2006-2306: RATS: STUDENTS WORKING IN TEAMS, DO THEY REALLY BENEFIT?

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Abstract

This paper presents various findings from an investigation of several issues surrounding students working in teams. The main data for this study comes from students who are part of the senior capstone design course. Educators and practitioners know that working in teams is a reality in the engineering profession. ABET expects academic units to demonstrate that interdisciplinary teams are mainstream in engineering programs. In support, educators give a varying degree of commitment in support of a team approach for solving engineering problems. However, much like problem solving skills, there is a temptation to assume that students already know how to implement the teaming skills without any formal learning. Unlike problem solving skills, teaming skills require varying levels of personal interaction in achieving success. Hence, does placing students in a group automatically lead to a level of success that individuals working alone can not reach? Do students really know how to maximize the benefits of teaming? If the conditions lead to successful teams, how can it be determined that synergy occurs and the whole is truly greater then the sum of individual parts?

Surveying students in the capstone design course on their abilities to function in teams is one mechanism for assessing success in developing teaming skills. Several semesters of observations are presented and comparisons are made among students with formal team education as their team skills advance over the course of a semester. Results will be presented from student surveys, faculty assessment, and readiness assessment tests (RATs). Anecdotal and empirical evidence supports the need for doing more with students than simply placing them around the same table and expecting them to be a successful team. The results and conclusions are based on evaluations from student presentations and student perceptions as well as individual and team test scores as the teams progress throughout the semester. Students received formal team skill and interdisciplinary skill training. Students were also given sufficient time to implement these skills within their team to create more cohesive and productive teams. Furthermore, learning outcomes were quantified using readiness assessment tests. While not specifically designed to investigate the differences in individual learning and group learning, these assessments show that team learning is quantifiable greater than individual learning.

Introduction

Over the past two decades much has been accomplished to reform engineering education. The adoption of *Engineering Criteria 2000*: *Criteria for Accrediting Programs in Engineering in the United States*,[1] required that engineering programs demonstrate that graduates are able to function on multidisciplinary teams.[2,3,4] As a result, student teams in undergraduate engineering courses have become much more prevalent. Unfortunately, however, some of the stronger students continue to resist working in teams despite clear research findings that document that "teams outperform individuals acting alone or in larger organizational groupings, especially when performance requires multiple skills, judgments, and experiences."[5] The primary purpose of the current manuscript is to document the advantages accrued when engineering faculty

incorporate Readiness Assessment Tests (RATs)[6,7,8] into engineering curriculum to provide concrete evidence to students and instructors that they really do benefit from working in teams.

The Readiness Assessment Test (RAT) is an in-class tool originally developed by Michaelsen et al. as an element of his Team-Based Learning instructional strategy originally proposed as a potential solution to the problems of large classes [9]. RATs typically consist of 15-20 multiple choice and short answer questions taken from assigned readings that provide the opportunity for peer teaching and enable faculty to assess whether or not students have a sound understanding of the key concepts for the readings. As a result, the RAT questions focus on foundational concepts (and avoid picky details), but are difficult enough to create discussion within the teams.[10] RATs essentially function as diagnostic tools for determining student readiness while simultaneously promoting individual accountability. In short, the RATs ensure that students prepare for class by studying assigned instructional materials and completing pre-class assignments so that they are prepared for in-class teamwork.

Background

In terms of logistics, the same RAT is taken twice by students—once by an individual (IRAT) and then again as a team (TRAT) in order to provide ample opportunity for the instructor to evaluate their knowledge of the current material by instantly assessing the students' readiness to apply concepts and to determine if there are able to move on to new material.[10] Students were encouraged to take ownership for their learning, and hence they were required to take the identical RAT as a team. Immediately after students completed their individual assessment (and before they receive their results), the individual members of the team collaborated to complete the assessment test by coming to a consensus on the answers. This way the students have the opportunity to discuss and debate answers and correct errors in their learning. The discussions allowed student to gain reassurance in their correct answers, learn more concepts for the questions to which they did not know the answer, and gain confidence in questions within which they were not confident before. This discussion also served as an excellent review of the readings, provided the opportunity for peer teaching, and ensured group accountability. The teams recorded their collective answers to each question in the same way they did as individuals. In order to provide immediate feedback to both instructor and students for a unit of instruction, both team and individual tests were scored in class using SCANTRON readers. Students compared individual and team answers in order to determine how effectively they had been in using the intellectual resources of all group members.

