

# **The Effects of Roles and Personality Characteristics on Software Development Team Effectiveness**

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(ABSTRACT)

The objective of this research is to show the utility of roles and personality characteristics to the evaluation and formation of software development teams. The goals of this research include demonstrating empirically that Belbin's team roles can be used to form and evaluate software teams, providing a partial validation of the analyses by using the Belbin roles to analyze teams from the software industry, and comparing the personality data collected for this research to data from two previous studies and to the general population.

In the highly competitive software industry, improving the software development process can be critical to a company's success. More specifically, improving a team's productivity can save employers significant time and money. This investigation addresses the productivity of software development teams in a series of studies. First, controlled studies empirically show that Belbin's roles can be used in team formation to improve team performance. Second, additional studies, both qualitative and quantitative, demonstrate that Belbin's roles can be used as criteria in team evaluation and formation. Finally, teams from the software development industry are evaluated, providing a partial validation of the usefulness of Belbin's roles to software teams.

The cumulative effect of the results of the studies in this investigation demonstrate that Belbin's roles can be used effectively in team formation and evaluation. Specifically, Belbin's roles for leadership and innovation are shown in empirical studies to be important in the formation of software teams, and all of the Belbin roles are used in the evaluation of teams in academia as well as in industry.

The results of this investigation should be used in team formation and evaluation, in an academic setting as well as in the software development industry. For team evaluation, deficiencies uncovered in the Belbin roles should be remedied, and positive aspects should be encouraged. In team formation, teams should contain the complement of Belbin roles and should specifically contain the leadership and innovation roles focused on as part of this investigation. It is clear from this investigation that Belbin's roles can be used effectively to improve software development teams.

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# Chapter 1

## Introduction

In the highly competitive software industry improving the software development process is a critical need. This research investigates one means of improving the effectiveness of software development teams in quite an innovative manner, namely, by forming teams based on who can work effectively together. The **effectiveness** of a team is described in the management literature with a focus on two areas: **performance and viability** (Sunstrom, 1990). For the purposes of this research, performance of software development teams consists of factors such as customer satisfaction, schedule and cost adherence, and productivity. Viability “entails (team) members’ satisfaction, participation, and willingness to continue working together” (Sunstrom, 1990). These definitions clearly correspond to the terminology of studies addresses the dual problems of productivity and manpower costs (Cherlin, 1981; Boehm, 1981; DeMarco, 1987). The current investigation addresses the effectiveness of software development teams in a series of studies designed to demonstrate the utility of approaching this problem in an innovative manner.

### 1.1 Research Goals

The general utility of this research lies in the ability to evaluate the effectiveness of software development teams and the part that **roles** play in that evaluation. The specific goals of this research are to:

Goal 1: Develop quantitative models that can be used in evaluating and in forming software development teams.

Goal 2: Compare the distribution of the personality type data collected for this study to the general population and to previous studies.

Goal 3: Demonstrate that *team roles*, as described by R. Meredith Belbin (Belbin, 1981), can be utilized to improve the effectiveness of software development teams.

Goal 4: Determine whether the Belbin team roles need to be understood and accepted by the team members.

Goal 5: Demonstrate that the Belbin team roles can be applied to industry teams, in a way similar to the studies involving students.

The first goal of this research is to develop quantitative models that can be used to evaluate and to form software development teams, with the intention of improving those teams. The initial approach for this research effort consisted of a *general model* that would include several indicators that would describe all software development teams. This overly ambitious goal was refined to pursue only *some* of the indicators, which are the more important ones to software development teams. Toward the development of such a general model, measurable attributes of personality characteristics have been identified as the focus of this research, i.e. personality indicators are used in the model. It is the measurable indicators of Belbin's team roles (Belbin, 1983) that demonstrated to be useful for team evaluation and formation.

The second goal of this research deals with the issue of relating the information from this investigation to previous studies and the general population. Statistical data descriptions for the measures are presented for the personality data collected to establish teams for this investigation. This statistical information is compared to both the distribution information of the general population and previous studies extracted from the literature. Additionally, since the literature does not contain any distribution information for one type of data collected for this investigation, distribution information about this data is provided for future comparative studies.

The third goal of this research focuses on how roles can be used in evaluating team effectiveness and in developing the quantitative model. Specific roles can be defined or associated with the individuals in a group, and these roles describe how individuals interact or how they are typically allowed to interrelate. Role theory indicates that for a given social system certain roles are necessary in order for the system to survive, or, as in the case of a team, certain roles are necessary for a team to succeed.

This research investigates this aspect of role theory for software development teams. The set of roles that make up the foundation of this research are defined by R. Meredith Belbin (Belbin, 1983) for management teams; this research quantitatively demonstrates the applicability of these roles to software development teams.

