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Knowledge Organizations Resulting from Pairs' Problem-Solving Versus Information Gathering Activities

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Abstract: We examined the externalized knowledge structures elicited from subjects who used the multimedia program *BrainStorm: An Interactive Neuroanatomy Atlas* under two contexts. In the problem-solving context, student pairs were asked to solve a clinical case resulting from cranial nerve injury. In the second, information-gathering context, student pairs were given traditional questions to answer about these cranial nerves. We assessed student knowledge using individual pre- and post-tests, and concept-based Pathfinder Networks (PFNETS), and surveyed students' opinions of the contexts. Although the survey seemed to indicate a preference for the problem-based context, the preference was not universal, and only marginally significant. The information gathering context yielded higher gain scores, and generated PFNETS more similar to the instructors' relative to the results from the problem-solving context. In addition, students who were in pairs with at least one graduate student were more likely to yield higher post-test scores and PFNETS that resembled the instructors' networks.

The Role of Technology for Problem-Based Learning

Computer technology may prove to be an important ally in support of PBL, and may help to alleviate several of the shortcomings associated with it. By providing an authoritative source that is readily available (theoretically) at any time, it allows an instructor to provide more one-on-one attention to those students who require it, thus potentially lowering the cost of the time-intensive aspects of PBL. It may also be used to alleviate the occasional problems regarding structured feedback that are sometimes associated with PBL; this readily available source of information might reduce the frustration that some students feel when trying to solve problems in a PBL environment. In addition, computer programs, to varying degrees, can be used independently or collaboratively, both in and out of classrooms. Both Linn (1992) and Okada and Simon (1997) recommend the use of student pairs as an effective alternative to group learning that incorporates the advantages of group learning, while minimizing its disadvantages. The latter reported that pairs of subjects were more successful than individuals while interacting with a computer simulated genetics laboratory during a discovery activity. White and Frederiksen (1998) report that collaborating with a higher-achieving partner while engaging in reflective activities may significantly improve the performance of lower achieving students. Just this type of effective combination can occur in heterogenous pairs of students engaged in problem based learning.

Very few, if any, studies have investigated how multimedia use in a problem-based format may differ from its use in the service of more traditional school tasks--such as information gathering--with regard to measures of problem solving ability, domain knowledge, and knowledge organization, etc. The paucity of research in this area, in part, motivated the present study.

The Utility of Pathfinder Associative Networks

One of the characteristics of PBL that accounts for the advantages attributed to it may be the way resultant knowledge is organized (Norman & Schmidt, 1992). This conjecture has support from Durso, Rea, and Dayton (1994), who used Pathfinder Associative Networks ("PFNETS"; Schvaneveldt, 1990) to measure the knowledge organizations of subjects solving an insight problem, relative to those who were given the information as a story (rather than as a problem to solve). Pathfinder networks reflect general conceptual proximities that are empirically derived from subjects' ratings of the relatedness of pairs of terms. Each network representation (PFNET) yields a "concept map" of a subject's knowledge organization (e.g., Figure 1). Durso, et al. (1994) report that people who solved an insight problem had a significantly different knowledge organization, as measured by PFNETS, than did those who (a) did not solve it or (b) were presented with the information in a non-problem format.

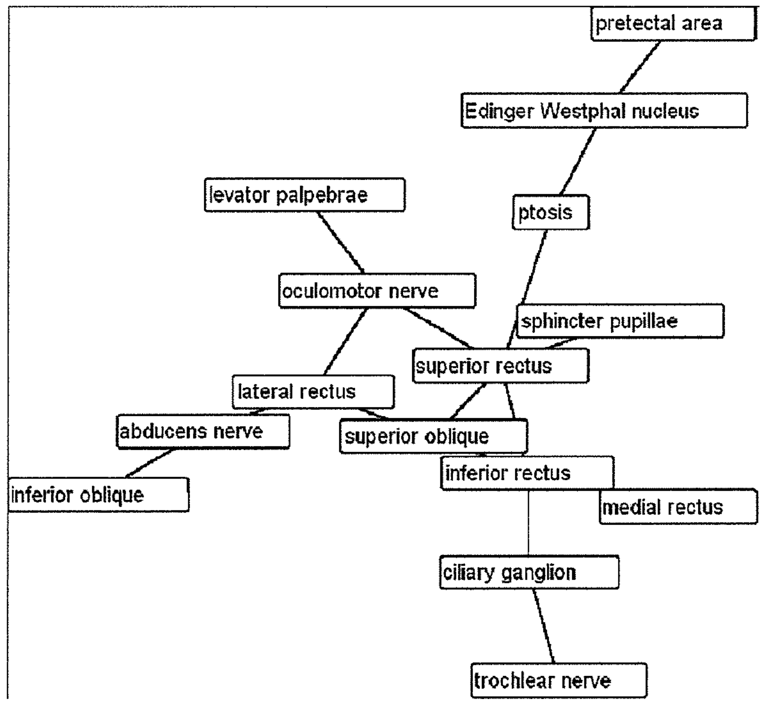

Figure 1. A student's PFNET for Exercise 1.

