

Leading Engineers into the Twenty First Century

**Paul Wellington,
Department of Mechanical Engineering,
Monash University.**

Abstract: Reviews of engineering education in Australia and elsewhere, have recommended that engineers should become more entrepreneurial and develop greater management and leadership skills. If engineers are to have a greater impact on business, government and society in the future, they should start to develop the appropriate leadership and other essential interpersonal skills while still undergraduates.

Constructivist educational ideas claim that skills can not be developed by listening to lectures, but by application, interaction, reflection, feedback and constructing one's own knowledge.

In 1996, Monash began a Multi-Disciplinary Industry Project in which engineering, industrial design, marketing and accounting students work in consulting teams on feasibility studies for client companies. To promote appropriate skills, an elective seminar "Leading and Participating in Successful Teams" (LPST) is arranged prior to the start of the projects. The seminars are run by a combination of psychologists from Monash Community Services and academic staff and address issues such as working with different personality profiles, team building, communicating with other cultures, conflict resolution, problem solving, role allocation, providing positive feedback, time management and establishing a critical path.

The paper will explore the needs for engineering students to develop leadership skills, student perceptions of leadership, the structure and outcomes of the Monash seminars and projects, and potential improvements to the current leadership program.

Introduction

Batterham¹ and Dearing² point out the increasing importance to both the Australian and British governments of universities providing trained manpower for business, and economic advantage for the country. This is at a time when industry is rapidly changing and its need for graduates with diverse team, interpersonal and personal skills, as well as those of their discipline are essential if graduates are to achieve leadership roles and management positions.

While business and commerce departments devote considerable time to discussing organizational and management skills, management is a likely destination for engineering graduates. Of the top 60 Australian companies in 2001³, 15 were involved in metal manufacture and/or mining. Nine of these 15 had CEOs or Managing Directors who had engineering or related first degree qualifications⁴. Engineers Australia⁵ indicate that in the 2001 census, over 40% of graduate engineers identified themselves as managers, either in construction, manufacturing or just as engineering managers. However, there have been many concerns expressed by employers and graduates, that students have little chance to develop the necessary skills while at university. Those who combine study with appropriate work experience are seen to be better prepared, but well structured cooperative programs are not extensive enough in Australia to be available to the majority of engineering students.

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Clarke and Wellington⁶ outlined the Monash University Multi-Disciplinary Industry Project established as a subject in which students apply their professional knowledge to real problems in real world situations, and also develop team and leadership skills. The purpose of this paper is to look at the need for engineers to develop such skills, evaluate alternative approaches and specifically discuss the Monash program starting with the elective seminar “Leading and Participating in High Performance Teams.”

The Changing Emphasis on Graduate Skills.

IN the UK in 1998, Dearing², stated 'With increasing competitionnations will need, through investment in its people, to equip themselves to compete at the leading edge of activity. In the future, competitive advantage for advanced economies will lie in the quality effectiveness and relevance of their provision for education and training, and the extent of their shared commitment to learning for life.' One of the approaches he envisaged was by “increasingly active partnerships between higher education institutions and the worlds of industry, commerce and public service.”

Batterham¹, Australia’s Chief Scientist echoed these sentiments when he stated that "Universities will be at the heart of its effort to build this knowledge-based economy. Developing the culture of commercialisation within universities will need the skills and the infrastructure to translate science into products".

Oblinger and Verville⁷ stated "American business has experienced a transformation in the past decade that dwarfs the changes brought about by the industrial revolution. Today's corporation is leaner and more productive, flatter and less hierarchical. It focuses relentlessly on quality and customer satisfaction. Global competition as well as the challenges and opportunities offered by technology are forcing businesses to rethink their strategies and operating structures." They also stated “In the twentieth century, the development of professionals -in the classroom and on the job -focused on management. People were taught how to plan, budget, organize, staff, control and problem solve. We must now develop leaders - people who can create and communicate visions and strategies. Management deals mostly with the status quo; leadership deals mostly with change. We must become more skilled at creating leaders.”

The results of a 1992 survey of business Chief Executive Officers (CEOs) and university Vice Chancellors (VCs)⁸ on the desired characteristics of graduates is shown in Table 1. It is apparent that business leaders see most of the team and interpersonal skills as significantly more important than the VCs except for professional theoretical knowledge.