A fourth goal relates to team members fulfilling a given role. As described as part of *role theory* in Chapter 2, team roles are typically defined in terms of functions that a role is supposed to exhibit or assume. A person can unconsciously assume a role, explicitly assume a role, or be assigned a role. This goal is not concerned with investigating the effects of assigning roles to members, but it is concerned with the fact that an individual may or may not have the capacity or natural attributes to accomplish a given role. The focus of this goal is on whether a team member needs to be aware of his or her role(s) and functions in order to fulfill the role; the alternative is that merely having the necessary characteristics for a role allows an individual to naturally assume the role. That is to say, can team members assume a role implicitly because they have the natural characteristics; or, do members need to be explicitly aware of their roles? The assignment of roles is not considered at all.

The final goal of this research deals with applying the quantitative model developed in the initial work to software development teams in industry. The same type of data, Belbin role information, is collected for this study. The major difference for this part of the investigation is that industry teams are not acting within a controlled, or limited, environment, as is the case for the other parts of this research. Therefore, a different approach is required to apply the Belbin roles to software development teams from industry. The following approach is taken for five industry teams:

1. Find teams that indicate a commitment to, or interest in, participating in an analysis of their team;
2. Have all team members fill out the Belbin Self-Perception Inventory (Belbin, 1983) in order to gather data for analysis;
3. Interview the leader of the team in order to obtain an independent analysis and verification of the Self-Perception data;
4. Analyze the Self-Perception data looking for trends in the data from which qualitative assessment can be made;

5. Compare the Belbin analysis with the interview information, identifying similarities and differences between the two, thus providing verification of the Belbin analysis.

These analyses provide a partial validation of the controlled experiments and observational studies that constitute the analyses for the previous goals.

## **1.2 Motivation and Solution Approach**

The significance of this work lies in the fundamental ability to “improve” a team or teams. This research shows that personality information, viz. data indicating that team members have a natural propensity toward acting in certain ways, can be used to enable a team to perform better. The significance of this improvement to teams is twofold: the evaluation of extant teams and the formation of new teams. When evaluating a team, if deficiencies within a team can be identified, then these problems can be resolved; the first step to solve any problem is to identify it. Also as part of an evaluation, positive aspects of a team, if identified, can be emphasized and encouraged so that a team can improve. Further, if the same type of information can be used when forming new teams, then the positive aspects for a team can be maximized and the negative aspects can be minimized from the outset.

To address these rather imposing goals, related work from the literature is detailed in order to discover a reasonable method of achieving the goals, to uncover pertinent research, and to focalize the investigation. Second, three controlled experiments are conducted to demonstrate, at a fundamental level, that roles can be used to improve team performance. Third, a partial validation of the utility of the roles is demonstrated with analyses of 1) teams from a programming competition and 2) student teams formed based on application of role theory. Fourth, qualitative analyses are applied to several software development teams from the industry to further validate the utility of the roles. Finally, for scholarly completeness, distribution information is provided for all of the data derived from this research, and, where available, this data is compared to data from pertinent background studies.

The above investigation is organized in the following order: Chapter 2 details the background and foundational work; Chapter 3 presents the controlled experiments;

Chapter 4 provides the validation analyses and distribution information; Chapter 5 presents the analyses of industry team. Chapter 6 closes with conclusions and direction for future work.

# Chapter 2

## Background and Foundational Analyses

This research project began with a discussion about programming teams and culminated in the following informal observation, “Why is it that a team of very gifted individual programmers doesn’t necessarily make a *great* team?” The general conclusion that resulted from that discussion was that some programmers could not work well together, not due to lack of ability or sets of skills that the individual members might possess, but due to personality issues. Such teams composed of exceptional individual programmers have outstanding ability and potential, but personality conflicts or deficiencies make the team unable to perform to achieve their expected potential. This thought germinated in an investigation of the software development process in non-traditional, non-computer science ways. Such interdisciplinary research in computer science has been conducted for decades (Weinberg, 1971; Shneiderman, 1980). In the 1980s, the realization that software could not keep pace with hardware improvements “focus(ed) attention on human factors in the process of system development as well as the performance of the end user of computer systems” (Nichols, 1982).

This chapter provides a synopsis of previous work that is related to this research, motivation for this research, its significance, and background information necessary to understand the work.

### 2.1 Motivation and Related Work

Since the initial impetus for this research began with an interest in empirical studies and personality characteristics, this background information has a necessary interdisciplinary flavor. Hence, this investigation examines software development teams from the perspective of various disciplines, much the same way as Curtis has encouraged (Curtis et al., 1986). He mentions several factors that might be relevant to such interdisciplinary research including psychological factors, the transfer of skills from other

domains, and communication issues. Interest in interdisciplinary work precipitated this research through an investigation of various fields that have their own distinct sets of literature: empirical studies, personnel, management, psychology, as well as computer science. It should be noted that research involving various fields differs from research on interdisciplinary teams, which is an area being examined by others (Curtis 1990b; Trower and Straub 1991).

