Research in Science Education **34:** 389–401, 2004.

Conceptual Mediation Program in Practice: Educational Outcomes from Two Sites

Gregory C. R. Yates[1] and E. Harry Lyndon[2]
[1]*University of South Australia*
[2]*Department of Education and Children's Services, South Australia*

Abstract

We report on two studies in which high school students who had been exposed to a cognitive training procedure known as the Conceptual Mediation Program (CMP) were compared to students who had not participated within the program. In the first study, based on data from two sites, it was found that 70 CMP students exhibited higher levels of school affect and strategy awareness than 103 comparable students not in the program. In the second study, based on retrospective data from one site, 53 students who had participated within CMP classes were found to exhibit higher levels of attainment on Year 12 South Australian public examination results (effect size of 1.04 on the aggregate). On the Year 12 examination results, the CMP students outperformed both the school and state norms.

Key Words: conceptual change, high school students, metacognition, prior knowledge, proactive interference

The primary goal of constructivist science educators involves helping young people to acquire scientific knowledge with greater facility, to achieve a deeper level of understanding in their studies, and for these understandings to be lasting. It has been established, however, that a universal problem in schooling concerns the fact that science learning is evidently difficult for most students. A general conclusion is that even students who are successful in examinations are unable to retain and apply scientific concepts (Pfundt & Duit, 1994). In Gauld's (1986) study, students were found to have reverted back to their pre-teaching conceptions even to the extent of reconstructing observations made during teaching so that they now supported their pre-teaching views.

In their report on their national study of science teaching and learning in Australian schools, Rennie, Goodrum, and Hackling (2001) concluded that when students move into high school "many experience disappointment, because the science they are taught is neither relevant nor engaging and does not connect with their interest and experiences" (p. 455). The Third International Mathematics and Science Study (TIMSS) indicated that there were concerns regarding Australian students' attitudes to science. They were reported as being amongst the poorest of the English speaking countries in this aspect of the study (Martin et al., 2001).

The present paper reports on one attempt to increase the effectiveness of high school science learning through the explicit use of psychological theory. The Conceptual Mediation Program (CMP) was developed as an attempt to derive educational applications of associative interference theory (Baddeley, 1990; Dempster & Corkill, 2000; Postman & Underwood, 1973; Underwood, 1957). The CMP evolved through the collaborative work of science educators, an educational psychologist, and senior science teachers in two Australian schools. The conceptual mediation procedure was developed and researched in the area of students' conceptions of volume (Dawson & Lyndon, 1997; Lyndon, 1989; Rowell, Dawson, & Lyndon, 1990), and later applied to the teaching of science, mathematics, and physics, to several classes within a high school setting, Years 8 through to 12. A previous article within this journal was concerned with both theoretical aspects and specific instructional procedures (Dawson & Lyndon, 1997). This current paper, however, will present data pertaining to the evaluation of the program conducted within two Australian schools.

At the outset, it is valuable to understand the context from which the program has emerged. Associative interference theory (Dempster & Brainerd, 1995; Dempster & Corkill, 2000; Postman & Underwood, 1973) is concerned with explaining the difficulty inherent in acquiring new knowledge, especially when the possibility of interference between new information and existing knowledge becomes strong (i.e., the principle of proactive interference). In the past, interference theory has received support from controlled laboratory research, but specific applications in the field of education have remained ill-defined.

Background Principles

Mediational learning theory (Lyndon, 2000) and the Conceptual Mediation Program (CMP) are derived from associative interference theory. Mediational learning theory and the associated program describe and explain the critical role in conceptual change of psychological phenomena such as proactive interference, retroactive interference, accelerated forgetting, and unlearning. Proactive interference is best understood as the effect of conflicting prior knowledge on new learning. The Conceptual Mediation Program (CMP) stresses the principle of proactive interference. Information already held within the mind tends to be resistant to new learning, and can become a source of misconceptions. Such notions are well documented within the literature of science teaching (Chinn & Brewer, 1993). What has been less clear, however, is how such natural sources of misconception can be addressed directly and effectively within the context of classroom instruction.

The general sequence for conceptual mediation is presented below:

(i) Firstly, students are presented with a learning model that explains why learning for conceptual change is difficult. Students are expected to develop competency in the recommended cognitive strategies, which they should apply to the learning for understanding of science concepts. The key strategy recommended is detailed under (v) below. The learning model thus provides a common learning framework for teachers and their students.

