), further univariate tests on the appropriate variables were carried out. Post-hoc comparisons were made using Duncan's procedure (Kirk, 1984).

[3] These are presented in table form in the appendix.

RESULTS AND DISCUSSION

Study 1: Quantitative Methodology Implementation

The questions addressed in this study were all those stated in **Research Objectives** (page 28) except number 5. concerning acquisition and organization of knowledge, and depth of knowledge representation.

Motivation

We studied two aspects of motivation in this study: goal orientation (mastery, performance, affiliative, and work-avoidance) and causal beliefs about success and failure (ability, effort, task difficulty, luck, and help from peers). There were no significant effects on goal orientation.

There was a significant effect of instructional treatment on causal attributions to help from peers, $F(1,29) = 6.20$, $p = .019$. Students taught using cooperative networking made significantly more causal attributions to help from peers (adjusted $M = 3.84$) than did students taught by traditional methods (adjusted $M = 2.81$).

Strategies

We examined five strategies that students reported using: information processing, motivation, use of study aids, self-testing, and selecting main ideas. There was a significant effect of instructional treatment on students' reported use of strategies involving the selection of main ideas, $F(1,30) = 9.21$, $p = .005$. Students taught using cooperative networking reported using such strategies significantly more (adjusted $M = 3.15$) than did students taught by traditional instruction (adjusted $M = 2.50$).

Affect

There were two measures of feelings about learning used in this study: positive and negative affect. There was a significant main effect of gender on negative feelings towards learning quantitative methodology, $F(1,33) = 4.23$, $p = .014$. Male students had significantly more negative feelings about learning quantitative methodology (adjusted $M = 2.84$) compared to female students (adjusted $M = 2.13$). Note that since this result is not a treatment effect it will not be mentioned again.

Achievement

There were two measures of achievement used in this study: scores on a common summative test and scores on the common class test covering the material taught during the two weeks when cooperative networking was used extensively in the experimental class. There were significant pre-existing differences in quantitative abilities between students in the experimental class and those in the control class ($F(1,56) = 14.8$, $p < .001$). Students in the control class performed significantly better ($M = 26.5$) than did students in the experimental class ($M = 21.7$).

There was a significant effect of instructional treatment on student performance on the common final, $F(1,29) = 6.67$, $p = .015$. Students who were taught using traditional means performed significantly better (adjusted $M = 6.22$) than did students taught using cooperative networking (adjusted $M = 5.00$). However, there was a significant interaction between instructional treatment and gender on student performance on the class test of the material taught using cooperative networking, $F(1,29) = 10.19$, $p = .003$. While female students who were taught using traditional methods (adjusted $M = 8.05$) outperformed female students taught using cooperative networking (adjusted $M = 5.66$); male students taught using cooperative networking (adjusted $M = 6.73$) outperformed male students taught by traditional methods (adjusted $M = 5.66$).

Teacher Reactions

We interviewed the experimental teacher concerning her use of the strategy. This is a summary of her responses.

This teacher believes that the networking part of cooperative networking is useful for creating and organizing ideas about a domain. She reported that concept mapping was a valuable tool in clarifying her own thought processes about quantitative methods. The strategy helped her re-visit already understood material from the perspective of a first time learner. This allowed her to see clearly what the focus of her presentations should be.

Her maps formed the basis for her lectures, implicitly or explicitly, and provided a framework for moulding students' understanding of statistics. Using this framework, she developed and communicated a general procedure for problem solving which students were expected to apply. She supported student use of the procedure implicitly by continuing to use mapping to structure her problem solving presentations, and explicitly by modelling her thought processes and by providing students with feedback on their problem solving.

She combined the networking and cooperative learning components in three ways: students worked in groups, attempting to create and revise networks which would serve as guides to solving problems; classes were structured so that students practised solving problems in small groups; class quizzes, based on individual homework assignments, were written and graded as a group.

However, this class was the teacher's first experience with first year students in the social science program. She felt that they were less academically motivated and skilled than the students she had previously taught using cooperative learning. For example, the quantitative methods students often engaged in work-avoidance behaviours, especially when they were uncomfortable with their understanding of the course topic. Thus, the teacher reported that classroom management problems interfered with the effective implementation of the strategy. Consequently, she recommended that student and classroom characteristics be taken into consideration prior to intervention. For example, students' tardiness needs to be addressed before introducing group work.

Discussion

This study demonstrated that cooperative networking enhanced: students' causal attributions to help from peers; use of strategies involving the selection of main ideas; and, if the students were male, their performance on an achievement test assessing their understanding of the material taught using cooperative networking. We were not able to show that cooperative networking enhanced their academic goals, their causal attributions to effort, or their feelings towards learning quantitative methodology. In addition, we demonstrated that students who were taught by traditional instructional methods, emphasizing direct instruction, whole class discussion and individual seat work, performed significantly better on a final examination assessing the entire semester's work. In the discussion which follows we attempt to explain these findings with reference to the nature of the cooperative networking strategy and a theory of settings proposed by Ruth Garner (Garner, 1990).

The networking component of the cooperative networking intervention in this study emphasized: the selection of main ideas expounded in the students' textbook; the connection of these ideas with the students' experience of social science; and the organization of these ideas into a coherent body of knowledge that could be used to solve research problems. Therefore, it is not surprising that the students taught by cooperative networking reported a significantly greater use of strategies involving the selection of main ideas than did students taught traditionally.

Such attention to the important concepts in a domain has been shown to enhance recall of geology (Holley & Dansereau, 1984; Holley, Dansereau, McDonald, Garland, & Collins, 1979), human biology (Rewey, Dansereau, & Peel, 1991; De Simone, 1993), and psychology (Lambiotte, Peel, & Dansereau, 1992). Some of these studies were carried out in "laboratory" conditions, and thus measured recall over a limited period of time. Two important questions commonly arise when strategy training is implemented in a classroom using either an immersion or embedded approach. First, does the strategy training that occurs in the classroom reduce learning "in breadth", e.g., as measured by performance on an achievement test covering the whole semester? Second, does the strategy enhance learning "in depth", i.e., application of knowledge, as opposed to recall, as measured by an achievement test covering only the material taught over a short period of time using the strategy. In this study we addressed both of these issues.

The strategy training was embedded/immersed in the course content. We estimate perhaps 50% of class time was spent on modelling the strategy and on group work. Testing for breadth was carried out by a comparison of final exam scores between students in the control and experimental sections. Students in the control class performed significantly better on the final than did students in the experimental class. This result may indicate that the equivalent time spent in the control class on direct instruction and individual seat work, combined with direct instruction, is a more effective instructional strategy. However, there are other possible explanations for this finding. First, the control students had significantly greater quantitative abilities (results of the CCAT) than did students in the experimental class. Although, we attempted to control for this pre-existing difference by statistical means (ANCOVA), there is a possibility that this was not effective. Second, since the same instructor taught both the control and experimental classes, the control students may have benefitted from the teacher's organization of the course content, constructed from networking, i.e. the control students gained benefits from the strategy without the investment of time made by experimental students. A similar experiment indicated that the knowledge structure of the instructor may be the key ingredient in student success. Third, in this implementation, individual accountability was structured into the group work by having frequent testing (four class tests during 15 weeks and one final) which the students wrote individually. However, individual accountability describes students' perceptions of the individual contribution to a group task, not to an individual task. Further, as Slavin (Slavin, 1983) has stressed, individual accountability is required in group work if it is to enhance achievement. Thus, in this study the lack of proper individual accountability might have contributed to the lack of performance shown by experimental class students. We speculate that the mechanism involved here is that experimental class students may have relied on group-members to help them solve problems but that such help was not available to students during test situations, thus lower test scores would be anticipated. Attempts were made to address some of the above problems in subsequent implementations.