Table 1. CEO and VC Ranking of Graduate Skills.

Skills	Business		University	
	Rank	Mean	Rank	Mean
Communication (written, verbal)	1	4.29	7	3.26
Capacity to learn new skills	2	4.21	5	3.36
Cooperation and team work	3	4.18	8	3.24
Make decisions and solve problems	4	4.17	3	3.54
Apply knowledge to real problems	5	4.05	4	3.51
Work with minimum supervision	6	3.65	6	3.33
Professional theoretical knowledge	7	3.52	1	4.02

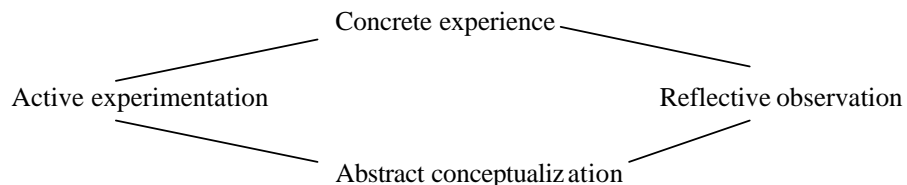
Academic Course Orientation

Clarke⁹ identified three implications of the transfer of professional education into universities. He stated “Professional knowledge is framed in scientific terms where possible, and those aspects of professional knowledge that do not lend themselves to this form of presentation are ignored. Front-loading of theoretical knowledge means students have little timely opportunity to apply and integrate their knowledge. Finally, the university fragments professional knowledge, which is naturally holistic, amongst departments and subjects.” While leadership skills may be capable of analysis by psychologists and knowledge of leadership traits and actions can be addressed in lectures, knowledge alone does not make a leader. Leadership does not belong to one profession, and leading teams to address real world problems requires application of skills from diverse disciplines. The traditional approach to professional education Clarke identified, will not develop the skills society is seeking. Clarke advocated a constructivist approach to education which claims that each individual has to construct their own knowledge. To effectively construct knowledge of team behaviour and develop leadership skills, there needs to be a level of experience which can be reinforced by discussion, interpreted by reflection and feedback and built into a deep level of understanding.

Tynjälä¹⁰ noted that both traditional and constructivist learning groups reported high levels of knowledge acquisition, but a striking difference was found with the constructivist group developing higher-level thinking skills like concept development, critical perspectives and moving from a dualistic to a relativistic view of knowledge; and on the acquisition of communication, cooperation, teamwork and writing skills, the skills society needs increased.

Kolb’s¹¹ experiential learning cycle helps provide a basis for constructivist thought. He suggested that learning came about as a result of a cycle shown in Fig 1 A program to develop leadership and team skills, requires students to be involved in each of these stages.

Figure 1. Kolb’s Model of Experiential Learning



Management and Leadership

Hundreds of management text books are readily available, with widely varied definitions of management and leadership. Robbins et al¹² define a manager as “an organizational member who integrates and coordinates the work of others.” Senior¹³ cites early management theorists like Fayol¹⁴ who saw management as involving “planning, organizing, commanding, coordinating and controlling” but as Oblinger and Verville⁷ pointed out, such views have become outdated. Mintzberg¹⁵ saw management as involving “interpersonal roles (figurehead, leader, liaison), informal roles (monitor, disseminator spokesman) and decisional roles (entrepreneur, disturbance handler, resource allocator, negotiator).” Senior also cites Mullins¹⁶ who stated management is concerned with formal structure and goals while leadership is more related to a person’s skills rather than position, and is based on good communication and interpersonal skills, developing a shared vision and having the ability to motivate.

Engineering Management

Adapting Robbins definition from above, engineering managers can be defined as those who integrate and coordinate engineering activities such as design, construction, research, development, manufacturing, quality, and projects.

Wearne et al¹⁷ carried out a comprehensive survey of skills engineering graduates needed in the work-place, and found that their university courses had poorly prepared them in areas such as supervision and motivation of others (table 2.)

Table 2. Relationship between graduate need and student preparation.

