"EARTHQUAKE!" — A COOPERATIVE LEARNING EXPERIENCE

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ABSTRACT

A highly structured exercise which was designed as a team-building experience for managers can be used to demonstrate to science students the potential benefit of group decision-making. The exercise, which involves ranking of options for surviving a large earthquake, yields quantitative measures of individual student knowledge and how well the groups function.

INTRODUCTION

For the past three years the first laboratory exercise in a second-year university course on Earth's Resources and Hazards has been one in which students are required to work in groups. While it serves to "break the ice" in the course by immediately requiring interactions between students and between students and staff, it also offers a foretaste to the workplace situation these students are ultimately likely to experience. Hackman (1990) observes that group work is increasingly the way professionals work in a variety of settings, a theme echoed by Beiersdorfer and Beiersdorfer (1995) and Basu and Middendorf (1995). Advertisements for employment also invariably require that applicants be good "team players". Also, pertinently for this particular course, it is not difficult to demonstrate from media coverage of earthquakes, volcanic eruptions and floods that group decision-making is common in times of environmental crisis.

A significant proportion of students enrolled in the course have aspirations for a career in environmental management or planning and many are reading for a social sciences or management degree. These students are likely to be favourably disposed towards group learning activities and recognize that the activities would be valuable preparation for professional life. The other significant group of students enrolled in the course are science majors who typically expect laboratory work to support material given in lectures. These students are less likely to have experienced much group work in the courses undertaken at the university and were perceived to have attitudes ranging from ambivalent to hostile to group activities. It was primarily for this group that an exercise was selected for which group work could be demonstrated quantitatively.

THE EXERCISE

"Earthquake" was developed as a management dynamics training exercise by Fisher and Peters, 1990. It involves the ranking of twelve action steps for survivors of a large earthquake who are trapped in the basement of a damaged multi-storey office building. The opening scenario paints their predicament as uncomfortable, but not immediately life threatening. Their way out from the basement is blocked by rubble, indicating there has been some damage to the structure of the building. There is no electricity or telephone available, but they do have water supplies and the cracks in the foundation walls will admit air. After searching through the rubble they find:

- a working battery operated radio
- two candles
- cleaning supplies (mop, bucket, bleach, window cleaner, screwdriver, wrench and work gloves)
- a first aid kit (bandages, gauze and aspirin)
- a package of matches
- a coffee machine, half a pot of coffee and three packages of instant coffee
- a flashlight with extra batteries
- four left-over chicken salad sandwiches in the refrigerator and two bags of crisps
- three full ice-cube trays in the freezer
- six cans of soft drink.

Such an opening scenario makes this exercise a simulation as defined by Jaques (1991, p. 102), and it is a cooperative one in the sense of Bykerk-Kauffmann (1995) in that it:

> *... is structured so that group members both need each other to succeed and are individually accountable for understanding the material. Practitioners of co-operative education set expectations of behaviour within the groups and monitor that behaviour ...*

The exercise requires the ranking of twelve options, seven of which should be taken to ensure survival and five that should not be taken because they are either unnecessary or harmful. The options are given in Table 1.

The options available can either be beneficial or injurious to the participants and may help or hinder their chances of rescue. Course participants initially undertook this ranking exercise individually, assigning "1" to their most preferred option, and "12" to the least. After this, the students formed groups of unrestricted size and composition and undertook the exercise again. The numbers of participating students and groups are shown in Table 2.

Only after completing the exercise individually and in groups, were the participants told the order of ranking by "experts". The sum of differences between the rankings of the individual and "expert" responses - without regard to sign - gives the individual score (S); the sum of differences between the rankings of the group and "expert" responses gives the team score (T), as shown on Table 3.

Each group of N members was asked to calculate the average individual score, viz., (A = [SS] / N), and also to

Preferred Rank	Option
1 (best)	Shut of all utilities
2	Check for injuries and administer first aid
3	Assign someone to monitor the radio and listen for updates
4	Locate and secure a water supply
5	Develop a day and night signalling system and begin signalling immediately
6	Discuss long-term survival strategies as a group
7	Divide sandwiches and eat them this evening
8	Purify the water source
9	Pound on the pipes with the steel wrench
10	Divide the sandwiches and ration them over the next few days
11	Attempt to remove the rubble from the entrance to the first floor
12 (worst)	Light the candles so you can see and rescuers will be able to locate you.