Male students taught by cooperative networking performed significantly better on the test assessing "in depth" knowledge of the specific topic than did male students taught traditionally. On the other hand, female students who were taught using traditional methods outperformed female students taught by cooperative networking. In other words, the results indicate that female students benefitted by direct instruction followed by practice while the male students benefitted by cooperative networking. This result may reflect gender differences in preferred instructional style.

One would expect that training students in cooperative networking would increase their mastery, ego and affiliative goals but decrease their work-avoidance goals relative to those of students taught traditionally. We were not able to show any differences in academic goals between students taught by cooperative networking and students taught traditionally. Many of the students who participated in this study did not know why they had to learn quantitative methodology and resented being in the course. Moreover, many of the students did not have well-articulated academic goals. Therefore, it is not surprising that we were not able to show differences in goal structures.

The cooperative learning component emphasized the mutual help and support that students could provide to each other in developing an understanding of and expertise in quantitative methodology. Thus, their causal attributions to help from others should increase relative to those of students taught traditionally. In fact, students taught by cooperative networking did make significantly more causal attributions to help from others than did students taught traditionally.

To a certain degree the two attributions, to personal effort and to help from others, are diametrically opposed to each other. To the degree that you attribute success to help from others, you diminish causal attributions to personal effort. This is especially a danger when individual accountability is not stressed. Corno and Mandinach (Corno & Mandinach, 1983) have suggested that cooperative learning could have detrimental effects on students' self-regulated learning by promoting dependency on others' efforts rather than on ones' own effort. Graham and Baker (Graham & Baker, 1990) have suggested that when students with low-ability perceptions are helped by others, the help that is given confirms their low-ability perceptions. This in turn may reduce their effort and subsequent learning. While in this study we did not see any difference in causal attribution to effort, the above mechanism may have played a role in the inferior performance of the experimental students on the final exam.

Study 2: Physics Implementation

The questions addressed in this study were all those stated in **Research Objectives** (page 28) except numbers 2. and 5. concerning use of learning strategies and concerning acquisition and organization of knowledge, and depth of knowledge representation.

Motivation

We studied four aspects of motivation in this study: goal orientation (mastery, performance, affiliative, and work-avoidance); causal beliefs about success and failure (ability, effort, task difficulty, use of strategies, and help from teacher); achievement motivation; and, achievement locus (intrinsic, extrinsic). There were no significant effects on any variable.

Affect

There were two measures of feelings about learning used in this study: positive and negative affect. There was a significant interaction between instructional treatment and gender on negative feelings towards learning physics, $F(1,51) = 5.31$, $p = .025$. Female students taught by cooperative networking had significantly fewer negative feelings towards learning physics (adjusted $M = 1.56$) than did male students taught by cooperative networking (adjusted $M = 2.38$). However, female and male students, taught by traditional methods, did not differ in their negative feelings towards learning physics (adjusted $M = 1.72$, and 1.68, respectively).

Learning Style

There were two learning style measures used in this study: meaning and reproducing orientation. There were no significant effects on these learning styles in this study.

Achievement

There was one measure of achievement used in this study: scores on a class test covering the material taught during the two weeks when cooperative networking was used extensively in the experimental class. There were no significant effects on achievement.

Teacher Reactions

We interviewed the experimental teacher concerning her use of the strategy. This is a summary of her responses.

In her quest to help students to become more astute physics thinkers, she acknowledged students as co-learners with intellectual capacity. To prepare them for this, she created a forum for dialogue whereby small groups of students could think actively and constructively about physics. Moreover, her approach to cooperative networking was a dynamic one in that she tried to alter the use of the strategy in response to changes in students' skills, knowledge, and interests. Moreover, she guided students in making sense of the strategy for their own purposes so that they could become active, resourceful, and strategic learners who are responsible for their own learning.

This teacher believes that the cooperative networking strategy is useful in helping students think about ideas in physics. However, she believed that students need certain skills such as language fluency and questioning prior to engaging in the construction of maps. Consequently, she has added questioning skills instructions to her overall training in cooperative networking.

She also felt that cooperative networking require deep reevaluation of the course content as well as organization of its presentation. Consequently, the initial investment of energy and work on the part of the teacher is rather demanding. It is to be expected that once an appropriate curriculum has been developed, the heavy work load will diminish. An important aspect of this strategy is that students construction of meaning leads to less predictability in the nature of their work. Consequently more time must be spent in evaluating their work. However, she contends that if understanding and constructing one's own meaning are the teaching goals, then such an investment is certainly worthwhile.

Discussion

The most important finding in the physics implementation is the observation that there was no significant difference in motivation, learning style and achievement between students instructed using cooperative networking and students instructed using traditional methods. There was a significant difference between experimental and control students in the measure of negative feelings towards learning physics. The interaction between treatment and motivation/learning style requires further statistical analysis which is not yet complete. Consequently, we will focus our discussion on the effect of the treatment on achievement and on negative feelings towards the learning of physics.

Both networking (Dansereau, 1991; De Simone, 1993) and cooperative learning (Cooper, 1989; Cuseo, 1990; Witmer & Kealy, 1993) have been shown to result not only in a higher level of thinking skills (e.g. application, evaluation and synthesis, better performance on tasks requiring comprehension), but also in better performance in tasks requiring recall. Thus, we expected to observe a significant difference in achievement between experimental and control students. We hypothesized that a combination of these two strategies would exhibit a synergistic effect, i.e. enhance the effectiveness of both. The lack of effect in physics could possibly indicate that:

- the requirements of the strategy were mismatched with the students' characteristics;
- the strategy was mismatched with the learning tasks of the course;
- the types of achievement promoted by the strategy were mismatched with the types of achievement measured;
- the knowledge structure presented in both classes was identical, even if the strategies were different;
- or, the strategy is just not effective.

Levin (Levin, 1986) proposed a principle which says that a learning strategy is only effective if there is a match between the learner characteristics and the strategy. In his opinion, the learner's competence in the use of strategies, as well as domain specific competence, is a critical factor in the effectiveness of any strategy. Schmid (Schmid, 1992) believes that there is a critical phase in learning at which the use of concept mapping is effective. He believes that using the networking prematurely, before students have acquired sufficient declarative and some procedural knowledge, may be counterproductive. One of us experimented with the timing of usage of networking in a Classical Mechanics course. Although there was no control class to compare achievement, the effect on students' positive feelings towards learning were remarkable. In this implementation, unlike the experiment, networking was used as a review device to consolidate knowledge in a manner similar to Lambiotte's implementation (Lambiotte, Peel, and Dansereau, 1992). We are lead to speculate that the absence of a significant effect in our experiment could be attributed to our students' lack of minimal competence in the domain at the time that they were asked to implement the strategy. This possibility will be tested in our future research.