Skill	UK			Aus		
	Often required	Sometimes required	Received training	Often required	Sometimes required	Received training
Direct supervision of others	67 %	16 %	9 %	64 %	20 %	7 %
Motivate others	66	15	8	49	24	6

Williams¹⁸ found a need for undergraduates to have “more effective opportunities for interdisciplinary activities and better development of social, communication and management skills.” and went on to recommend that engineering education develop “balance between individual and group research projects, and between single and multidisciplinary research projects”. The IEAust committee under the chairmanship of Johnston¹⁹ wrote a report approximately 8 years after Williams, which stated engineering education must “become more outward looking, more attuned to the real concerns of communities. Courses should promote environmental, economic and global awareness, problem solving ability, engagement with IT, self-directed learning and life long learning, communication, management and team-work skills, but on a sound basis of mathematics and engineering technology”.

Summers et al²⁰ cited an EE times survey (Bellinger²¹) which indicated that professional EE graduates in the USA, saw leadership and related skills as extremely important but leading teams, resolving conflicts etc were major sources of frustration. Summers cited EAC/ABET claiming skills that engineering graduates lacked included “project management, team-work, engineering economics, organizational behaviour, decision making and communications.”

Cole²² emphasized engineers should lead innovation saying “if any country is to compete in the global economic race, the role of the engineer must increasingly be that of the engineering leader.” He also stated that “a merely technical education in the narrow compartments of the narrow professions is a totally inadequate preparation for engineering leadership.”

It has been established that there is an increasing trend to teams, often working together on projects which the Project Management Institute²³ defines as “a temporary endeavour undertaken to create a unique product or service”. Burke²⁴ extends this definition by identifying key features as including a clear deadline reached at the end of a life cycle, involving teams whose members have specific roles doing non-repetitive activities reporting to a team leader or project manager – all of which are features of the MDIP. He defines a project manager as using any skills, knowledge and tools to make the project meet its goals. The purpose of the Monash Leadership seminar is to provide appropriate knowledge, skills and tools to help team leaders and members make the MDIP a success.

Educational Approaches to Developing Leadership Skills.

A number of approaches can develop personal and interpersonal skills which form the basis of leadership skills, including Work Based (Cooperative) Learning, Double Degrees and Cross Disciplinary Electives which all give students broader viewpoints, but Brennan et al²⁵ noted that few help develop leadership skills. They cite a survey showing only 52% of business students and 33% of mechanical engineers felt their course had addressed the issue and only 47% and 39% respectively felt their work experience had redressed this lack.

While Australian undergraduate engineering courses place little emphasis on leadership training, numerous international courses are more effective, either within official programs or through student societies. One outstanding example is the ICAMES²⁶ program run by the Engineering Students Society at Bogazici University in Istanbul, Turkey. The students, with little faculty assistance, raise sponsorship, organize and host a week long conference on student projects along with cultural events for students and their advisors from 20 different countries. Some less ambitious approaches include the LEAP initiative at Cooper Union²⁷, the Engineering Leadership Awards of the British Royal Academy of Engineering²⁸, the Leadershape Institute²⁹, Purdue and Virginia Polytechnic as outlined by Summers et al²⁰. In Australia, CELM, a special interest group of Engineers Australia, helps address the problem, but only after graduation³⁰.

The Monash Multidisciplinary Industry Project

Wellington and Clarke³¹ outlined the objectives of the Monash Multi-Disciplinary Industry Project (MDIP) in which 3rd year engineering management, industrial design, marketing and accounting students join together in groups of approximately 8 to work as consultants doing feasibility studies for local companies. By third year, the students can apply a range of discipline-based skills to the project, along with problem solving and organizational skills. However, they need to develop skills in cross disciplinary communication, committee practices, taking responsibility, making decisions and making professional presentations.

In 1996, Monash engineering, business and design staff realized the potential learning of team based projects and the potential motivation if such projects related to real problems for real companies. Survey results shown in Table 3 indicate that students rate the MDIP as being highly motivating based on the reality of the experience. (1 being negative, 5 highly positive.)