*This preferred ranking is based on the premise that the safest course of action is to wait for help to arrive. They have plenty of supplies to last for several weeks. They have appropriate materials for signalling rescuers who will inevitably search for trapped people within the next few days. The ranking was provided in Fisher and Peters (1990) in association with the Bay Area [San Francisco] Regional Earthquake Preparedness Project.

+ The options were not numbered for the students. They assigned rankings from 1 to 12: the most preferred being "1", the least "12". Subtracting their rank number from the preferred rank number for each item, and adding the differences (regardless of sign) together gave them their score.

Table 1. Options for survival

Number of participants in each group	Number of groups				Number of students			
	1997	1998	1999	**Total**	1997	1998	1999	**Total**
3	1	5	6	**12**	3	15	18	**36**
4	7	10	10	**27**	28	40	40	**108**
5	8	4	4	**16**	40	20	20	**80**
6	0	6	2	**8**	0	36	12	**48**
9	0	1	0	**1**	0	9	0	**9**
total	16	26	22	**64**	71	120	90	**281**

Table 2. "Earthquake!": Group participant information.

note the lowest individual score (L) and the number of participants whose score was less than the team score (i.e., NS<T). These parameters (also shown on Table 3) enabled quantitative measures of the effectiveness of group work and the quality of the decisions made.

EVALUATION AND ASSESSMENT

The high noise level in the laboratory while the exercise was in progress suggested that students were certainly actively involved, although the variability of the scores attests to variations in the extent of cooperative involvement! The tabulation of the scores on the blackboard in the laboratory at the end of the exercise prompted some surprise, the result of which was that a few students volunteered the opinion that at least in circumstances of crisis management group decision-making might lead to a preferable outcome. A particularly telling consequence of the dynamics of one group was revealed when the exercise was completed and a lecture array was resumed for discussion of the results. Most participant groups actually remained intact during this discussion, but the members of the group that had performed poorly on all counts (Group 97P) remained noticeably distant from each other. When this group was invited to comment on how its members had resolved a conflict of views, they indicated that they had voted and the majority result was taken as the group decision. The group had behaved democratically, but with poor synergy and decision quality. In contrast, Group 97O, when faced with a similar conflict of

Group	Content scores		Process scores			
	Average individual Score+ $A=[\Sigma(S)]/N$	Team score T	Synergy(% change) $Y=[A-T]$	$([100.Y/A])$	lowest indiv. score L	proportion of indiv. scores < team score# $(N_{S<T})/N$
Groups with three members						
97A	20.3	16	+ 4.3	(+21%)	18	0
98E	31.0	16	+ 15	(+48%)	12	0.33
98H	13	12	+ 1.0	(+8%)	8	0.33
98M	25.3	16	+ 9.3	(+37%)	18	0
98O	22.7	20	+ 2.7	(+12%)	16	1
98S	29.3	18	+ 11.3	(+39%)	20	0
99B	21	14	+ 7	(+33%)	18	0
99C	22	16	+ 11	(+41%)	18	0
99D	27	16	+ 11	(+41%)	26	0
99F	30	18	+ 12	(+40%)	12	0.33
99M	25	16	+ 9	(+36%)	20	0
99W	24	10	+ 14	(+59%)	19	0
mean	**24.2**	**15.6**	**+ 9.0**	**(+34.5%)**	**17.1**	**0.11**
σ**	**4.8**	**2.6**	**4.2**	**(13.9%)**	**4.6**	**0.16**
Groups with four members						
97B	22	18	+ 4	(+18%)	12	0
97C	25.3	20	+ 5.3	(+21%)	22	0
97D	21	22	- 1	(- 4.7%)	18	0.75
97E	30	8	+ 22	(+73%)	36	0
97F	21.5	16	+ 5.5	(+34%)	18	0
97G	15.5	10	+ 5.5	(+35%)	24	0
97H	24	14	+ 10	(+42%)	20	0
98B	17.5	12	+ 5.5	(+31%)	12	0
98C	25.5	20	+ 5.5	(+22%)	22	0
98I	24.8	20	+ 4.8	(+19%)	20	0.25
98J	17.5	8	+ 9.5	(+54%)	10	0.50
98K	22.5	12	+ 10.5	(+47%)	14	0
98L	15.3	10	+ 5.3	(+35%)	8	0.25
98N	28	26	+ 2.0	(+7%)	24	0.25
98Q	29	24	+ 5.0	(+17%)	20	0.50
98R	33.8	30	+ 3.8	(+11%)	24	0.25
98T	18.3	10	+ 8.3	(+45%)	12	0
99E	23	16	+ 7	(+30%)	14	0.25
99G	25	20	+ 5	(+20%)	20	0
99H	25	22	+ 3	(+12%)	14	0.25
99I	27	24	+ 3	(+11%)	26	0
99J	25	22	+ 3	(+12%)	16	0.25
99L	30	16	+ 14	(+47%)	20	0
99O	19	20	- 1	(-5%)	16	0.75
99P	28	22	+ 6	(+21%)	20	0.25
99Y	28	18	+ 10	(+35%)	20	0
99Z	32	22	+ 10	(+31%)	18	0.25
mean	**24.2**	**17.9**	**+ 6.4**	**(+26.7%)**	**18.5**	**0.18**
σ	**4.8**	**5.7**	**4.5**	**(17.4%)**	**5.7**	**0.22**