We implemented the strategy in the final CEGEP science physics course. Students in their last semester of physics are characterized by their fairly rigid understanding of what a physics course should be and what it is important to do to produce satisfactory achievement. Although they may have become competent in the use of our strategy (in principle), their prior experiences probably diminished any effect of the networking. Based on practices common in the physics department at Vanier, students expressed their belief that the discussion of concepts and relationships between concepts is not a relevant activity in a physics class. In some sense, the cooperative networking contradicted their beliefs about learning physics. It has been shown that we have a tendency to disregard information which contradicts our beliefs. Thus, it could be that the strategy was rejected on this ground, and because of that, did not have a measurable effect. This possibility requires further testing in an introductory course in physics.

Cooperative networking requires an active search for meaning. Students are asked to wrestle with concepts, spend time and energy in discovering how a concept fits into the knowledge structure of the domain. Notably, time is an important factor because the construction of a network can be a tedious process. Students were required to edit their concept maps many times. Students entered the course accustomed to quick oversimplification of concepts. It is possible that the teacher in the experimental class was not sufficiently consistent in rejecting such oversimplification. Consequently, students may have rejected the newer and more complex strategy in favour of the older and simpler, even if imperfect, method. Although this phenomenon has been described (Spiro et al, 1991), it would require further analysis of the entire teaching method used in the experimental class before we could safely attribute the lack of measurable effect to this cause.

Due to the vagaries of scheduling, 18 of the 38 students in the experimental class were also registered in one particular biology class. While these students were participating in the experiment in their physics class they were also asked to participate in the pilot implementation in biology. This meant that they were asked to write the same pretest and post-test twice, it meant that they were asked to write the CCAT test twice, and also it meant that they were trained twice in concept mapping. Many of them complained and stated that they felt as if they were guinea pigs. Because of both the above mentioned over testing and a more general resentment towards any additional testing, we abandoned plans to use a special achievement test. Instead, we opted to use regular class tests. The general resentment towards non-course testing affected the atmosphere in the class and the teacher believes that it had an effect on the results of the experiment.

Cooperative networking may not be an optimal strategy for the tasks students were required to do in the physics course. Levin (Levin, 1986) has argued that for any strategy to be effective it has to be appropriate for the task. Further, he also states that appropriateness is validated empirically through the measurement of effectiveness in accomplishing the task. Although his argument appears to be circular, it seems reasonable that different tasks require the use of different strategies. Since problem solving is a pivotal task in physics, and since there was no significant effect on achievement, we may be lead to believe that cooperative networking is not an effective strategy for this task.

The effectiveness of a strategy is not the only factor in achievement since "time on task" is considered to be one of the most important factors in achievement (Walberg, 1991). We note that on the tasks which were subsequently tested in the achievement tests, experimental students spent less time than control students. We note that the experimental class students somehow were able to compensate for this lack of practice in problem solving since, as noted above, there was no significant difference in measures of achievement. Thus, although we have not explicitly tested for deeper understanding, we may infer that the experimental students acquired and used a richer conceptual structure to compensate for lack of drill. Lambiotte's (Lambiotte, Peel, and Dansereau, 1992) study demonstrates similar findings. In their study students showed ambivalence towards mapping, did not use it much, had more difficulties in concentration, and yet they were at least as good in problem solving as control students.

The achievement tests in this experiment consisted of traditional type exams which require rapid execution of rehearsed procedures in a short time period. We did not test problems that would have required development of a substantially novel procedure directly from conceptual understanding. Furthermore, due to scheduling difficulties, the exams in the two classes, experimental and control, were not identical. Although both the experimental and control teacher were testing similar principles, the actual problems were different, and in retrospect, we note that the level of difficulty was sometimes different. In addition, no attempt was made to test the reliability of grading. Thus, any conclusion concerning the affect of the strategy on achievement needs further testing.

None of the conceptual discussion which took place in the experimental class was tested by exams. As Tobias (Tobias, 1990) points out students are not motivated to take seriously work which is not on exams. Therefore, students in the experimental class may not have been motivated to use the strategy because we had not demonstrated its value, in this sense. A subsequent implementation in a Classical Mechanics course (without control class) allowed the testing to include items for which networking was clearly useful. In that setting, students reported using the strategy and demonstrated their motivation to use it. Thus, the lack of use of cooperative networking by experimental class students may also be responsible for the lack of difference between achievement of control and experimental students.

Despite the fact that two different instructors taught the control and experimental classes, close cooperation on the part of the two instructors led to virtually identical knowledge structures as presented in the two sections. Thus, any possible advantage that experimental section students might have been expected to gain because their teacher was restructuring her knowledge structure were lost. As noted above, a similar experiment indicated that the knowledge structure of the instructor may be the key ingredient in student success.

Female students in the experimental class had significantly fewer negative feelings towards learning physics than their male counterparts. No such difference was observed in the control class. It would appear that the cooperative learning component of our strategy had a differential effect based on gender. This will be remarked upon at greater length in the General Discussion section below.

Study 3: Biology Implementation

The questions addressed in this study were all those stated in **Research Objectives** (page 28).

Motivation

We studied four aspects of motivation in this study: goal orientation (mastery, performance, affiliative, and work-avoidance); causal beliefs about success and failure (ability, effort, task difficulty, use of strategies, and help from teacher); achievement motivation; and achievement locus (intrinsic, extrinsic).

There was a significant effect of instructional treatment on mastery goal orientation, $F(1,40) = 8.98$, $p = .005$. Students taught by cooperative networking were significantly more mastery oriented (adjusted $M = 3.52$), than were students taught with traditional instruction (adjusted $M = 2.92$).

There was a significant main effect of gender on attributions to help from teacher for success and failure, $F(1,39) = 11.20$, $p = .002$. Female students attributed success and failure to help from the teacher (adjusted $M = 1.68$) significantly more than did male students (adjusted $M = .60$). Note that since this result is not a treatment effect it will not be mentioned again.

There was a significant effect of instructional treatment on achievement motivation, $F(1,43) = 4.31$, $p = .044$. Students taught by cooperative networking had significantly greater achievement motivation (adjusted $M = 3.61$) than did students taught by traditional methods (adjusted $M = 3.13$). However, there were no significant effects on achievement locus.

Meta-comprehension

Metacomprehension was assessed by students' performance on an error detection and correction task. There was a significant interaction between instructional treatment and gender, $F(1,53) = 4.31$, $p = .043$. Female students who were taught by cooperative networking performed significantly better at the error-detection and correction task (adjusted $M = 6.18$) than did female students taught using traditional methods (adjusted $M = 4.26$) or male students taught by either cooperative networking (adjusted $M = 4.89$) or traditional methods (adjusted $M = 4.72$).

Affect

There were two measures of feelings about learning used in this study: positive and negative affect. There was a significant interaction between instructional treatment and gender on positive feelings towards learning biology, $F(1,41) = 5.74$, $p = .021$. Female students taught by cooperative networking had significantly more positive feelings towards learning biology (adjusted $M = 3.81$) than did female students taught by traditional methods (adjusted $M = 2.57$), and male students taught by either cooperative networking (adjusted $M = 3.15$) or traditional methods (adjusted $M = 2.99$).

Learning Styles

There where two learning style measures used in this study: meaning and reproducing orientation. There was a significant effect of instructional treatment on meaning orientation, $F(1,42) = 8.68$, $p = .005$. Students taught by cooperative networking had a significantly greater meaning orientation (adjusted $M = 3.56$), than did students taught with traditional instruction (adjusted $M = 3.17$). Analysis of the sub-scale scores indicated that the significant effect was on relating ideas, $F(1,41) = 4.84$, $p = .034$. Students taught by cooperative networking reported relating ideas significantly more often (adjusted $M = 3.75$) than did students taught by traditional methods (adjusted $M = 3.24$).