There is the possibility for some students to lose confidence if group dynamics are dysfunctional or conflicts exist with individual personality traits. For example a student who understands the concepts and performs well individually may be overshadowed in team discussions and give into a team consensus answer that they believe is incorrect. However, students who come to understand that a team can outperform individual members only when team interaction is transparent and open, quickly learn that the benefits far outweigh any potential costs. As team cohesion and trust increases over time, the negative influence of peers is diminished.

The reader needs to understand that the evaluation is not meant to be exhaustive, but rather to focus on key concepts and major themes. The RAT is a short "quiz" containing 15-20 questions

covering the general themes of a unit or lecture. However, it goes beyond a simple snapshot of the students' understanding. It also evaluates, to a certain degree, the students' confidence in their understanding by asking the students to provide three answers to each question (assuming a multiple choice format). If a student is very confident in her/his answer, then they could respond by providing the same choice for each of the three answers (e.g., c c c). The student can also split their answer if they are unsure (e.g., c c a) or guess if they have no idea (e.g., a c b). Guessing could potentially award them one point on the question. But a confident correct answer awards them the maximum points for the question. A note of caution: the effectiveness of this assessment is still heavily dependent on the instructor's ability to craft clear, appropriate, and sufficiently challenging questions. Confusing, overly detailed, or "tricky" questions will erode the usefulness and could potentially result in unproductive team discussions.

In some respects this RAT process can be compared to an expanded (and a bit more formal) think-pair-share process, in that students are asked to think about the concepts learned, get into groups (rather than with a partner) and discuss. The only real difference is that the instructor evaluates the student thinking before they share, and then evaluates the team after discussion. The reader needs no convincing that learning from peers is a valuable facet to our overall educational objectives. This RAT process gives us another strategy to enhance students' learning using teams. Of course the instructor also benefits from the immediate feedback and the ability to correct or enhance areas of weakness in the students' understanding by addressing these weaknesses before moving on.

For the purpose of this paper, the intent is to move beyond the obvious benefits of the RAT, and provide quantifiable evidence that when teams are functioning well, they can outperform even the highest performing individuals that constitute the team. Of course one would expect that the team score would be better than the average of the individual scores, but it seems unfair to expect the team score to be better than the highest individual score. Some might argue that the student with the highest score on the team, and hence presumably the greatest knowledge of the concepts, would tend to dictate the team score. At a minimum if the team used the highest scoring person's answers, all team members would benefit. But the student's do not know their score until after the team has completed the T-RAT. Because the team results are dependent upon individual personalities, strength and confidence, there are simply too many variables to warrant the assumption that the best individual will always dictate the team score.

One additional issue that is examined relates to whether team experience (or length of time as a team) has an impact on overall team performance. Rational thought would support the notion that teams with a longer history and experience of working together, where familiarity and trust is highly developed among the members, would allow for a greater level of team performance relative to any individual performance. In fact Katzenbach and Smith[3] have demonstrated such a result in their team performance curve and other studies have shown this as well. But in the course of a semester is it appropriate to expect that teams will reach optimal learning and production? The data presented below provides initial evidence that this is true. Of course it is critical to note that students are not simply thrown together and expected to perform. All students participated in a three-hour training session that includes issues related to team formation, goal setting, team norms and roles, and the importance of open and honest feedback. The training allowed students to compete in a series of activities that built cohesion and increased trust

(activities frequently engaged at leadership training seminars). Of course these students do have a certain level of familiarity, having spent several years together in school.

Results and Discussion

The data from this study were collected from the senior level required capstone design course in the Department of Civil Engineering at the University of Kentucky. All graduating seniors enroll in this course in their last semester. Over 75 students ty0pically graduate every year with roughly one third graduating in December and the remainder graduating in May. The sample for the current study included enrollments of 25 students in the 2005 fall semester and 46 students in the 2006 spring semester. Data are presented and discussed from three separate RATs (individual and team) obtained during both the fall and spring semesters. All the results presented from the RATs followed a similar structure and the same procedure as those given above. The third RAT from the fall semester differed from the others in that individual confidence in student answers was not assessed. Namely, students provided only one response on each of the questions for both the I-RAT and the T-RAT.