(ii) Secondly, students' associated knowledge, beliefs and ideas of a concept are elicited. This can be achieved in a variety of ways such as small group or whole-of-class brainstorming sessions, small-group discussion and poster preparation (for later class presentation), the preparation of concept maps, or more simply by the written response of students to a pre-test on the topic.

(iii) Thirdly, the teacher focuses on the active differentiation of words used in a scientific manner and how they differ from their common sense usage. This step is a necessary condition for the subsequent successful mediation between students' prior understanding and the scientific concepts associated with a particular topic.

(iv) Fourthly, the teacher explicitly teaches the new concept and provides opportunities for students to rehearse important aspects of it. This enables later comparison with old perspectives that are initially presented to the class by the students themselves.

(v) Fifthly, there is the mediational process itself. There are the three separate phases in the mediation process: the preparatory phase, the mediational phase and the application phase. In the preparatory phase the teacher facilitates the re-elicitation of the students' old concept and its comparison and differentiation from the new scientific concept. At this stage the material collected during the original elicitation of students' ideas can be presented again to facilitate discussion of their old perspectives. It is essential for the resolution of the natural phenomenon of accelerated forgetting that the students learn to differentiate between the conflicting perspectives. The students' preconceptions and alternative conceptions must be re-elicited at this preparatory stage and again during the mediational phase that follows. In the mediational phase of the method, the recall of the new concept and its active differentiation from the alternative perspectives is repeated, in a progressive manner, five separate times. When students deliberate in this way, there is growth in the individual's awareness of the similarities and differences between competing perspectives. However, at least three progressive differentiations appear necessary for the re-direction of accelerated forgetting to be initiated. The re-direction of accelerated forgetting, from the new to the old concept, is consolidated over the following differentiations. The third and final phase of this method is the application phase. Here the new concept is applied or generalized to at least six novel applications or problem solving situations.

Conceptual mediation learning procedures enhance personal awareness of learning strategies and metacognitive thinking. The learner is actively encouraged to (a) form accurate verbal discriminations, (b) talk oneself through a sequence by which one source of knowledge replaces another, and (c) maintain a level of vigilance and self-monitoring at least until new knowledge is fixed in place to a degree of satisfaction.

The Current Program

The CMP development teams strove to develop a whole-class lesson structure consistent with the theoretical model. The term *conceptual mediation* was used to describe the learner's active engagement with the change process. This terminology is appropriate in that (a) the procedure is targeted on changing concepts through careful analysis of words and their definitions, (b) new knowledge is mediated via differentiating, and consequently dissociating it, from old knowledge under specific conditions, and (c) the learning procedure is seen as the application of a goal-directed strategy under the control of the student. This active student ownership of a potent mental strategy is stressed as the critical component of the program.

Although developed on one school site, the program has been adapted for use on several other sites across Australia. It was possible to locate relevant data from two sites, for purposes of this article. On two sites, students who had, and had not, been exposed to the program, filled out a questionnaire pertaining to their liking for schooling, and also about the strategies they would employ to solve difficult problems in science or mathematics. On the development site it was possible to track students through their success in the Year 12 public examination process. These data are reported in terms of two separate studies.

Study 1

Design and Methods

Data were collected from two sites. Site 1 was an R-12 school (reception (kindergarten) to leaving) serving a lower-middle class suburban district around six kilometres from the Adelaide CBD. Although it is immediately evident as a well-run school with high quality, experienced staff, it is characterised as a generalist public school in an urban area in which competition with a number of selective private schools is inevitable. Site 2 was a Middle School (Years 6 to 10) serving an upper middle class suburb in Canberra, ACT. This school has a strong reputation and academic tradition.

Project staff within both sites had undertaken a minimum of three days of professional development in a program describing both the theory and practice of Conceptual Mediation (CMP) provided by one of the authors (HL). A training manual was used (Lyndon, 1998), and this and other resources are available on www.southsupportservices.sa.edu.au/resources.htm

Following on from initial induction, regular (weekly) contact was maintained by the teachers and HL. On the South Australian site the program was monitored and supported by the developer. On the Canberra site, the monitoring was undertaken by the executive teacher in the Science faculty, and support was provided via regular phone contacts with HL, and by bi-monthly site visits.