Conceptual Structures

There were three measures of conceptual structure used in this study (knowledge acquisition, knowledge organization, and depth of knowledge representation). There were significant effects of instructional treatment on both knowledge acquisition, $F(1,45) = 20.89$, $p = .001$, and knowledge organization, $F(1,45) = 7.98$, $p = .007$. Students who were taught using cooperative networking acquired more knowledge than did students taught traditionally (adjusted $M = 9.17$ and 3.95, respectively). Moreover, their knowledge structures were more complex, and therefore more organized (adjusted $M = 1.25$ and .75, respectively).

Achievement

There were two measures of achievement used in this study: a common summative final and a common class test covering the material taught during the two weeks during which cooperative networking was used in the experimental class. There was a significant effect of instructional treatment on student performance on the common class test, $F(1,33) = 13.62$, $p = .001$. Students who were taught using cooperative networking performed significantly better (adjusted $M = 5.01$) than did students taught using traditional instruction (adjusted $M = 2.96$).

The effects of the cooperative networking on low-level, high-level, and comprehension questions of the test were then analyzed. Cooperative networking enhanced students' performance on low-level questions $F(1,35) = 5.47$, $p = .025$, on high-level questions, $F(1,35) = 4.92$, $p = .033$, and comprehension, $F(1,35) = 14.68$, $p = .001$.

Teacher Reactions

We interviewed the experimental teacher concerning her use of the strategy. This is a summary of her responses.

Having had several opportunities to experiment with cooperative networking, the second teacher had become interested in the strategy as a vehicle to improve her teaching. She treated cooperative networking as two separate strategies. She used networking to organize ideas for her students, believing that this would allow them to arrive at a better understanding of the domain. Her course served as the students' basic introduction to biology. She focused on preparing expert maps to use as the basis of lectures, and as study handouts for the students.

Weekly journals and cooperative learning were used to develop a close rapport with her students. She feels that getting to know her students as individuals is integral to her teaching. In addition, cooperative learning was used to help students to learn from each other and to appreciate each other's contributions. However, although students worked in groups and were held accountable for their own learning, they were not instructed in cooperative learning, nor required to work together. Further, they were not expected to resolve conflicts. Thus, the degree of cooperation was determined by the inherent characteristics of the group.

This teacher believes that the strategy is a great organizational tool to help her students make sense of the vast amount of information in biology. She also contends that the adoption of the cooperative networking strategy has made her a better teacher by increasing her opportunity for a personal rapport with students. However, she reports that cooperative networking requires a serious commitment in time, effort, and thought to implement. Therefore, this may not be a suitable strategy for those who prefer not to make that commitment.

Discussion

The results obtained in this study present interesting findings concerning the impact of the cooperative networking strategy on attributional, motivational, affective, and cognitive outcomes. First, students instructed in cooperative networking had a significantly greater meaning orientation than did students taught using the traditional method. An examination of this variable revealed that significant effects existed only for relating ideas, although the means were in the predicted direction for the other components (deep approach and testing and evidence). It is not surprising to find that the relating ideas component reached significance. The teacher often reminded her students that a distinctive advantage of networking over other types of representation was in its flexibility to represent a multiplicity of relationships between ideas.

Second, experimental participants performed better than did controls on achievement tests comprised of rote and comprehension questions. An explanation for this better performance by the experimental group probably lies in the explicit focus of the strategy on discussion of both concepts and the links between concepts. Nothing similar to this took place in the control class. We believe that the focus of the strategy leads to increased student comprehension, which in turn improves their recall of facts. Studies conducted on networking have found networking to be particularly suited to tasks which require students to make inferences and build relationships (Lambiotte, Peel, and Dansereau, 1992; De Simone, 1993). Similarly, cooperative learning has been shown to enhance performance on achievement tests tapping both low and high level thinking (Abrami et al, 1993).

Third, results from the mental modelling task showed that experimental participants not only were able to retain more information and thought that they could relate ideas, they were also better able to actually relate and organize ideas than were the control participants. Cooperative networking enabled students to learn meaningfully by requiring them to actively think about ideas, organize them, relate them, and elaborate them. Consequently, this led to a coherent and rich body of knowledge.

Fourth, the results showed that students taught by cooperative networking were not only better than control students at acquiring ideas and organizing them, but also they were significantly more mastery oriented than were students taught with traditional instruction. These results suggest that cooperative networking helps students to develop a more valuable orientation towards learning.

Fifth, females taught by cooperative networking had significantly more positive feelings towards learning biology than did female students taught by traditional methods and males taught using either methods. It is possible that working with others made the classroom setting more comfortable for female students and thus led to an increase in positive feelings towards learning biology on their part. In fact, Tobias (1990) reported that females are less likely than males to do well in sciences because females perceive science as competitive and unfriendly.

Sixth, female students who were taught using cooperative networking performed significantly better at error detection and correction task than did females taught using a traditional approach or males using either instructional method. There is a body of literature which suggests that whereas females question their own abilities and understanding of situations, males do not. Consequently, males are more likely to forge ahead with tasks than are females. The latter may be hindered by the nature of their self-questioning. In this study, however, females tendency to question acted in their favour in the experimental group. Working in groups and learning to challenge ideas in a positive manner may have promoted females' tendency to question while simultaneously empowering them with a tool to proceed in detecting and correcting incomplete or incorrect information.

In summary, these results show that the strategy promoted better organization and relating of ideas than did traditional instruction. In addition, cooperative networking also enhanced achievement on a class test tapping both low and high level thinking, confirming earlier work done in cooperative learning and networking. Further, cooperative networking had a positive effect on non-cognitive outcomes, i.e., affect and orientation. Perhaps cognitive and non-cognitive variables are related in some as yet unknown way. Investigations that would explicate such relationships would certainly be worthwhile to pursue as we need to understand not only whether a strategy is effective, but also, why.

The results also showed that instruction in cooperative networking impacts males and females differently in terms of comprehension monitoring. Further exploration of the connection between the strategy and gender would be useful.

GENERAL DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

Knowing *whether* a strategy is or is not effective, comprises only part of a researcher's work. Another important part consists of knowing *why* a strategy succeeded or failed to do so and *how* it did so. Research into *whether*, *why*, and *how* can be conducted either as laboratory research or in a classroom. Although students' uses of learning strategies are imbedded within the classroom context, most strategy research is conducted in laboratory settings (Garner, 1990). However, both the laboratory and the classroom settings have drawbacks and benefits for the researcher.

If testing theory-based hypotheses by ruling out rival hypotheses is the major objective, then laboratory settings are ideal (Salomon, 1991). However, it is extremely difficult, if not impossible, to maintain treatment fidelity across classroom settings. Since teaching and learning are social acts requiring all participants to respond spontaneously to each other, teachers will use a strategy in a manner that they perceive best meets the needs of their class and not according to a prescription set out by researchers. That is, a teacher's first responsibility is to their class (Wong, 1993). This limits the degree to which researchers using classroom settings can test hypotheses by eliminating rival hypotheses.