Additionally, Goldsmith and Johnson (1990) used PFNETS to assess the knowledge structures of students over the course of learning in a conventional statistics classroom–and to compare the students' structures with those of the instructors, over time. They found that the knowledge representations as generated by Pathfinder offered a useful assessment of classroom learning and that the correlation between a student's structure and an instructor's was a good index of how much the student learned about the domain of study.

Results

Pre- and Post-Tests

Paired sample t-tests revealed significant score differences between the set of corresponding pre-test and post-test items for all combinations of exercises and context *(p's* $< .005$, see Table 1). The difference in the means on the (full) post-tests between the two exercises indicates Exercise 2 was more difficult, in terms of proportion correct (Exercise 1 = .74; Exercise 2 =.54; $p< .001$), but the context in which students learned the material had no effect on these post-test scores (PS=.62; IG = .66). However, the information gathering context yielded higher gain scores than the problem solving context when both exercises are combined (PS gain = .15; IG gain = .23; $p=.06$; marginally significant). Additionally, analyses of the post-test item scores by type of question (recall, analysis, or integration) or topic (anatomy, function, or symptoms) revealed no significant context-based differences in score.

Exercise	Context	Pre-Test Mean	Post-Test Items Mean	Mean Difference Gain	SD	Paired T-test	*p* value
1	PS	0.68	0.83	0.15	0.13	3.854	.003
	IG	0.67	0.89	0.22	0.12	6.000	.000
2	PS	0.41	0.57	0.16	0.16	4.528	.001
	IG	0.42	0.67	0.25	0.25	4.672	.001
Overall		0.55	0.74	0.19	0.14	9.048	.000

Table 1. Corresponding Pre-Test versus Post-Test Item Performance by Problem Solving (PS) and Information Gathering (IG) Contexts, as well as by Exercise.

Exercise	PFNET	PS Mean	IG Mean	F	Significance
1	Instructor 1	.4521	.4629	0.038	.847
	Instructor 2	.4765	.6461	3.106	.094
	Instructor 3	.3624	.5029	5.053	.037
	Instructor 4	.4777*	.4775	0.000	.997
	Instructor 5	.4533	.6108	4.189	.055
2	Instructor 1	.4375	.4863	0.588	.452
	Instructor 2	.4238*	.3976	0.464	.504
	Instructor 3	.4219	.4707	0.688	.416
	Instructor 4	.4520	.5072	0.877	.360
	Instructor 5	.4181	.4684	0.667	.424
Wilcoxon Signed Rank Test		*1 higher/1 tie	8 higher	Z=-2.395	.017

Table 2. Correlations of Student and Instructor PFNETS by Problem Solving and Information Gathering Contexts

Pathfinder Networks

Student pathfinder networks (PFNETS) were compared to instructors' PFNETS on both individual-instructor and a combined-instructor (averaged) bases. A significant difference among the correlations and instructional contexts was found for Exercise 1 regarding the major instructor for the course (Instructor 3 in Table 2). In this case, students who learned the material in the information gathering context produced PFNETS that yielded higher correlations with that instructor's PFNET than those learning in the problem solving context (.50 vs. .36; $p<.005$). Two additional experts (Instructors 2 and 4 in Table 2) yielded a marginally significant result for Exercise 1 ($p=.094$ *and* $.055$). More generally, a Wilcoxon Signed Ranks Test showed that overall, the information gathering PFNETS correlated more highly with instructor PFNETS than did the problem-solving PFNETS (Z= -2.395; $p=.017$). Comparisons among the instructors' PFNETS revealed significant correlations for every comparison (*r's* ranging from .40 to .93; $p<0.01$). In addition, we observed a significant meta-correlation between students' post-test scores and their PFNET correlations with the instructors. For both exercises, students who scored higher on the post-test had generally significantly higher PFNET correlations with the instructors' PFNETS (*meta-r's* ranged from .33 to .85; see Table 3).