In the fall semester individuals were assigned randomly to teams of five, in the spring semester to teams of five and six. Teams were composed to be somewhat multidisciplinary by selecting the students from the various sub-disciplines within Civil Engineering (i.e., structures, water resources, construction engineering, etc). Finally at least one female was assigned to every team to ensure that cohesive subgroups were not formed because good friends were not on the same team. Again it is critical to stress that students were not simply throw together and expected to perform.[11] In the fall semester, the teams were established and working together for a week before the class received its first RAT. The second RAT following several weeks later and the third RAT was taken after the teams had comleted formal presentations as part of the class requirements. In the spring semester time was isolated to determine how it affected team performance. The first RAT was administered immediately after the teams were formed and before any type of team learning/education took place. The second and third RATs were administered over the next few weeks after formal team training and exercises.

Tables 1 through 3 show the results for the three RATs administered in the Fall 2005 semester, and Tables 4 through 6 illustrate the results from the Spring 2006 semester. A quick examination of the results makes it immediately obvious that the team performance was greater than the average of the individual performances. For example, in the first RAT, team 1 received a team score of 49 (out of 50) while the average of the five individual members was 41.2, an improvement of 19%. You can see similar improvements for all five teams. As a class there was an overall improvement of 17% (average team score of 44.8 compared to an average individual score of 38.4). Of course this results is expected and supports the reality of teaming, namely that student results do improve when working within a team. Individuals were accountable and took ownership of the team score through the team discussion while forming a consensus. From observations of the team discussion during the RAT, when there was initially no consensus on the answer, students had to convince each other why they thought they were right. This discussion led to strengthening each team member's knowledge. Of course to really show if individual learning improved because of collaborative learning, it would have been necessary to provide the individual RAT immediate following the team discussion. This would have

Table 1: RAT1 from Fall Semester 2005 (50pts total).

Individual	Team 1	Team 2	Team 3	Team 4	Team 5
A	33	26	44	31	40
B	46	36	36	44	43
C	32	33	39	30	42
D	45	43	36	39	34
E	50	34	48	27	48
Individual Average	*41.2*	*34.4*	*40.6*	*34.2*	*41.4*
Individual Min	*32*	*26*	*36*	*27*	*34*
Individual Max	*50*	*43*	*48*	*44*	*48*
Team Score	*49*	*43*	*43*	*39*	*50*
% Improve as Team	18.9%	25.0%	5.9%	14.0%	20.8%
Team vs. Ind. Max	-2.0%	0.0%	-10.4%	-11.4%	4.2%

Overall individual average	38.4
Overall individual standard deviation.	6.8
Overall team average (No. of Teams = 5)	44.8
Overall improvement (Team vs Members)	16.9%
Number of Teams greater than Ind. Max.	1

Table 2: RAT2 from Fall Semester 2005 (39pts total).

Individual	Team 1	Team 2	Team 3	Team 4	Team 5
A	30	29	33	24	26
B	25	32	30	33	23
C	33	34	30	27	24
D	30	28	33	33	21
E	33	30	28	29	30
Individual Average	*30.2*	*30.6*	*30.8*	*29.2*	*24.8*
Individual Min	*25*	*28*	*28*	*24*	*21*
Individual Max	*33*	*34*	*33*	*33*	*30*
Team Score	*34*	*32*	*31*	*34*	*31*
% Improve as Team	12.6%	4.6%	0.6%	16.4%	25.0%
Team vs. Ind. Max	3.0%	-5.9%	-6.1%	3.0%	3.3%

Overall individual average	29.1
Overall individual standard deviation.	3.6
Overall team average (No. of Team = 5)	32.4
Overall improvement (Team vs Members)	11.8%
Number of Teams greater than Ind. Max.	3

Table 3: RAT3 from Fall Semester 2005 (36pts total).