A major drawback of laboratory settings is that they are not suited to discovering what would happen given normal conditions in a classroom. The environment in a classroom is much richer, and thus the classroom setting allows researchers to explore important contextual variables that moderate strategy use and effectiveness (Garner, 1990). That is, the strength of systemic approaches is in their ability to explicate the "pattern of interrelations among classroom events" (Salomon, 1991, p 16).

Thus, Salomon (Salomon, 1991) also recommends that the two approaches are complementary and so both should be used to understand classroom interventions. In this research project, we conducted three studies in which three different teachers taught three different subjects to three groups of students. Variability was rampant. We did not test the strategy in a laboratory setting since it was not available to us.

In this discussion we will note what some of the contextual variables are and how they may have affected outcomes (strategy use and effectiveness).

Characteristics of the physical setting

The class size varied from a low of 22 in the physics' pilot study to a high of 38 in the physics' experimental class. Our teachers felt that class size made a difference in the effectiveness of the strategy intervention. The larger class size posed problems in that the noise level and physical crowding often disturbed group work. It lengthened the time that it took students to get into and out of their groups, to share resources, to exchange completed work, etc. Since there were more groups, it reduced the amount of attention and guidance the teacher could provide to each group. Consequently, in the larger classes students felt that too much class time was spent on teaching learning strategies rather than teaching the content. In the smaller classes, less time was spent on the strategy and therefore students were less likely to resent and therefore resist cooperative networking. In effect, some of the differences in outcomes among the three studies may be attributable to the differences in class size.

Class schedules also varied. The quantitative methods course was a two-hour class scheduled at 8 AM, while the biology and physics classes were one and a half-hour classes scheduled later in the day. The early class meeting time in the quantitative methods class posed a problem in that students were often late. Groups which had late arrivals had difficulty in completing tasks. Also, the longer class time may have negatively affected the implementation in that students were used to class lengths of one or one and a half hours. Their attention and concentration were stressed by the longer class time. Thus, differences in class scheduling may have contributed to the variation in outcomes for the three experimental classes.

Characteristics of the teaching of each domain

Physics textbooks have been characterized as being procedurally driven rather than conceptually based and often incoherent and lacking in conceptual organization (Gordon, 1993). The physics student must: transform formulae and mathematical symbols into meaningful concepts; infer relationships among concepts; relate "text-book" examples to "real-life" examples; and, finally build a meaningful conceptual structure (Alexander & Kulikowich, 1992) from all of this. Thus, comprehension relies heavily on the reader's ability to transform, infer, relate, or in a single word, elaborate. On the other hand, biology textbooks are highly descriptive. Because they have many "seductive" details they are amply provided with graphic organizers (including concept maps). Thus, the student must: extract important ideas; subsume details under more general headings; organize a large amount of information; and, uncover an underlying conceptual structure. Thus, comprehension relies heavily on the reader's ability to summarize (using some effective organizational scheme). Quantitative methods texts, written for the social sciences, more closely resemble biology texts than physics texts. Thus, the cognitive processes engaged in by students while they used cooperative networking as a tool to gain understand of their textbook differed across the domains. Hence, differences in the nature of the teaching of each discipline possibly contributed to the differences in outcomes. Moreover, these discipline specific teaching differences lead to differences in the manner in which cooperative networking was implemented by the teachers (see below).

Characteristics of the implementation

Because of both discipline specific teaching differences and differences in instructional objectives, the three teachers implemented cooperative networking in dissimilar fashions. The biology teacher used cooperative networking as an instructional strategy, providing students with concept maps as advance organizers and summarizers. Studies have shown that providing students with schemata facilitates conceptual understanding (Klausmeier, 1990). Students immediately saw a "pay-off" for concept mapping and were likely to then value it. The physics and quantitative methods teachers used cooperative networking as a learning strategy. By modelling the process they encouraged students to construct their understanding of the domain. This is not only a more difficult task for a learner, perhaps requiring prior understanding of the separate topics, it may also occur later in the developmental process.

Researchers (Rumelhart & Norman, 1981; Shuell, 1990; Mosenthal & Kirsch, 1992) have suggested that as learners mature in their understanding of a topic, they progress through an initial *accretion* stage (the acquisition of new-information by its addition to pre-existing conceptual structures), an intermediate *tuning* stage (the slow modification of conceptual structures), to a final *restructuring* phase (the construction of new schemata by the subsumption of surface features by general principles). Both the learning processes and the salient variables affecting meaningful learning change systematically during this developmental cycle (Shuell, 1990). It may well be that the biology teacher was using cooperative networking to facilitate accretion while the physics and quantitative methods teachers were using the strategy in an attempt to enhance restructuring. The students in the latter domains may have not been adequately advanced in their conceptual understanding of the domains to profit from the strategy.

Differences in outcomes may also be attributable to differences in the researchers' operational definition of the cooperative networking strategy and/or the teachers' experience with the strategy. The quantitative methods teacher implemented the first draft of the strategy, while the physics and biology teachers implemented the second and third revisions, respectively. These revisions by the researchers may have contributed to the differences in outcomes. Moreover, the three studies also differed with respect to the teacher's opportunity to pilot-test the strategy prior to the experimental session. The quantitative methods study was done without a pilot testing, where physics had one pilot test and biology had two. Thus, differences in teacher experience with the strategy are also a contributing factor.

Characteristics of control classes

The nature of the relationship between the experimental class teacher and the control class teacher varied across the three studies. We propose that the strategy impacts student achievement in two ways: directly, through student use of the strategy, causing organization and re-organization of their knowledge; and, indirectly through teacher use of the strategy, causing re-organization of the curriculum, and so indirectly affecting student learning. We believe that the variation in teacher relationships affected the difference in indirect effect between control and experimental classes. This helps to explain the pattern of effects on student achievement noted across the three studies.

In the first study, involving quantitative methods, the same teacher taught both the experimental and control sections. This teacher reported that using the strategy caused her to restructure her view of the material to be covered. This restructuring affected both sections equally. It is interesting to note that in this study there was no significant difference in achievement between control and experimental groups. Perhaps this is because the major effect of the strategy is truly indirect.

In the second study, involving physics, although there were different teachers for the control and experimental sections, the two teachers were close friends who have shared ideas, philosophy, beliefs, etc. over a 20 year span of teaching together. This close collaboration continued through the experiment. Thus both teachers restructured their course organization in a similar manner. Consequently, both classes benefitted from this effect of the strategy equally. Thus, it is not surprising that no significant difference in achievement was measured here either.

In the third study, involving biology, there were two different teachers for the control and experimental sections. There was little if any contact between the two teachers and certainly no discussion of the reorganization that the strategy encouraged the experimental teacher to undertake. Thus, this was the first study where measurement of an indirect effect was truly possible and it was in fact the first study to note a significant difference in achievement between control and experimental classes.

<u>Characteristics of the students</u>

There is a body of literature which contends that students' expectations influence the way in which they approach tasks and consequently, their performance. Both the strength and the type of expectations (Brophy, 1981) affect achievement. These expectations may covary in a systematic manner across the three studies. For example, the students in the different studies were from different programs (Social Studies and Commerce, Pure and Applied Sciences, and Health Sciences). The different programs have different admission standards, assessment traditions, and pedagogical practices. These factors, in turn, may give rise to systematic differences in student expectations across the three studies which may have affected the use and effectiveness of cooperative networking.