Table 3. "Earthquake!"* participant data (1997-1999). Table continues on next page.

Group	Content scores		Process scores			
	Average individual Score+ $A=[\Sigma(S)]/N$	Team score T	Synergy(% change) $Y=[A-T]$	$([100.Y/A])$	lowest indiv. score L	proportion of indiv. scores < team score# $(N_{S<T})/N$
Groups with five members						
97I	28.6	20	+ 8.6	(+31%)	22	0
97J	20.2	18	+ 2.2	(+12%)	16	0.4
97K	23.2	22	+ 1.2	(+ 5%)	14	0.4
97L	20	12	+ 8	(+40%)	12	0
97M	27	20	+ 7	(+26%)	24	0
97N	27.8	22	+ 5.8	(+21%)	18	0.2
97O	20.8	4	+ 16.8	(+81%)	8	0
97P	29.6	30	- 0.4	(- 1.4%)	18	0.4
98A	19.6	12	+ 7.6	(+39%)	14	0
98D	21.2	12	+ 9.2	(+43%)	12	0
98F	23.6	12	+ 11.6	(+49%)	18	0
98G	21.2	20	+ 1.2	(+6%)	18	0.2
99A	28	20	+ 12	(+43%)	20	0
99K	24	20	+ 4	(+17%)	17	0.4
99Q	26	16	+ 10	(+38%)	16	0
99X	22	24	- 2	(-9%)	12	0.4
mean	**23.9**	**17.8**	**+ 6.4**	**(+27.5%)**	**16.2**	**0.15**
σ**	**3.3**	**6.0**	**4.9**	**(22.0%)**	**4.0**	**0.18**
Groups with six members						
97Q	31	12	+ 19	(+61%)	20	0
97R	22	12	+ 10	(+47%)	16	0
97S	20.5	12	+ 8.5	(+41%)	10	0
97T	19.2	16	+ 3	(+19%)	14	0.33
97U	24.3	10	+ 14.3	(+58%)	14	0
97V	22	16	+ 6	(+27%)	15	0.17
99N	28	12	+ 14	(+50%)	20	0
99R	24	16	+ 8	(+33%)	12	0.33
mean	**23.2**	**13**	**+ 10.1**	**(+42.2%)**	**14.8**	**0.08**
σ	**4.2**	**2.5**	**5.8**	**(16.7%)**	**3.3**	**0.14**
Group with nine members						
98P	23.3	16	+ 7.3	(+31%)	9	0.11

* Fisher and Peters (1990).
+ individual score is S
# The number of individual scores lower than the team score is an extension of the "lowest individual score in the team" idea. Teams that function effectively seldom have more than one person on them that did better than they did collectively, and often they have none. Groups that work poorly together will have the ratio $N_{S<T} > 1/N$, i.e., greater than 0.33 for $N = 3$, greater than 0.25 for $N = 4$, greater than 0.2 for $N = 5$, and greater than 0.17 for $N = 6$.
** σ is sample standard deviation

Table 3, continued. "Earthquake!"* participant data (1997 - 1999).

views, had also taken a vote, but then used this as a basis for further discussion, as should a jury during its deliberations, eventually reaching a consensus decision, but not necessarily one that reflected the original majority view.