Table3 Student Attitudes to the MDIP

Item	2001	2002	2003	2004
Working on a real project will be great.	4.55	4.59	4.53	4.67
Working for a real client will be highly motivating	4.45	4.65	4.43	4.50
Working in a multidisciplinary group will be a great experience	4.45	4.51	4.24	4.63

The Leadership Seminar

Following the first projects in 1996, it was apparent to staff that the groups with competent leaders were more successful. Accordingly, it was decided to hold a 1 day leadership seminar in preparation for the '97 projects for interested students, in the week prior to the start of semester. The 20 participants were highly positive. Various formats have been tried but a 2 day off campus retreat is now run for interested students not just team leaders, so the seminar has been relabeled "Leading and Participating in Successful Teams"(LPST).

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The constructivist learning model requires experience, reflection, social dialogue and knowledge construction. Hence, for the LPST to be effective it needs to be integrated with the 16 week experience of the MDIP, so that a range of experiences applied to a whole project can become the base of real learning. The semester's interaction provides team leaders and the other team members to gain a holistic experience of undertaking a feasibility study which reaches final recommendations based on extensive problem solving activities. This experience is shared between all members of the team and indeed in discussions with members of other teams. Individual reflection is enhanced by submission of 3 reflective reports during the semester, laying the necessary foundations for knowledge construction. This is all carried out within a context of feedback to individual students both by their supervisors and their peers.

Structure of the Seminar “Leading and Participating in Successful Teams, 2004”.

For the first time, the seminar was held off campus, at a local yacht club which provided all the necessary facilities for large and small group discussions, catering etc. The majority of students found the relaxed off campus retreat a significant improvement on conventional on-campus activities. The structure of the seminar is shown in Table 4.

Table 4. Timetable for the LPST Seminar

Introduction and team building	13:30 – 15:00
Interpreting and applying Myers Briggs	15:30 – 18:00
Dinner and after dinner speaker	18:30 – 21:00
Multicultural communications	10:00 – 11:15
Resolving conflict	11:30 - 12:45
Lunch	12:45 – 1:45
Improving Performance, Problem solving, brainstorming, allocating roles	1:45 – 2:30
Providing positive feedback, using feedback, reflection	2:30 – 3:00
Tea	3:00 – 3:15
Market research role play	3:15 – 3:45
Time management, mapping out the critical path.	3:45 – 4:15

Students Prior Attitudes to Leadership

A survey is conducted prior to the start of the seminar on what students saw as the characteristics of a good leader. They responded to a 70 item survey with responses appropriately categorised. The aggregate responses as listed in table 5 indicating what students saw as the key characteristics of leaders on a 1 to 5 scale with 1 unimportant and 5 important.

Table 5 Responses to 2003 Survey.

Characteristic	Score (maximum 5)
Vision	4.82
Emotional Intelligence ³²	4.53
Ambition for a good result	4.53
Nurturing of team members	4.5
Achievement Orientation	4.38
Ethical Behaviour	4.33
Leadership Style	4.14

Introduction and team building

The opening seminar sessions are run by staff with psychology backgrounds from the Community Services Department. After initial introductions, a team skipping exercise is carried out with teams of approximately 8 students, who need to decide who turns the rope and how timing is to be carried out. This proves to be an excellent ice breaker which students enjoy and allows a number of team skills to be identified in subsequent discussion. This is followed by presentation of the common forming-storming-norming-performing-adjourning model, so students realize that it is normal for conflicts to arise and for changes in group dynamics during the semester. The 9 team roles suggested by Belbin³³ are also discussed.

Interpreting and Applying Myers Briggs Type Indicator (MBTI)

Many companies use psychometric tests in helping with staff selection. The MDIP has used one of the most common, the MBTI to both introduce this common industrial practice and also to use it to help students understand personality differences and to help optimize team performance. This is usually rated as the most interesting topic of the seminar as most students are experiencing totally new ideas which they find personally interesting and useful. The students complete the survey prior to the seminar and receive their feedback at the seminar. The session leader after brief discussion of the diverse types, divides them into groups of all extroverts and all introverts. It soon becomes apparent that noisy discussion and people talking at once occurs in the extrovert group, much more than the quieter introvert group, although the introverts often achieve more. Similar exercises are held as long as time permits for the sensing-intuitive, thinking-feeling and judging-perceiving groups. The conclusion is that diverse teams are usually better than uniform ones. These results are taken into account as far as possible in team formation by the program coordinator.

Meals, Breaks and After Dinner Speaker

Easy and cheap meals are brought in from local shops and meal and break times provide opportunities for the delegates from different courses to get to know each other and informally discuss the concepts raised in the previous session. These breaks are quite important in maximizing the participation and benefits of the seminar.