The South Australian project had begun in 1995, and data were first collected in the 1998 school year. The Canberra data were collected at the end of 2001, after the program had been implemented at that school for almost two years. In each instance, the students who were in the CMP groups had been involved with the program for at least 18 months.

At each site CMP had been introduced and taught as a viable learning and memory enhancing process for roughly one half of the students at each year level. The teaching of CMP to the students was achieved via the normal classroom teacher. The logic of the current design was to regard intact classes of students as either having been exposed to CMP or not having such exposure.

On the South Australian site, it was possible to identify 24 students who had experienced CMP, and 32 who had not had relevant exposure. All these students were in Year 10. On the Canberra site, it was possible to identify 25 Year 8s and 21 Year 9s who had experienced CMP, and 23 Year 8s and 48 Year 9s who had no exposure. Of the total 173 students in the study across both sites, 82 were female and 88 were male.

School Affect

School affect was indexed using 19 items from a questionnaire designed for this study. The items focussed on aspects of positive affect (e.g., "Overall, being a high school student is a rich and rewarding experience"), love of work (e.g., "I like to work on those problems that take a long time to do"), love of learning (e.g., "To help me to learn I like to work on difficult problems"), and intrinsic motivation (e.g., "I don't mind if problems take me a long time"). Nine questions were phrased in the positive direction, and 10 were in the negative direction (e.g., "School is really boring", "If I can't solve a problem quickly, I quit"). The integrity of the scale was established by principal components (factor analysis) procedures. From a pool of 25 items, it was found that 19 items loaded onto a single factor at greater than .4 loading. An additional SPSS Reliability procedure established that the internal reliability coefficient (alpha) was .87, with every item contributing to the overall total. The 25-item scale, as originally used, is found on www.unisanet.unisa.edu.au/edpsych/quests as a rich text format document.

Strategy Awareness

Strategy awareness was tapped by a single item which asked for a written response to a single question. The question and its scoring rubric are shown in Table 1. The protocols were scored by two people, that is, one of the current researchers (GY) and a research assistant unfamiliar with the current project. Protocols were scored in a manner blind to treatment condition or gender. Initial agreement level was high (92%), and disagreements were then reconciled through discussion.

Results

School affect

An overall 2 × 3 × 2 ANOVA (CMP treatment, year level, gender) procedure indicated that the school affect score did not differ significantly across year levels, and no gender effects were obtained. However, there was a statistically significant

Table 1
Scoring Rubric for Strategy Awareness.

Level	Probe: *Suppose you have a very difficult problem to solve in mathematics or science. What sort of things could you do to help you work on this problem?*
0	No meaningful response.
1	Non-specific response (includes "*I'd ask for help"*).
2	Viable strategic response cited.
3	Response suggests integrated or sequential strategies to a mature level.

Table 2
Means and Standard Deviations for Positive Affect Scores.

Year	Program			
	Non-CMP		CMP	
	Mean (SD)	*n*	Mean (SD)	*n*
8	65.1 (11.7)	23	69.9 (8.4)	25
9	67.9 (7.2)	48	71.9 (8.5)	21
10	67.2 (10.5)	32	74.2 (7.7)	24
Total	67.1 (9.4)	103	71.9 (8.3)	70

effect for CMP treatment ($F(1, 169) = 9.9$, $p = .002$, effect size $d = .91$). All interaction terms were non significant, indicating that the CMP effect was independent of both gender and year level. It can be acknowledged that our analysis confounds Year level with site (Canberra, Adelaide). However, the year level factor did not achieve significance in either main effects or interaction terms, and separate analyses on data from the two sites yielded similar findings, in terms of the main effect for CMP.

The means are shown in Table 2. The scale was scored in the positive direction such that high scores reflect a greater overall level of positive affect (i.e., general liking for school and attitude to learning).

Strategy awareness

On the strategy awareness data, an overall $2 \times 3 \times 2$ ANOVA (CMP treatment, year level, gender) procedure indicated a statistically significant effect due to CMP ($F(1, 169) = 18.9$, $p < .001$, effect size $d = .72$). Although the gender effect was not significant, the gender by CMP interaction term was approaching statistical significance ($F(1, 169) = 3.5$, $p = .061$). Further analyses therefore were conducted separately for boys and girls. It was found that although CMP was associated with higher scores for both boys and girls, the impact in terms of statistical effect size was far greater in the case of the boys than the girls (effect sizes of .96 and .5, Cohen d). Further, it was found that for the students who had not been exposed to CMP, the girls outperformed the boys (means of 1.58 and 1.2, $F(1, 99) = 6.5$, $p = .012$, effect size of 0.5), whereas no such significant effect was found in the case of those students who had been exposed to CMP (means of 1.97 and 1.94). Thus, the interaction noted in the overall analysis reflected the fact that CMP appeared to attenuate a gender-related effect on this specific indice.