Students in the quantitative methods course were in their second semester at the college. Most of them had no prior experience with either quantitative methods or with the rigours of social science research. We believe that many of them held the expectation that the course would be incomprehensible, and that success would based on the teacher's transmission of information which they would need to memorize by rote. The physics students were at least in their third semester. They already had passed two physics and two mathematics prerequisites. We feel that as a result they had strong beliefs about the nature of physics courses. We believe that these students expected that success in physics is based on the memorization of both formulae and procedural rules which are subsequently applied to problem sets by matching surface features. Most of the biology students were in their fourth semester, and taking the one required biology course to graduate. We feel that their expectations were that biology courses generally require a great deal of memorization and success is based on developing efficient memory aids.

The above postulated student expectations may have interacted with the cooperative networking strategy to produce different results in the three studies. In both the quantitative methods class and the physics class the teachers' objectives and implementations of the strategy contradicted the postulated student expectations. We believe that this contradiction diminished student willingness to use the strategy and consequently diminished its effectiveness as well. Students in the experimental biology class, however, were not confronted with this contradiction. The teacher's use of cooperative networking supplied the efficient memory aid that the students sought. It is likely that this led to increased willingness to adopt the strategy. This in turn lead not only to improved recall of information, but also, through better organizational structure of information, to increased comprehension.

Recommendations

Our experiences with implementing cooperative networking have lead us to make the following recommendations for teachers and researchers.

Using cooperative networking in the classroom

1. Experiment with the strategy by using it initially as an instructional tool over small portions of the course.
2. Take the students' beliefs and expectations about learning into consideration before introducing the strategy.
3. Select appropriate tasks to illustrate the benefits of cooperative networking and to train the students in its use.
4. Make sure that students have the appropriate prerequisite skills and knowledge before they attempt to reconstruct their understanding of a topic.
5. Monitor the students carefully while they are working in their groups and be prepared to intervene when students are either experiencing problems working effectively or are developing misconceptions about the topic.
6. Make enough time available for students to develop a deeper understanding of the topic.
7. Match the evaluation methods to the learning objectives.

Extending the research on cooperative networking

1. Consider classroom studies to be exploratory in nature.
2. Develop cooperative networking over more settings and engage teachers in the development of the strategy, materials and instruments.
3. Collect data on the teachers' conceptual structures and investigate the impact of the teachers' presentations on students' conceptual understanding.
4. Include process measures as well as product measures.
5. Analyze the relationships among variables (systemic research).
6. Follow up systemic research by testing specific hypotheses in experimentally controlled settings.

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APPENDIX: TABLES OF RESULTS

In the following tables data in normal print is for measures carried out prior to any experimentation, and ***data in bold italicized print is for measures carried out after experimentation.***

CLASS: Quantitative Methods

TREATMENT: Experimental							TREATMENT: Control					
Female			Male				Female			Male		
M	SD	N	M	SD	N	MEASURE	M	SD	N	M	SD	N
3.47	0.69	15	3.21	0.56	14	MASTERY	3.17	0.58	16	2.98	0.46	14
3.18	***0.64***	***7***	***2.62***	***0.83***	***10***	GOALS	***2.87***	***0.69***	***13***	***2.80***	***0.71***	***11***
2.18	0.58	15	2.19	0.75	14	WORK	2.06	0.82	16	2.48	0.78	14
2.52	***1.17***	***7***	***2.73***	***0.91***	***10***	AVOIDANCE GOALS	***1.72***	***0.54***	***13***	***2.42***	***0.96***	***11***
3.49	0.73	15	3.07	0.76	14	PERFORMANCE	2.90	0.67	16	2.64	0.58	14
3.43	***0.57***	***7***	***2.90***	***0.77***	***10***	GOALS	***3.18***	***0.54***	***13***	***2.73***	***0.73***	***11***
3.24	1.09	15	3.12	0.61	14	AFFILIATIVE	2.71	0.64	16	2.95	0.58	14
3.19	***0.74***	***7***	***2.93***	***1.06***	***10***	GOALS	***2.67***	***0.90***	***13***	***2.70***	***0.74***	***11***
1.93	1.06	15	1.91	0.77	14	NEGATIVE	2.00	0.83	16	1.92	0.74	14
2.39	***0.71***	***7***	***2.91***	***0.74***	***10***	AFFECT	***2.01***	***0.84***	***13***	***2.52***	***1.06***	***11***
2.92	0.99	15	2.98	0.77	14	POSITIVE	2.84	0.75	16	3.01	0.52	14
2.80	***0.79***	***7***	***2.62***	***0.97***	***10***	AFFECT	***2.78***	***0.88***	***13***	***2.50***	***0.74***	***11***
4.07	1.03	15	3.71	0.47	14	ATTRIBUTION	4.13	0.72	16	3.64	0.84	14
3.71	***0.95***	***7***	***3.30***	***0.67***	***10***	TO EFFORT	***4.23***	***0.83***	***13***	***3.36***	***1.12***	***11***
2.00	0.93	15	2.57	1.02	14	ATTRIBUTION	2.13	0.96	16	2.36	1.08	14
2.14	***1.22***	***7***	***2.11***	***1.05***	***9***	TO LUCK	***1.92***	***1.04***	***13***	***2.36***	***1.12***	***11***
4.07	0.83	14	3.64	0.74	14	ATTRIBUTION	3.75	0.93	16	3.86	0.66	14
3.43	***0.98***	***7***	***3.60***	***0.97***	***10***	TO ABILITY	***3.92***	***0.76***	***13***	***4.18***	***0.60***	***11***
2.87	1.51	15	2.79	0.80	14	ATTRIBUTION TO	3.50	0.89	16	2.79	1.05	14
4.14	***0.90***	***7***	***3.80***	***1.14***	***10***	HELP FROM PEERS	***3.15***	***1.21***	***13***	***2.27***	***0.90***	***11***
3.33	0.90	15	3.36	0.63	14	ATTRIBUTION	4.06	0.77	16	3.43	0.76	14
3.29	***0.49***	***7***	***3.40***	***0.97***	***10***	TO DIFFICULTY	***3.54***	***1.05***	***13***	***3.18***	***1.08***	***11***
3.23	0.49	15	3.23	0.58	14	INFORMATION	3.29	0.57	16	3.09	0.62	14
3.27	***0.50***	***7***	***2.81***	***0.47***	***9***	PROCESSING	***3.17***	***0.88***	***13***	***3.09***	***0.67***	***11***
4.00	0.63	15	3.20	0.60	14	MOTIVATION	4.06	0.62	16	3.56	0.52	14
3.57	***0.77***	***7***	***2.78***	***0.49***	***9***	STRATEGY	***3.79***	***0.63***	***13***	***3.33***	***0.79***	***11***
3.88	0.51	15	3.41	0.54	14	USE OF	3.95	0.67	16	3.36	0.76	14
3.54	***0.60***	***7***	***2.87***	***0.51***	***9***	STUDY AIDS	***3.71***	***0.74***	***13***	***2.89***	***0.68***	***11***
3.42	0.86	15	3.36	0.71	14	SELF	3.21	1.13	16	3.50	1.07	14
3.76	***0.53***	***7***	***2.98***	***0.65***	***9***	TESTING	***3.31***	***1.19***	***13***	***3.79***	***0.65***	***11***
3.14	0.54	15	2.60	0.88	14	SELECTING	3.02	0.75	16	2.64	0.89	14
3.48	***0.74***	***7***	***2.78***	***0.73***	***9***	MAIN IDEAS	***2.62***	***0.54***	***13***	***2.36***	***0.75***	***11***
37.67	***9.08***	***15***	***38.31***	***8.91***	***13***	C.C.A.T.	***42.50***	***5.63***	***16***	***46.14***	***5.05***	***14***
5.12	***1.36***	***13***	***5.32***	***1.27***	***14***	UNIT TEST ONE	***5.92***	***1.83***	***16***	***5.99***	***1.63***	***13***
6.02	***1.77***	***13***	***6.19***	***0.90***	***13***	UNIT TEST TWO	***6.99***	***1.11***	***14***	***7.19***	***0.90***	***11***
6.59	***1.46***	***11***	***7.59***	***1.35***	***10***	UNIT TEST THREE	***8.29***	***0.97***	***12***	***8.21***	***1.16***	***10***
5.95	***1.58***	***11***	***6.53***	***1.53***	***9***	UNIT TEST FOUR	***8.22***	***1.34***	***12***	***5.93***	***1.70***	***11***
4.43	***1.80***	***14***	***4.52***	***1.20***	***12***	F.T. GRADE	***7.32***	***1.18***	***12***	***6.33***	***1.61***	***12***