Dinner in 2004 was followed by an IE graduate of almost 20 years experience at levels to senior management providing an after dinner speech. She highlighted ways she had used the MBTI for dealing with difficult colleagues and how she went about managing new projects. Having a highly successful graduate use her career to exemplify key issues raised in the seminar was an excellent way of reinforcing the value of the issues being discussed.

Multicultural communications

With at least 3 different disciplines represented along with a number of different ethnic groups, this is a particularly important session. Discussion on non-verbal as well as verbal communications and issues such as personal space, eye contact, gestures and expressions were discussed for both the local Australian culture but also for minorities, especially those of South East Asia. A strong case was made for Australian students providing international students with time to phrase and make comments without the locals filling all the available time with their own comments. This concept was developed further in at least 1 group by an African student who recognized the need to address the dominance in meetings of one

Australian student. When chairman, the African student put an item onto the agenda to discuss the difficulty he and other international students had in making their points due to limited quiet time. This leadership was recognized by several of his Australian colleagues in their peer assessment and generated praise in several of their reflective reports.

Resolving conflict

It is hard getting students to understand that conflict can be a positive experience, but this session provided insights into various models of addressing conflict and the difference between functional and dysfunctional conflict. The models of competing (shark), compromising (fox), avoiding (turtle), accommodating (teddy bear) as conflict handling styles was discussed with the benefits of win-win collaboration (owl) being clearly established.

Improving Performance: Problem solving, Brainstorming, Allocating Roles

The early sessions had been taken by Counselling personnel with high levels of small group interaction. Problem solving strategies using brainstorming and other techniques had been introduced at least to the engineering students earlier in their course, and it was considered that a brief review should suffice. This was probably overly optimistic and will in future be addressed in more detail and again increasingly involve small group discussions. The engineering students had also participated in teams where roles were allocated in an earlier subject, but again more time was needed in the seminar to gain deeper insights.

Providing positive feedback, improving performance in response to feedback, reflection.

The MDIP requires students to carry out peer assessments on each of their team members, including themselves, 3 times during the semester. The assessment is based on 4 criteria – cooperation, communication, initiative and reliability. The assessment in week 5 is an introduction to the process, but that in week 10 flags to students who are not contributing effectively, that they need to improve performance while there is still time. In week 16, the teams make their final presentations and submit their final team and reflective reports and their final peer assessment. This final peer assessment is used to generate a multiplier which raises the average group mark for valued team members and lowers it for those below average. This session in the LPST seminar discussed the peer assessment and reflective reporting processes in detail, gaining confirmation from the participants that they considered such assessment useful and appropriate.

Market research role play

One key element in which engineering as well as business students often participate, is researching the market for the anticipated product. Most students enjoy the process of discussing the possible markets with the company and prospective clients, but benefit by getting basic pointers on questioning and gain confidence in the seminar. One project done by a team in 2001 was used as a case study: determination of the feasibility of injection moulding plastic coffins. The group recommended that there was an insufficient market to justify the high tooling costs, but only after an extensive survey of coffin makers, cemeteries, funeral parlours, crematoria and members of Christian, Jewish, Muslim and other faiths. The students in the seminar identified who would be appropriate to approach, effective ways of making contact and the sort of questions which should and should not be asked.

Time Management and Mapping the Critical Path.

The coffin case study was extended in the seminar to provide a basis for discussion on how to identify key roles for each team member and map out a critical path and a timeline was subsequently drawn up. This was a useful case study as it showed several problems which groups can encounter such as wasting substantial time over pros and cons of coffins and caskets, and what plastic should be used. Several students became deflected from the critical path by an obsession with handle design and attachment.

Feedback on the Seminars.

Most students felt that the seminars in '03 and '04 had been of great value. Responses on the different sessions are shown in Table 6 using the same scales as in earlier tables.

Table 6. Responses to the LPST Seminars '03 and '04.