Study 2

Public Examination Data

On Site 1, permission was sought to access data from the students' Year 12 results, obtained via the public examination process. This involved cooperation between the researchers, the school executive and teachers, and also the Senior Secondary Assessment Board, South Australia (SSABSA). It was possible to search the records for the entire school cohort, over the four year period between 1998 and 2001. In this way, it was possible to track the examination results of 155 individual students, 78 males and 77 females. Each student's subject results are expressed as a score between 0 and 20 within each curriculum area in accord with SSABSA procedures. Students submit in 5 curriculum areas to obtain their HEES (Higher Education Entry Score) aggregate which is used for tertiary admission. The tally out of 20 represents a mediated or scaled score, and the overall mean score (i.e., for all subjects over 5 areas) was 11.83. Preliminary analyses revealed that the students' year of completion was not associated with any changes in HEES scores on either the aggregate or individual subject analyses.

It was found that of the 155 graduating students, 53 had been exposed to CMP training within their study programs in chemistry, mathematics or physics, at Years 10, 11 or 12 (i.e., final years of their high school experience). The other 102 students had not been exposed to CMP training within their school experience. Through tracking individuals thus it was possible to contrast the HEES scores of students who had exposure to CMP in preparation for submitting for formal public examinations, and those students who had no such preparation.

Results

The results for CMP and non-CMP students are shown in Table 3, in relation to 20 subject areas. The CMP students obtained higher HEES scores in 7 of these areas, as well as on the overall HEES aggregate score. In particular, it can be noted that students that had experienced CMP obtained higher HEES scores than their non-CMP peers within economics, ESL, English, and geography, that is subjects in which the teaching staff had not specifically used CMP methods. In the vocational subject, however, the non-CMP students obtained higher scores than the CMP students.

Gender differences were statistically significant in the case of the overall HEES aggregate, and in three subject areas (business maths, physical education, and vocational). In each contrast, the girls outperformed the boys. An interesting pattern emerged when we added CMP experience to the gender breakdown, and this is shown in Figure 1. An ANOVA (2×2) confirmed the pattern of significant main effects for both gender and CMP status, but also indicated no significant interaction between these two factors. The absence of an interaction between gender and CMP status was also found in a set of two-way ANOVAs performed on each of the subject area results. That is, in terms of actual HEES outcomes, the impact of gender and CMP appear independent of each other. In terms of statistical effect sizes, the Cohen d coefficient for gender was .41, whereas for CMP exposure it was 1.04.

Although Figure 1 may appear to show that boys in the CMP treatment appear closer to the girls' than is the case within the non-CMP group, in fact this was not a significant effect in terms of formal means testing (i.e., the ANOVA interaction term was not significant). Hence, the conclusion that the program had equal impact on both genders fits the overall data more accurately.

Table 4 shows the effect sizes associated with each of the statistically significant program effects, relative to the non-CMP school sample. However, additional data, accessed from SSABSA records, enabled us to also contrast CMP students with all other South Australian Year 12 students for the year 2001. It was apparent that the CMP students were outperforming the state-wide norms on these seven subject contrasts (see Table 5). This should be seen as a notable result in that the school concerned appears, on overall SSABSA figures, to sit slightly below the mean data overall aggregates (mean tertiary entrance rank score being 66.2 for the school, versus 71.1 for the state average, indexed out of 100).

Discussion

The data from two studies indicate that the Conceptual Mediation Program had been associated with positive educational outcomes. Students who were exposed to CMP within the course of their high school exhibited more positive attitudes to schooling and learning, were able to describe more sophisticated learning strategies in handling difficult problems, and scored around 3 points higher (out of 20) on public 'high stakes' examinations, when contrasted against peers who had not experienced program exposure.