Individual	Team 1	Team 2	Team 3	Team 4	Team 5
A	36	34	34	22	24
B	34	34	28	30	30
C	34	26	26	28	28
D	28	30	30	32	22
E	24	28	36	34	32
Individual Average	*31.2*	*30.4*	*30.8*	*29.2*	*27.2*
Individual Min	*24*	*26*	*26*	*22*	*22*
Individual Max	*36*	*34*	*36*	*34*	*32*
Team Score	*34*	*36*	*36*	*32*	*34*
% Improve as Team	9.0%	18.4%	16.9%	9.6%	25.0%
Team vs. Ind. Max	-5.6%	5.9%	0.0%	-5.9%	6.3%

Overall individual average	29.8
Overall individual standard deviation.	4.2
Overall team average (No. of Teams = 5)	34.4
Overall improvement (Team vs Members)	15.8%
Number of Teams greater than Ind. Max.	2

definitively shown whether there was improvement as a result of team work. Because of instruction to the team, consensus requirements and taking ownership, the team score reasonable reflects the individual understanding. Case in point, in two instances (RAT3 in the fall semester and RAT1 in the spring semester) one of the team members did not support the team's consensus answer. The majority of the team believed one thing about a particular answer, whereas one student thought differently. Only after the student was allowed to formally make a note of his/her exception did they comply with the team result. This anecdotally illustrates the sense of ownership demonstrated by individuals regarding team answers.

It was hypothesized that a team would perform better than any one of its individual members. Therefore it is telling to examine how the team compared to the maximum individual score on the team. Again the Tables demonstrate mixed results. Using RAT 1 and Team 1 as an example, the team score was 49 whereas the highest score for a member from Team 1 was 50 (a perfect score). So in this case, early in the team development, the team performed worse than the best individual. Obviously it is impossible for a team to outperform a member who scores perfectly, so there is an unfortunate upper constraint. This constraint is not present in real life open-ended projects, so this constraint is somewhat artificial. The reader can see that only one team (Team 5) out of the 5 teams performed above the maximum individual. Three of the teams scored below the maximum individual, and one team did the same as the best individual. As a side note, with three of the teams performing worse than the best individual, this demonstrates that one member did not carry/dominate the entire team. Still only one of the five teams had this super-performance. Given the circumstances of newly formed teams, the result was consistent with what expectations for the first RAT. In fact it is surprising that any team outperformed its

Table 4: Descriptive statistics for individual and team scores for the 2005 Fall Semester.

Test	N	Mean	Standard Deviation
Individual RAT #1	25	38.36	6.788
Team RAT #1	25	44.80	4.203
Individual RAT #2	25	29.12	3.632
Team RAT #2	25	32.40	1.384
Individual RAT #3	25	29.76	4.216
Team RAT #3	25	34.40	1.528

Table 5: Paired-samples t tests comparing individual to team scores for the 2005 Fall Semester.

Comparison	t	df	Significance (p)
IRAT #1 – TRAT #1	-5.039	24	.0001
IRAT #2 – TRAT #2	-4.541	24	.0001
IRAT #3 – TRAT #3	-5.432	24	.0001

best member. While students were provided with ample time to start working together and becoming familiar with one another, this was their first challenge (an evaluation) that had a meaningful and significant outcome (i.e., a grade).

Skeptics may wonder whether a team can develop a working relationship and trust within a week and then achieve some type of super-performance. In deed, a week or two is not enough time to form a cohesive and trusting team. Without an established trust and a deeper knowledge of fellow teammates, it is reasonable to expect a certain reservation on the part of each individual to claim ownership for the things they do not have total control over. But the exception (team 5) in this case was able to develop sufficient positive team dynamics and trust to demonstrate this super-performance. Again though observations of teams working together in the initial stages of the formal classroom exercises, team 5 seemed to have "clicked" right from the very beginning. Hence this exception seems almost logical given the qualitative observations.

So if it takes time for teams to develop the trust, then it is reasonable to expect that over time the team will improve. In fact these results were apparent in two separate pieces of evidence. Table 2, which reports the results of RAT2 for the fall semester, shows that three out of the 5 teams performed above the highest individual. And for the two teams that did not outperform the highest individual, they were very close to matching the high performer. A nice result of RAT2 is that no individual experienced the artificial ceiling as far as the maximum score (highest individual score was 34 out of 39); hence there was room for improvement. This is important since individuals score perfectly on RAT3 (Table 3) and hence it is impossible to demonstrated team super-performance. Still RAT3 had two of the teams outperforming the highest individual, one team had equal performance, and the other two were again very close. While it is expected that all teams would demonstrate super performance by this time, on average team performance consistently exceeded individual performances. Descriptive statistics are provided in Table 4 and results of paired-samples t tests are presented in Table 5 to further

Table 6: Pre-semester RAT from Spring Semester 2006 (30pts total).