Session	'04	'03
Team Building	4.3	4.3
MBTI	4.5	4.5
Communications	4.2	4.6
Conflict Resolution	3.6	4.5
Improving Performance (problem solving, role allocation)	3.4	4.2
Planning (Time management, critical path)	3.8	4.5
After Dinner Speaker	4.3	-

Students were asked to identify the benefits they gained. Multiple students indicated that they had a better understanding of their own and other personalities, with several particularly citing a better understanding of other cultures and the importance of giving international students opportunity to phrase their comments.

Reflective reports:

A number of students addressed issues raised in the LPST in the reflective reports written some weeks into the semester. One international student discussed the seminar saying:

“It was good and interesting as some of the material covered is rarely approached in university lectures though it’s important. The personality’s indicator was a definite plus as it didn’t just classify the personalities into the 4 main groups: sanguine, melancholic, phlegmatic and choleric, but highlighted the different traits.”

Another student discussed the multicultural session saying:

We had those discussions about cross-cultural communication and differences in our backgrounds. I viewed things differently after that. I spoke with a girl about my Egyptian culture and she spoke about Hong Kong. There were some clear differences. She was telling me that Australian people view Asians as quiet and shy and she said when she went to school in HK all the students had to be quiet in class and they couldn’t talk at all and they couldn’t look at the teacher. They couldn’t have eye contact with the teacher. They were always looking at the ground, showing respect or politeness. I had no idea about that. She said that’s why people view Asian people as shy or embarrassed. What I got out of that was, I’m not the only one in the world, people do things differently from me and I should accept that. I don’t know how I would have viewed that before the seminar. I wouldn’t have been as patient.

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A third student made the following comments on the introductory session:

You saw both the groups going out just started skipping without having a plan. Without talking about who was going to hold the ropes or what they were going to do first. That was interesting to think about. We all just went out there, two people held the skipping rope without talking about it. just started swinging it, people started jumping. I picked up a few things from that. Communication. I knew communication was important but I didn't know it was such a vital part of a team.

A fourth student who had completed the seminar and become a team leader said the following (XXX has been used instead of the name of the student being referred to);

I found in the last few weeks especially, a few of the other students have felt comfortable to approach me with their concerns as well, especially XXX. XXX I believe is the quietest person of the group who tends to hold back with his views especially when the group is together during scheduled meetings. However, XXX has slowly become more comfortable with me but is still hesitant most times. ... Having worked closely with XXX I have found that he needs somebody there for support and encouragement so he feels comfortable.... I believe the language barrier plays a major role on how comfortable he is around the others and may be the reason why he tends to come to me for help and reassurance on his work.

Restructure for 2005.

There is a high level of student support for both the MDIP and the LPST. However, the coordinators have adopted a continuous improvement approach based on surveys, anecdotal information and reflective reports. In the last 2 years, the reflective reports have gone from 1 at the end of semester to 3, with the first providing formative feedback only, the second 5% and the third 10% of the total mark. This has led to improved levels of reflection by most students and greater insight for staff into issues which effected students early in the semester.

Areas which are to have increased focused in 2005 in the LPST seminar are to discuss and apply the ideas of Belbin³² on different personal as opposed to task roles which people adopt in team situations. Students from 2004 will present previous projects as case studies to give a broader perspective. A workshop on giving and receiving positive criticism will be implemented as students have felt that this would enable better responses to be made to the early peer assessments.

Conclusion.

The workplace of the future is certain to be one requiring a range of personal and interpersonal team skills and for many graduates, significant leadership ability as well. The concept of the Multi-Disciplinary Industry Project involving students with expertise and insights gained in the seminar *Leading and Participating in Successful Teams* provides students with an opportunity to learn, develop and enhance the personal and interpersonal skills which leaders require. This program meets the needs of constructivist learning theories providing a series of concrete experiences on which students can reflect and on which they gain feedback, about which they are encouraged to conceptualize and then plan and implement improvements. The seminar is the start of a process, and should be seen as laying the foundations for successful team based projects which follow. This experience at the undergraduate level, should enable these students to approach leadership in their subsequent careers with skill and confidence.

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Biographical Information.

Paul Wellington is a senior lecturer teaching Industrial Engineering and Engineering Management students in the Mechanical Engineering Department at Monash University, Caulfield Campus, where he lectures on Design and Manufacture of Plastics and Composites, and on Project and Change Management. He coordinates the Monash Multi-Disciplinary Industry Project and the seminar Leading and Participating in Successful Teams.

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