These data were based upon naturally occurring circumstances in which the CMP procedures were taught to intact classes within the context of normal instructional periods. In each case, the program was embedded into normal lessons by the classroom teachers within mathematics, physics, or chemistry. The students were taught

Table 3
Mean Year 12 Achievement Data (HEES Public Examination) Associated with Exposure to CMP.

Subject	School (*n*)	Non-CMP (*n*)	CMP (*n*)	*F* (*df*)	*p*
Biology	12.92 (45)	11.23 (26)	15.24 (19)	27.2 (1, 44)	.001
Chemistry	15.31 (33)	*na*	15.31 (33)	*na*	
Physics	14.3 (33)	12.0 (9)	15.17 (24)	10.1 (1, 32)	.003
Maths 1	13.69 (50)	11.89 (22)	15.11 (28)	10.5 (1, 49)	.002
Maths 2	15.44 (17)	14.88 (4)	15.62 (13)	*ns*	
English	10.64 (41)	10.33 (32)	11.78 (9)	*ns*	
Economics	13.23 (11)	11.0 (6)	15.9 (5)	6.1 (1, 10)	.035
ESL/Languages	13.24 (27)	11.86 (14)	14.7 (13)	10.5 (1, 26)	.003
English studies	11.56 (35)	10.57 (21)	13.04 (14)	6.3 (1, 34)	.016
Geography	12.18 (36)	11.3 (23)	13.7 (13)	5.3 (1, 35)	.028
Legal studies	12.09 (37)	11.97 (30)	12.6 (7)	*ns*	
Visual arts	9.95 (29)	9.33 (24)	12.9 (5)	*ns*	
Info technology	9.60 (46)	9.5 (40)	10.17 (6)	*ns*	
Applied maths	13.04 (25)	12.7 (13)	13.38 (12)	*ns*	
Business maths	11.42 (40)	11.22 (27)	11.85 (13)	*ns*	
Business studies	12.80 (61)	12.67 (45)	13.19 (16)	*ns*	
Physical Ed.	9.5 (24)	8.6 (18)	12.17 (6)	*ns*	
Hospitality	10.32 (28)	10.23 (24)	10.88 (4)	*ns*	
Accounting	10.43 (46)	10.21 (41)	12.3 (5)	*ns*	
Vocational	9.92 (37)	10.27 (32)	7.7 (5)	5.0 (1, 36)	.032
Overall HEES	11.83 (155)	10.8 (102)	13.7 (53)	38.0 (1, 154)	.001

Notes: (a) the numbers of students in the CMP and non-CMP categories are shown within brackets; (b) only statistically significant F ratios ($p \leqslant .05$) are depicted, with degrees of freedom noted in brackets; (c) *ns* means not statistically significant, *na* is not applicable; (d) all scores expressed as SSABSA scaled scores, out of a possible 20.

a method of learning new and difficult material by overcoming obstacles to learning and retention. The methods were based upon a theory of overcoming obstructions stemming from faulty prior knowledge. The theory (a) incorporates an optimistic view in that it both explains why learning is so hard, and (b) articulates cognitively-based procedures that students can apply once they become aware of likely sources of learning interference.