For 1998 and 1999, the exercise concluded with a short questionnaire. Participants were invited to rank on a five point scale (1, minimal; 2, limited; 3, modest; 4, high; 5, considerable) their perceptions of:

- their initial understanding of the content of the exercise;
- their contribution of ideas to the group;
- the effectiveness of the group in working together
- any improvement in the group understanding of the content

The initial perception students had of their knowledge of content bore some relation to their individual scores: those with higher perception ratings had lower S scores, more in line with the "experts". There was no obvious correlation between the perception of a student's con-

Variables		
X =	perception of synergy	perception of improvement
Y =	Synergy parameter (Y/A)	knowledge parameter (A - T)
Expected relationship for $Y = M * X + B$		
	$M > 0$	$M > 0$
Regression parameters		
Slope (M)	+ 1.50	- 12.5
Intercept (B)	+ 1.74	+ 78
Correlation coefficient+	0.15	0.36

Table 4. Linear regression parameters for the correlation between perceptions and quantitative parameters from "Earthquake!" (1999 data* only)
***Not all participants in the exercise itself completed the questionnaire**
+There are 18 data points (i.e., 1 for each group); the low values indicate low significance for the regression; at best the regressions suggest a trend.

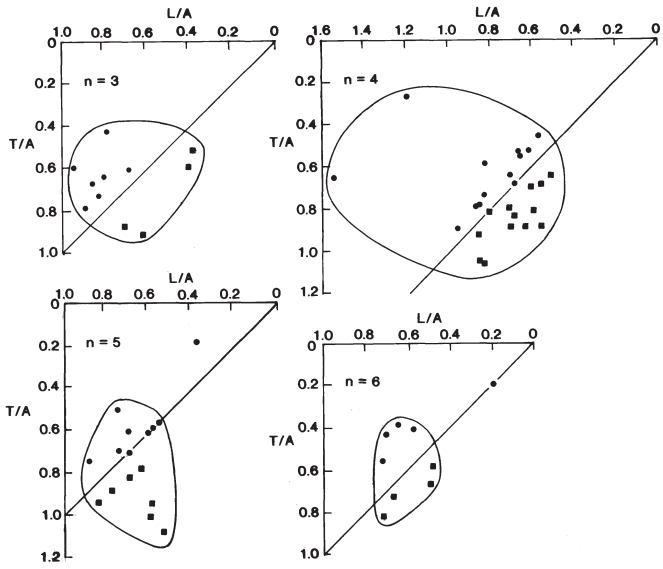

Figure 2. Representation of the contribution of the participant with the lowest individual score (L) to the team score (T), for teams of size 3 - 6. Because each group has a different A- value (see Table 3), the plot is shown as L / A versus T / A. Where L > T (above sloping line), ideas are captured; when L < T (below line), the participant who has good ideas appears not to contribute - "hitch-hikes" - or is "shut out" of the discussion by other group members. Square symbols correspond to those groups where NS<T > 1 / N , being groups with a high proportion of participants having lower (better) individual scores than their group score.

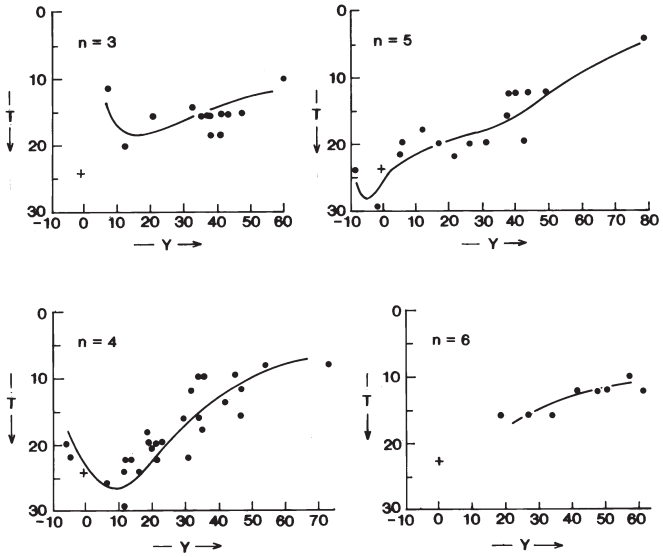

Figure 1. Team score (T) versus synergy (Y) for groups of N members. While there are positive relationships between these parameters, suggesting that the teams that perform better as a group also make better decisions, the trend for 4-member groups (N = 4) is highly reminiscent of Katzenbach and Smith's (1993, fig. 11-1) curve of "performance impact" (analogous to decision quality, T) vs. "team effectiveness" (analogous to synergy, Y). This minimum in this plot indicates that teams may appear to work modestly well, yet not necessarily achieve a quality decision. Such a team may even perform less well than the average of the individuals that make up the team (i.e., T = A when Y = 0, shown as the crosses [+] on the plots).