Exercise	Instructor	1	2	3	4	5	Combined
1	Post-Test	.77*	.59*	.83*	.68*	.85*	.83*
2	Post-Test	.61*	.33	.50*	.54*	.58*	.55*

Table 3. Pearson (Meta-)Correlations of Post-test Performance with Student/Instructor PFNETS Correlations (*significant at the .001 level; 1-tailed).

Pair Composition

Across both exercises, pair composition had significant effects on student performance, both on the post-test score proportions and on student/instructor PFNET correlations (see Table 4). Although there were no differences in the pre-test scores of undergraduates based on pair membership, those who were paired with graduate students performed better on the outcome measures (i.e., both gain-scores and PFNET correlations) than their counterparts who were paired with fellow undergraduates (see Table 5). In fact, graduate students in mixed pairs also benefitted more from the mixing when comparing their PFNET correlations with the instructors' relative to those in graduate-graduate pairs (r =.60 vs .50; $p < .05$).

Exercise	Measure	Undergrads	Grads	Mixed	F	Significance
1	Post-Test Score	.64	.76	.79	4.850	.020
	PFNETS Correlation	.32	.54	.60	13.634	.000
2	Post-Test Score	.44	.59	.58	3.988	.036
	PFNET Correlation	.34	.49	.45	5.737	.011
Overall	Post-Test Score	.54	.68	.69	4.526	.017
	PFNET Correlation	.32	.49	.57	18.002	.000

Table 4. Differences in Pair Performances based on Composition. "Score" indicates mean proportion of correct answers, and "Correlation" indicates comparison with experts' combined PFNETS.

	Measure	Homogenous Pairs	Mixed Pairs	F	Significance
Undergrads	Pre-Test Score	.48	.49	.002	.969
	Gain-Score	.14	.30	4.742	.045
	PFNET Correlation	.33	.53	16.402	.001
Graduates	Pre-Test Score	.59	.59	.003	.956
	Gain-Score	.19	.20	.044	.836
	PFNET Correlation	.50	.60	4.437	.046

Table 5. Graduate and Undergraduate Performance Based on Pair Membership. "Score" indicates mean proportion of correct answers, and "Correlation" indicates comparison with experts' combined PFNETS.

Survey/Questionnaire

On the questionnaire that elicited student opinions about the relative merits of each of the tasks, students agreed that both methods (1) helped in comprehending and remembering the material, (2) allowed for success in accomplishing the task, and (3) should be incorporated as regular course activities. Fourteen of the 26 items yielded statistically significant findings. Students were more likely to agree that problem-solving, rather than information gathering, a) contributed to the integration of the material, b) promoted reflection, c) provided insight into applications, d) supported collaboration, e) required the use of prior knowledge, f) piqued curiosity, g) encouraged deep understanding, h) provided contextual meaning, i) helped to better understand the lab, j) prompted additional questions, k) provided relevance, and l) was a meaningful activity (all p's $< .05$). Conversely, students were more likely to agree that information gathering, rather than problem-solving encouraged both rote memorization and attention to detail (p's $< .05$). However, while students seemed to prefer, in general, the problem-solving method, this finding was only marginally significant on a five point scale (in which 5= "strongly agree" and 1= "strongly disagree": PS mean =3.55, IG mean=2.77; p=.108).

With regard to their opinions about the multimedia program, 63% of students disagreed or strongly disagreed–while only one student agreed–with the statement, "Learning this material could have just as easily been done by using a textbook." Indeed, 82% agreed or strongly agreed (with no one in disagreement) with the statement, "The program provided support that would be difficult to obtain through other methods."

On the survey questions that elicited their attitudes about working on each of the tasks, students were more likely to agree that they enjoyed the problem assignment (relative to the IG assignment), and were interested, motivated, and involved in the problem. Still, although 79% of respondents disagreed or strongly disagreed with the statement, "The questions were too difficult to answer using the program," significantly fewer (59%) disagreed that "the problem was too difficult to answer using the program" (5 point scale: IG = 2.23, PS = 2.59, $t= -2.16$, $p < .05$). The opinion that the problem was too difficult to solve was modulated by the particular exercise; students who received the problem as their second exercise were more likely to view it as difficult (E1=2.4 vs E2=3.0;

p=.024). Students overwhelmingly agreed or strongly agreed that solving case problems encourages the integration of concepts (96%), whereas only 27% agreed that answering direct questions does so (*t=4.271, p<.001*).

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