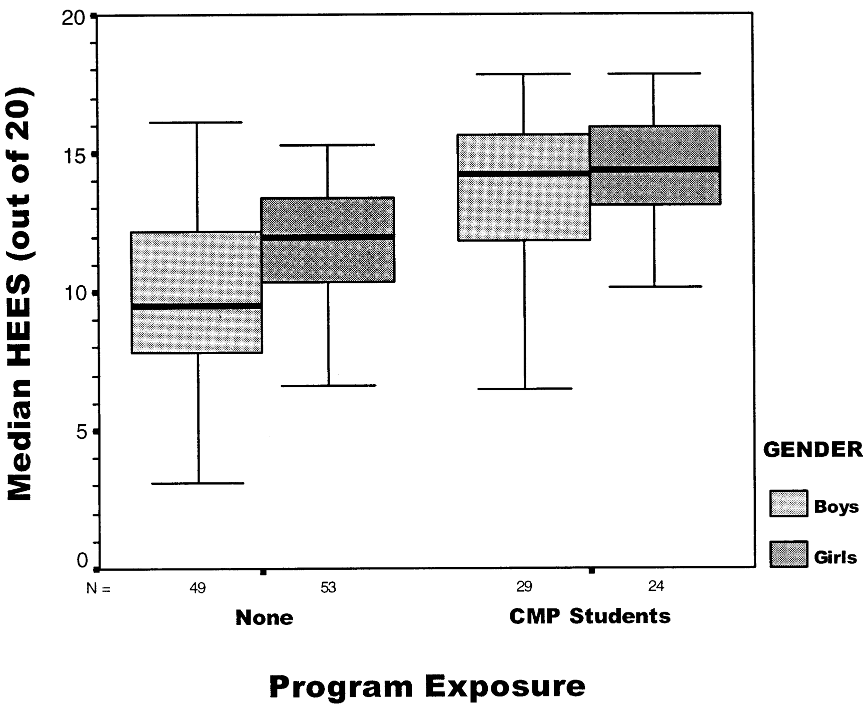

Figure 1: Boxplots of Year 12 public examination data (HEES) by gender and CMP exposure. (Note: Boxplot depicts median scores, rather than mean scores.)

Table 4
Means and Effect Sizes for CMP on Different Subject Areas (HEES).

Subject	Non-CMP (n)	CMP (n)	Effect size
Biology	11.23 (26)	15.24 (19)	1.56
Physics	12.0 (9)	15.17 (24)	1.21
Maths 1	11.89 (22)	15.11 (28)	0.91
Economics	11.0 (6)	15.9 (5)	1.37
ESL/Languages	11.86 (14)	14.7 (13)	1.21
English studies	10.57 (21)	13.04 (14)	0.85
Geography	11.3 (23)	13.7 (13)	0.78
Overall HEES	10.8 (102)	13.7 (53)	1.04

Notes: (a) n = number of students; (b) effect size refers to Cohen's d; (c) means expressed as scaled scores out of a possible 20.

Table 5
Comparing CMP Groups to South Australian State Norms.

Subject	CMP (n)	State of SA (n)	Effect size
Biology	15.24 (19)	13.11 (4337)	0.60
Chemistry	15.31 (33)	14.04 (2433)	0.38
Physics	15.17 (24)	14.32 (2496)	0.24
Maths 1 (S)	14.33 (15)	12.89 (2682)	0.35
Maths 1 (D)	16.0 (13)	15.5 (1327)	0.09
Maths 2	15.62 (13)	14.58 (5576)	0.29
Economics	15.9 (5)	13.97 (1137)	0.59
Geography	13.7 (13)	13.22 (2082)	0.15

Notes: (a) n refers to number of students; (b) effect size coefficient is Cohen's d.

It should be noted that in the current data set, there are no process indicators monitored, and hence no independent evidence to the effect that students were actually carrying out the CMP procedures faithfully. In this study we were concerned only with outcome indices, and can only note that the CMP program appears to have been accepted as a viable learning method by sizeable groups of students who appear to be able to use these strategies within their knowledge building. We have collected another set of data from Site 2 (not reported here) which does suggest that students in general will accept CMP as one valid method to use when faced with difficult learning problems. In short, although students are expected to master a range of viable learning strategies as they progress through their schooling experience, it can be noted that CMP does appear to offer the student another viable learning tool.

The logic of the present study was that CMP and non-CMP classes could be contrasted on measured outcome indices. Since these were naturally occurring classes, the study does not reflect controlled research as such. In each contrast we assume that the comparison is a valid one, but we have no clear way of confirming this assumption. Thus, we conceive of this project as a form of action research based on naturally occurring field trials, in which teachers committed to using CMP were found to be teaching classes in schools that had immediately comparable classes on the same site. Across the two sites, a similar pattern of data emerged, and the examination performance of the CMP students was of especial significance in that the CMP students performed at a level as high as or higher than the South Australian state norms (see Table 5), despite coming from a school that evidences public examination scores (HEES) below the state averages.

The suggestion is that CMP procedures can be incorporated into conventional instruction by teachers who have been trained in the learning theory behind the approach. It should be noted that CMP is not a 'curriculum package' in any meaningful sense. Instead, CMP hinges upon both teachers and students jointly recognising potential obstacles to learning and devising adaptive procedures that make conceptual retention an achievable goal. Indeed, we suggest that it is most helpful to conceive of CMP as training in both strategic processing and self-regulation at the same time.