Individual	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8
A	10	17	18	10	13	14	15	13
B	11	14	14	16	15	10	8	19
C	14	11	14	15	12	13	9	12
D	18	12	13	10	15	12	14	14
E	13	18	13	21	13	14	6	15
F	5	13	10	10	14			
IndividualAverage	*11.8*	*14.2*	*13.7*	*13.7*	*13.7*	*12.6*	*10.4*	*14.6*
Individual Min	*5*	*11*	*10*	*10*	*12*	*10*	*6*	*12*
Individual Max	*18*	*18*	*18*	*21*	*15*	*14*	*15*	*19*
Team Score	*13*	*15*	*18*	*16*	*16*	*18*	*12*	*17*
% Improve as Team	9.9%	5.9%	31.7%	17.1%	17.1%	42.9%	15.4%	16.4%
Team vs. Ind. Max	-27.8%	-16.7%	0.0%	-23.8%	6.7%	28.6%	-20.0%	-10.5%

Overall individual average	13.1
Overall individual standard deviation.	3.2
Overall team average (No.of Teams= 8)	15.6
Overall improvement (Team v Members)	19.5%
Number of Teams greater than Ind. Max.	2

support this claim. All differences are statistically significant at the .0001 probability.

The individual summary group data presented provides evidence that teams have the potential to outperform individuals. In order to determine whether team training influences the ability of groups to perform, a pre-semester RAT was administered to the 45 students (one student was absent) in the 2006 spring semester. The questions contained on the Pre-RAT were general knowledge about engineering design. Student may have learned about the topics over the previous three years of schooling, but the content is part of this capstone course. Immediately after teams were formed, and before any type of team instruction or workshop was presented, individuals and groups completed the pre-semester RAT. The teams were only minutes old but a possible bias exist because students somewhat familiar with each other having complete four years of classes together. Hence, students begin with some baseline of familiarity and trust. So this exercise is not like putting together complete strangers. When asked about experience with form team training in the past, about 1 in 3 students reported some formal team training. Students have all worked in teams, some informally, some formally, as requirements by Civil Engineering curriculum.

Table 6 shows the results of the 2006 spring "pre-semester" RAT. In this case, 2 out of the 8 teams showed a super-performance, a somewhat surprising result. However, overall the teams significantly underperformed the individual maximum score. For instance Team 1 performed 28% lower than the best individual. While the majority of the teams did not outperform the best

Table 7: RAT1 from Spring Semester 2006 (66pts total).

Individual	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8
A	39	37	48	42	42	55	50	46
B	45	42	52	53	47	41	53	36
C	42	39	40	45	46	47	51	42
D	39	62	49	45	51	47	33	51
E	46	43	44	62	47	44	38	53
F		50	58	50	45	51		
IndividualAverage	*42.2*	*45.5*	*48.5*	*49.5*	*46.3*	*47.5*	*45.0*	*45.6*
Individual Min	*39*	*37*	*40*	*42*	*42*	*41*	*33*	*36*
Individual Max	*46*	*62*	*58*	*62*	*51*	*55*	*53*	*53*
Team Score	***56***	***51***	***61***	***62***	***61***	***59***	***57***	***55***
% Improve as Team	32.7%	12.1%	25.8%	25.3%	31.7%	24.2%	26.7%	20.6%
Team vs. Ind. Max	21.7%	-17.7%	5.2%	0.0%	19.6%	7.3%	7.5%	3.8%

Overall individual average	46.4
Overall individual standard deviation.	6.4
Overall team average (No of Teams = 8)	57.8
Overall improvement (Team v Members)	24.9%
Number of Teams greater than Ind. Max.	6

individual on the team, relative to the individual average, there was still improvement. Hence the students benefited from working in teams.