CLASS: Physics

TREATMENT: Experimental							TREATMENT: Control					
Female			Male				Female			Male		
M	SD	N	M	SD	N	MEASURE	M	SD	N	M	SD	N
3.13	0.50	14	3.27	0.44	18	REPRODUCING	3.26	0.40	16	3.50	0.55	16
3.22	*0.59*	*13*	*3.38*	*0.44*	*20*	ORIENTATION	*3.30*	*0.38*	*17*	*3.45*	*0.44*	*14*
3.27	0.47	14	3.32	0.63	18	MEANING	3.50	0.39	16	3.41	0.49	16
3.35	*0.55*	*13*	*3.27*	*0.78*	*20*	ORIENTATION	*3.58*	*0.42*	*17*	*3.41*	*0.48*	*14*
3.21	0.62	14	3.33	0.82	18	RELATING	3.52	0.68	16	3.52	0.78	16
3.28	*0.61*	*13*	*3.35*	*0.84*	*20*	IDEAS	*3.53*	*0.62*	*17*	*3.40*	*0.68*	*14*
3.50	0.45	14	3.39	0.92	18	DEEP	3.71	0.40	16	3.46	0.50	16
3.69	*0.64*	*13*	*3.28*	*0.91*	*20*	APPROACH	*4.02*	*0.42*	*17*	*3.62*	*0.55*	*14*
3.09	0.65	14	3.25	0.56	18	USE OF	3.27	0.42	16	3.27	0.55	16
3.08	*0.68*	*13*	*3.16*	*0.89*	*20*	EVIDENCE	*3.19*	*0.44*	*17*	*3.21*	*0.44*	*14*
2.74	0.79	14	2.87	1.07	18	INTRINSIC	3.08	0.86	16	2.69	0.67	16
2.90	*0.88*	*13*	*2.77*	*0.91*	*20*	MOTIVATION	*2.92*	*0.81*	*17*	*2.79*	*0.75*	*14*
3.14	0.69	14	3.20	0.73	18	EXTRINSIC	3.06	1.02	16	3.29	0.58	16
2.82	*0.93*	*13*	*3.47*	*0.78*	*20*	MOTIVATION	*3.24*	*0.84*	*17*	*3.29*	*0.71*	*14*
3.67	0.47	14	3.43	0.96	18	ACHIEVEMENT	3.96	0.64	16	3.83	0.56	16
3.67	*0.69*	*13*	*3.30*	*0.83*	*20*	MOTIVATION	*3.92*	*0.69*	*17*	*3.69*	*0.69*	*14*
3.15	0.65	14	2.87	0.70	18	MASTERY	3.23	0.32	16	3.25	0.70	16
3.03	*0.56*	*12*	*3.03*	*0.64*	*20*	GOALS	*3.24*	*0.59*	*17*	*3.30*	*0.62*	*14*
2.36	0.72	14	2.83	0.92	18	WORK	2.19	0.76	16	2.77	0.64	16
2.19	*0.73*	*12*	*2.88*	*0.86*	*20*	AVOIDANCE GOALS	*2.29*	*0.75*	*17*	*2.60*	*0.75*	*14*
3.14	0.72	14	2.62	0.81	18	PERFORMANCE	3.19	0.57	16	3.15	0.81	16
2.94	*0.78*	*12*	*3.06*	*0.76*	*20*	GOALS	*3.12*	*0.78*	*17*	*3.00*	*0.76*	*14*
2.90	0.67	14	2.72	0.83	18	AFFILIATIVE	2.99	0.77	16	3.01	0.79	16
2.81	*0.89*	*12*	*2.78*	*0.88*	*20*	GOALS	*3.22*	*0.92*	*17*	*2.86*	*0.77*	*14*
2.31	1.02	14	2.44	1.00	18	NEGATIVE	1.79	0.50	16	1.96	0.75	16
1.60	*0.65*	*12*	*2.45*	*0.71*	*20*	AFFECT	*1.63*	*0.73*	*17*	*1.67*	*0.60*	*14*
3.09	0.96	14	2.74	0.92	18	POSITIVE	3.01	0.64	16	2.89	0.95	16
3.18	*0.88*	*12*	*2.99*	*0.66*	*20*	AFFECT	*2.94*	*0.69*	*17*	*3.09*	*1.00*	*14*
3.93	3.02	14	4.06	1.89	18	ATTRIBUTION	4.38	2.09	16	3.44	1.86	16
4.31	*2.29*	*13*	*4.20*	*3.19*	*20*	TO EFFORT	*3.47*	*2.21*	*17*	*3.21*	*1.76*	*14*
2.50	1.74	14	3.17	2.46	18	ATTRIBUTION	3.75	1.98	16	3.25	1.88	16
2.54	*2.18*	*13*	*2.30*	*2.36*	*20*	TO STRATEGY	*3.94*	*2.61*	*17*	*2.57*	*1.74*	*14*
1.57	1.45	14	1.28	1.27	18	ATTRIBUTION	0.69	0.87	16	1.31	1.14	16
1.38	*1.04*	*13*	*1.40*	*1.43*	*20*	TO ABILITY	*1.06*	*0.97*	*17*	*1.50*	*1.56*	*14*
1.36	1.15	14	2.17	1.69	18	ATTRIBUTION TO	1.56	1.50	16	1.75	1.39	16
1.46	*1.05*	*13*	*1.35*	*1.31*	*20*	HELP FROM TEACHER	*1.00*	*1.12*	*17*	*1.64*	*1.45*	*14*
2.43	1.70	14	1.33	1.61	18	ATTRIBUTION	1.56	1.75	16	2.19	1.80	16
2.31	*2.14*	*13*	*2.75*	*3.13*	*20*	TO DIFFICULTY	*2.47*	*3.12*	*17*	*3.07*	*1.86*	*14*
31.00	*8.99*	*14*	*34.71*	*3.87*	*21*	C.C.A.T.	*32.94*	*9.28*	*17*	*32.82*	*6.70*	*17*
8.02	*1.34*	*14*	*8.26*	*1.13*	*21*	UNIT TEST ONE	*9.10*	*0.66*	*18*	*8.25*	*1.39*	*15*
6.97	*1.54*	*13*	*8.20*	*1.25*	*21*	UNIT TEST TWO	*8.12*	*0.89*	*18*	*8.01*	*1.04*	*17*
5.83	*0.57*	*14*	*5.81*	*0.70*	*22*	UNIT TEST THREE	*6.02*	*0.81*	*18*	*6.19*	*0.62*	*18*
8.04	*0.95*	*14*	*8.28*	*0.95*	*22*	F.T. GRADE	*8.68*	*0.66*	*18*	*8.34*	*0.60*	*18*