tribution to the group and their actual contribution, as measured by the difference between their individual and team score, S - T. This suggests students found it hard to assess the value of their contribution to the group. While there was a weak correlation between the averaged perceptions of effectiveness of group members and the actual synergy, this was not matched by a correlation between the perceptions of improvement of knowledge and the actual improvement, A - T (Table 4). This suggests that at least at the time the students undertook the questionnaire they had not grasped the potential benefits of the exercise and confirms the value of subsequently explaining the significance of the individual and group measures obtained in the exercise. This explanation during class discussion after the exercise had been undertaken was complemented by a poster about the exercise which was displayed for the rest of the semester.

THE SYNERGY OF GROUPS

In this exercise low scores indicate a better knowledge of earthquake preparedness and crisis management, or less difference between the student and the "experts". The average individual score, A on Table 3, is a measure of the quality of the information that members brought to the

group. The team score, T , is a measure of how well the group solved the problem, i.e., the quality of the team's decision. However, the team score alone says nothing about the process by which the group reached that decision. Table 3 shows clearly that the quality of the decision is improved by working in groups. For most groups the team score is lower than the average individual score, i.e., $T < A$.

If the team functioned neither better nor worse than its individual members, then the team score, T, would be expected to be the same as the average individual score. The difference between the average individual score of members in the group and the team score is a measure of how effectively the team worked together – the team's synergy. When this parameter is positive, i.e., $Y = A - T > 0$, the team is more effective at solving the problem than is the average individual. The ratio $(A - T) / A$, expressed as a percentage in Table 3, is probably a better indicator of synergy especially for groups with individuals who are already reasonably knowledgeable about the problem, i.e., groups with low A-values.

Figure 1 indicates that most groups that were better at solving the problem, those with low T scores, also had good synergy, i.e., high Y percentages. It is noteworthy that just a few groups had high T scores and low synergy, giving a minimum in the plot. The decision making process in the groups to the left of the minimum was probably dominated by a particular individual and, thus, was not a real "team" effort. Katzenbach and Smith (1993) would have considered the groups just to the right of the minimum to be "pseudo-teams". As the right-hand branch of the plot is ascended the groups become "potential teams", "real teams", and - at the uppermost right of the diagram - "high performance teams".

The lowest individual score, L, in the group compared to the team score, T , is a measure of the group's use of individual knowledge. If any member of the team did better alone than the team did together, $L < T$, then there was sound information available to the team that it did not use. Perhaps the owner of that information chose not to contribute to the deliberations of the group and was a "hitch-hiker" (Marras Manner, 1995), or perhaps other members "shut out" him / her from the activity. One way of assessing this is to plot of the ratio of the team score to the average individual score, T / A , versus the ratio of the lowest individual score to the average individual score, L / A . This is shown for various sized groups in Figure 2. About 40% of groups fail to make the best use of the information available, but this is not obviously related to group size.

FEEDBACK

At the discussion session following "Earthquake!" Table 3 was displayed as part of a poster about the exercise and an explanation was given of what the various parameters meant. Because each student knew his/her own scores, the team score and team synergy, he/she could determine for themselves how effective his/her team was.

Many students commented favourably on the exercise when it was over, several being surprised that this activity was presented as a laboratory exercise in a science course. Some students had not expected that their deliberations in a group would lead to a better decision than they would have made on their own. Students undertaking management courses tended to be more interested than others in the quantitative analysis of the group behaviours.

"Earthquake!" also established an expectation for group work in the other practical sessions of the course. However, not all subsequent activities in the laboratory streams for this course involved interactive groups. To give variety, individual exercises or video screenings, usually followed by open class or lecturer-led discussion, were interspersed between group sessions. These later group sessions were less structured than "Earthquake!", in that their content outcomes were less prescribed (Hodder, in press) but they still enabled an informal appreciation of the potential professional advantage of group work. The word "informal" is important in this context, for Earth's Resources and Hazards was not intended to be either a course in disaster management or one in group dynamics.

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