After this "pre-semester" RAT, the students engaged in formal team activities and instruction. Over the next few weeks the students were asked to perform as a team. During this time RAT1 and RAT2 were administered, just as in the fall semester. The point totals for the spring RATs were slightly different than the fall due to some changes in the questions. Tables 7 and 8 show the results of RAT1 and RAT2 for the spring semester, respectively. The most significant note is that a week after extensive team training and activities, 6 out of the 8 teams outperformed the best individual. Only one team (Team 2) did not outperform the best individual. When RAT2 was administered, 5 out of the 8 teams outperformed the best individual, and again only one team (Team 7) did not outperform the best individual. The team performance relative to the average of the individuals was greater (RAT1) and more uniform across the teams (RAT1 and RAT2). Clearly formal training and familiarity (time) with teammates lead to a significant increase in team performance.

When data are aggregated and individual composite scores are compared to team composite scores (see Table 8), the results are even more striking. Descriptive statistics are provided in Table 9 and results of paired-samples t tests are presented in Table 10 to illustrate the differences between individual and team scores. All team scores were significantly higher than individual scores and statistically significant at the .0001 level.

Table 8: RAT2 from Spring Semester 2006 (48pts total).

Individual	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8
A	27	32	36	28	42	39	33	39
B	39	35	42	39	37	29	34	37
C	33	39	35	30	37	39	27	42
D	39	39	40	28	36	36	31	35
E	42	38	30	36	40	38	27	36
F	33	38	36	36	33	34		
IndividualAverage	*35.5*	*36.8*	*36.5*	*32.8*	*37.5*	*35.8*	*30.4*	*37.8*
Individual Min	*27*	*32*	*30*	*28*	*33*	*29*	*27*	*35*
Individual Max	*42*	*39*	*42*	*39*	*42*	*39*	*34*	*42*
Team Score	***42***	***45***	***39***	***42***	***42***	***42***	***40***	***47***
% Improve as Team	18.3%	22.2%	6.8%	27.9%	12.0%	17.2%	31.6%	24.3%
Team vs. Ind. Max	0.0%	15.4%	-7.1%	7.7%	0.0%	7.7%	17.6%	11.9%

Overall individual average	35.5
Overall individual standard deviation.	4.3
Overall team average (No of Teams = 8)	42.4
Overall improvement (Team v Members)	20.0%
Number of Teams greater than Ind. Max.	5

Table 9: Descriptive statistics for individual and team scores for the 2006 Spring Semester.

Test	N	Mean	Standard Deviation
Individual Pre- RAT	45	13.11	3.192
Team Pre-RAT	45	15.62	2.037
Individual RAT #1	45	46.40	6.397
Team RAT #1	45	57.87	3.609
Individual RAT #2	46	35.46	4.293
Team RAT #2	46	42.33	2.348

Table 10: Paired-samples t tests comparing scores for the 2006 Spring Semester.

Comparison	t	df	Significance (p)
Pre-IRAT – Pre-TRAT	-5.147	44	.0001
IRAT #1 – TRAT #1	-11.581	44	.0001
IRAT #2 – TRAT #2	-10.738	45	.0001

Conclusion

Based on the data collected from the senior level required capstone design course, where most of the work is performed in teams, overall teams outperform the individuals, as expected and supported in the literature. By establishing team requirements to encourage individual members to take ownership of the team performance, through team discussion and consensus building, individuals perform better as a team than when they work independently. Learning is enhanced through team collaboration. In addition, teams will demonstrate super-performance as individuals gain experience with the group and are able to build trust and solid working relationships.. Namely the team outperforms the best individual member. This fact supports the goal that teams collectively are greater than the individuals that comprise the team, even under the limits of a one-semester class timeframe. Vince Lombardi has been credited with the quote "individual commitment to a group effort – that is what makes a team work, a company work, a society work, a civilization work." RATs create a feedback-rich learning environment, encourage pre-class preparation and intensive give-and-take interaction, and increase students' ability to solve difficult problems. Pre-class preparation and lively discussion, in turn, build the intellectual competence of team members and enhance students' ability and willingness to provide high-quality feedback to one another. T-RATs provide concrete evidence to students that they really do benefit from working in teams. Furthermore, as engineering students begin to trust each other and develop a commitment to the goals and welfare of the design groups, they truly become a team. When they become a cohesive team, the team can accomplish tasks and solve problems that neither a single individual nor a newly-formed group could ever accomplish.

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