CLASS: Biology

TREATMENT: Experimental							TREATMENT: Control					
Female			Male				Female			Male		
M	SD	N	M	SD	N	MEASURE	M	SD	N	M	SD	N
3.30	0.64	13	3.33	0.45	19	REPRODUCING	3.46	0.59	10	3.08	0.50	16
3.24	0.52	11	3.49	0.55	16	ORIENTATION	3.01	0.63	8	3.13	0.40	19
3.37	0.60	13	3.41	0.54	19	MEANING	3.41	0.24	10	3.42	0.36	17
3.78	0.66	11	3.33	0.55	16	ORIENTATION	3.37	0.42	8	3.16	0.44	19
3.46	0.90	13	3.72	0.76	19	RELATING	3.30	0.62	10	3.69	0.60	16
3.95	0.80	11	3.52	0.81	16	IDEAS	3.42	0.71	8	3.30	0.71	19
3.38	0.56	13	3.40	0.53	19	DEEP	3.83	0.45	10	3.49	0.59	17
3.70	0.67	11	3.40	0.66	16	APPROACH	3.42	0.46	8	3.16	0.61	19
3.27	0.73	13	3.11	0.55	19	USE OF	3.10	0.46	10	3.13	0.60	16
3.68	0.77	11	3.06	0.53	16	EVIDENCE	3.28	0.36	8	3.01	0.55	19
2.69	0.91	13	2.96	0.83	19	INTRINSIC	3.10	0.83	10	3.08	0.86	17
3.00	0.98	11	2.92	0.79	16	MOTIVATION	3.29	0.63	8	2.88	0.82	19
3.10	0.88	13	3.05	0.72	19	EXTRINSIC	3.03	0.85	10	2.92	0.69	16
3.23	0.72	11	2.92	0.69	16	MOTIVATION	3.21	0.85	8	2.89	0.88	19
3.41	0.72	13	3.49	0.71	19	ACHIEVEMENT	3.33	0.96	10	3.48	0.83	16
3.82	0.74	11	3.33	0.92	16	MOTIVATION	3.42	1.00	8	3.18	0.74	19
3.06	0.61	12	3.19	0.39	19	MASTERY	3.53	0.44	10	3.31	0.62	16
3.74	0.88	11	3.03	0.75	16	GOALS	2.98	0.80	8	3.10	0.74	19
2.25	0.73	12	2.81	0.65	19	WORK	2.20	0.61	10	2.60	0.86	16
2.30	0.96	11	2.71	0.75	16	AVOIDANCE GOALS	2.23	0.94	8	2.72	0.71	19
2.99	0.57	12	3.06	0.66	19	PERFORMANCE	3.23	0.63	10	2.94	0.69	16
3.30	0.67	11	2.81	0.98	16	GOALS	2.88	0.78	8	2.91	0.67	19
2.74	0.59	12	2.58	0.66	19	AFFILIATIVE	2.37	0.67	10	2.90	0.91	16
3.12	0.87	11	2.46	0.71	16	GOALS	2.29	0.97	8	2.72	0.83	19
2.13	1.04	11	1.90	0.85	18	NEGATIVE	1.79	0.81	10	2.30	0.67	16
1.90	0.96	11	1.98	0.80	16	AFFECT	1.98	0.68	8	2.19	0.78	19
2.98	0.91	11	3.22	0.80	18	POSITIVE	3.30	0.80	10	3.19	0.78	16
3.62	0.90	11	3.16	0.60	16	AFFECT	2.80	0.93	8	3.02	0.60	19
3.92	2.25	13	4.89	2.69	19	ATTRIBUTION	5.10	3.28	10	3.19	2.66	16
4.73	2.69	11	5.19	2.71	16	TO EFFORT	5.75	3.37	8	4.84	2.48	19
3.23	1.64	13	2.74	2.40	19	ATTRIBUTION	1.90	1.91	10	2.56	2.22	16
3.27	1.85	11	3.31	2.91	16	TO STRATEGY	1.88	2.53	8	2.74	2.21	19
1.46	1.33	13	0.95	1.03	19	ATTRIBUTION	0.80	0.63	10	2.13	2.68	16
1.27	1.01	11	0.75	1.34	16	TO ABILITY	0.75	0.89	8	1.16	1.07	19
1.54	1.56	13	1.58	1.71	19	ATTRIBUTION TO	1.90	1.60	10	1.56	1.90	16
1.55	1.51	11	0.63	0.96	16	HELP FROM TEACHERS	1.38	1.19	8	0.79	0.92	19
1.77	1.59	13	1.79	1.87	19	ATTRIBUTION	2.30	1.70	10	1.88	1.82	16
1.18	1.66	11	2.13	1.75	16	TO DIFFICULTY	2.13	2.10	8	2.37	1.71	19
0.58	0.67	12	0.77	0.73	13	LOW QUESTION ON	0.36	0.67	11	0.36	0.63	14
1.92	0.67	12	1.83	0.86	18	ACHIEVEMENT TEST	1.14	0.90	7	1.00	0.96	14
1.25	0.87	12	0.85	0.80	13	HIGH QUESTION ON	1.00	0.63	11	1.07	1.00	14
2.00	0.74	12	1.83	0.71	18	ACHIEVEMENT TEST	1.57	1.40	7	1.57	1.16	14
0.38	0.48	12	0.35	0.38	13	ESSAY QUESTION ON	0.00	0.00	11	0.11	0.29	14
2.13	1.05	12	2.36	1.22	18	ACHIEVEMENT TEST	0.29	0.49	7	0.96	1.01	14
0.42	0.19	12	0.47	0.32	18	NEAR TRANSFER TASK	0.21	0.39	7	0.36	0.35	14
3.82	2.99	11	3.44	2.57	18	FAR TRANSFER TASK	4.50	2.11	12	3.32	2.50	19
6.15	1.60	11	4.91	1.60	18	ERROR DETECTION CORRECTION TASK	4.38	1.30	12	4.78	1.64	18
19.25	9.07	12	15.82	8.60	17	TOTAL # IDEA UNITS	5.33	3.01	6	9.88	3.23	8
17.50	8.33	12	13.35	7.50	17	ACCURATE & RELEVANT IDEAS	4.00	3.58	6	8.25	4.23	8
0.58	1.38	12	0.35	0.70	17	STRUCTURE	0.17	0.41	6	0.00	0.00	8
9.83	6.58	12	7.06	6.95	17	ELABORATIONS	1.83	1.72	6	3.50	2.93	8
16.00	6.73	13	18.21	6.21	19	C.C.A.T.	16.73	5.16	11	19.40	5.19	20
1.84	1.27	12	1.63	1.03	13	UNIT TEST ONE	1.14	0.93	11	1.28	1.29	14
5.03	1.07	12	5.02	1.59	18	UNIT TEST THREE	2.50	1.60	7	2.95	1.95	14
4.96	2.86	11	4.17	2.40	18	F.T. GRADE	6.05	1.56	12	3.91	2.31	19