Should a student begin to discover the benefits accruing from successful strategy usage, the assumption is that the student may apply the strategy in a new learning context. This is a weighty assumption, and the available data within cognitive psychology would suggest that the goal of transfer of training is considerably harder to achieve than any simple analysis might suggest (Pressley & McCormick, 1995). However, at both sites it was apparent that teachers encouraged persistence, and the message that *concept learning is naturally difficult, but strategies make it easier if you keep using them* is an explicit and intrinsic part of the CMP procedure.

Within the present data set we are struck by the finding that students who had undergone CMP training in some subject areas, and scored relatively well in those areas, also evidenced higher examination scores in certain other subject areas in which CMP strategies were not explicitly used by their teachers. We spoke to the site's Head teacher in biology about this issue. He ventured the opinion that although he did not use CMP himself, he nevertheless was aware of the program at the site, and frequently made suggestions to his Year 12 classes that CMP procedures could be used to strong advantage in some specific contexts. That is, he admitted cueing students to employ cognitive strategies which included using the CMP procedures.

Finally, we wish to suggest that the present data add weight to the overall notion that when students confront errant prior knowledge within science and mathematics classes, they are in a far better position to resist the mind's natural tendencies to reject new and anomalous data. Chinn and Brewer (1993, p. 29) concluded that "theory change is more likely when people process contradictory information more deeply than when they do not." Conceptual mediation strategies appear to assist a learner by helping her abandon old ideas through addressing them at a crucial instructional moment. In that CMP encourages a student to activate old ideas at the very moment of learning new ones, the learning strategies it recommends are initially counter-intuitive. However, the present data suggest that these counter-intuitive strategies can be effective and useful to students within the normal classroom experience.

Correspondence: Greg Yates, School of Education, University of South Australia, St. Bernards Road, Magill, SA 5072, Australia
E-mail: g.yates@unisa.edu.au

References

Baddeley, A. D. (1990). *Human memory: Theory and practice.* Hove, UK: Lawrence Erlbaum.

Chinn, C. A., & Brewer, W. F. (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction. *Review of Educational Research, 63*, 1–49.

Dawson, C., & Lyndon, H. (1997). Conceptual mediation: A new perspective on conceptual exchange. *Research in Science Education, 27*, 157–173.

Dempster, F. N., & Brainerd, C. J. (1995). *Interference and inhibition in cognition.* New York: Academic Press.

Dempster, F. N., & Corkill, A. J. (2000). Neo-interference research and the development of intelligence. In M. Anderson (Ed.), *The development of intelligence* (pp. 215–243). New York: Psychology Press.

Gauld, C. (1986). Models, meters, and memory. *Research in Science Education, 16*, 49–54.

Lyndon, H. (1989). I did it my way!: An introduction to "Old Way/New Way" methodology. *Australasian Journal of Special Education, 13*(1), 32–37.

Lyndon, E. H. (1998). Conceptual mediation program training guide. Department for Education and Children's Services, South Australia. Available on www.southsupportservices.sa.edu.au/resources.htm

Lyndon, E. H. (2000). Conceptual Mediation: A new theory and a new method of conceptual change. Unpublished doctoral thesis, Department of Education, University of Adelaide. Available on www.southsupportservices.sa.edu.au/resources.htm

Martin, M. O., Mullis, I. V. S., Gonzales, E. Z., Gregory, K. D., Smith, T. A., Chrostowski, S. J., et al. (2001). TIMSS 1999 international science report: Findings from IEA's repeat of the third international mathematics and science study at the eighth grade [WWW document]. URL http://timss.bc.edu/timss1999i/science_achievement_report.html (accessed April 2003).

Pfundt, H., & Duit, R. (1994). *Bibliography – Students' alternative frameworks and science education* (4th ed.). Kiel, Germany: IPN.

Postman, L., & Underwood, B. J. (1973). Critical issues in interference theory. *Memory and Cognition, 1*, 19–40.

Pressley, M., & McCormick, C. (1995). *Advanced educational psychology*. New York: Harper Collins.

Rennie, L. J., Goodrum, D., & Hackling, M. (2001). Science teaching and learning in Australian schools: Results of a national survey. *Research in Science Education, 31*, 455–498.

Rowell, J. A., Dawson, C. J., & Lyndon, E. H. (1990). Changing misconceptions: A challenge to science educators. *International Journal of Science Education, 12*, 167–175.

Underwood, B. J. (1957). Interference and forgetting. *Psychological Review, 64*, 49–60.