All of the disciplines mentioned above have a natural intersection that can be viewed as interdisciplinary, for example, managers use psychology as part of their management approaches, techniques, or philosophies. Information used in the field of personnel management encompasses all disciplines in that most employees get hired through a Personnel Office. Some personnel information is germane to this research because employees in Personnel positions make use of questionnaires, psychometrics, tests, etc., that are used to evaluate or assess potential employees. It is the questionnaires that are of particular interest for this research. Further, empirical investigations are used to effect progress or substantiate ideas in many disciplines.

In the following sections, each of the fields mentioned above is presented in terms of the background literature to support this investigation. Many of the cited references are in more than one of the succeeding sections because of their interdisciplinary nature.

### **2.1.1 Empirical Studies**

This research is quantitative in nature, and quantitative research is a well-used analytical tool. Measurement in the social sciences created interest in other fields to investigate the applicability of quantitative analysis to their work. Software engineering has been using measurement since the 1970s (Conte et al., 1986) and has spawned powerful support and interest in both academia and industry to such an extent that many software development organizations, particularly ones that deal with the federal government, require a measurement or metrics program.

The current investigation began with an interest in quantitative research and empirical studies, which led to the discovery of a workshop series called *Empirical Studies of Programmers* that occurs about every two years (Soloway and Iyengar, 1986;

Olson et al., 1987; Koenemann-Belliveau et al., 1991; Cook et al., 1993). The proceedings from the workshops contain diverse descriptions of studies, with qualitative and quantitative conclusions, that are derived from, and are useful to, software developers.

Empirical studies take on a variety of forms, based primarily on the type of data being evaluated and the type of results anticipated, e.g. conceptual models, quantitative models, or identifying trends. Some of this empirical research focuses on the actions and verbal cues expressed by developers (Walz et al., 1987; Holt et al., 1987; Curtis, 1990a; Flor, 1991; Straus and McGrath, 1994), sometimes defining categories for the cues. Work such as this tends to focus on formulating models to explain observed behaviors. Other research focuses on “hard,” numeric data that might be collected automatically, for example through modifications to compilers or editors to count the number of modifications, amount of time to accomplish a modification, etc. (Henry and Humphrey, 1993). This type of work tends to produce results with general applicability that is difficult to dispute. Actually, the work described by Henry and Humphrey uses a combination of objective data in tandem with subjective questionnaire data; it demonstrates empirically that an object-oriented language is easier to use and makes individuals more productive.

The most interesting of the empirical studies focuses on more personal information such as personality attributes (Bostrom and Kaiser, 1981; Nelson et al., 1991), which led this research toward an investigation of individual differences, a superset of personality characteristics. Consequently, this research addresses the empirical relationships between personality factors of team members and team effectiveness.

### **2.1.2 Personnel**

As stated in the introductory material, Boehm feels that personnel issues will eventually be acknowledged as a key issue in productivity (Boehm, 1981), not language and implementation issues that are currently prevalent in research. One type of personnel investigation concerns questionnaires for new or potential employees (Chang and

McLeod, 1991; McLean et al., 1991). This type of study provides insight into personality characteristics that are of interest within the personnel field and of potential use to the current research, e.g. initiative, self-confidence, flexibility, intelligence, and organizational skills. The Bostrom and Kaiser study takes a different approach; it contains an analysis of the Myers-Briggs Type Indicator (MBTI) results, comparing management-users and technical staff-users in large firms (Bostrom and Kaiser, 1981). The MBTI is detailed later in Section 2.3.1 as part of the description of personality types.

Varney provides some useful personnel insights into individual differences that can affect the selection of team members (Varney, 1990). He suggests that age, individual skills, positive attitudes, and team skills have a significant effect on a positive team chemistry. Curtis also discusses individual differences in one of his seminal papers (Curtis, 1988). His key issue is that there are productivity differences among employees in a ratio of 1:20, and he considers this productivity difference an individual difference in and of itself. This view of individual differences is decidedly different from more-current work since it is more of a result than a cause.

Another item of interest in the personnel arena is the Job Diagnostic Survey (JDS), developed by Hackman and Oldham (Hackman and Oldham, 1980). They describe the JDS in the following way:

The survey measures several job characteristics, employees' experienced psychological states, employees' satisfaction with their jobs and work content, and the growth need strength of respondents... The JDS was designed to be completed by the incumbents of the job or jobs in question - not by individuals outside the job. (Hackman and Oldham, 1980)

Some studies in the personnel field that use the JDS address motivation. A proposal for a study by Trower and Straub (Trower and Straub, 1991) focuses on improving performance of information systems (IS) personnel through understanding of their motivation factors. Their study builds on the work of Couger and Zawacki (Couger and Zawacki, 1980) and shows that IS employees demonstrate much higher Motivating Potential and lower Social Need scores, which are measured by the JDS. Part of Trower and Straus's analysis includes personality variables: self-esteem, self-efficacy, perceived ability, need for achievement, locus of control, need for autonomy, need for strength, and

need for independence. Myers takes this a step further by presenting a survey of motivation research, which focuses on three studies (Couger and Zawacki, 1980; Ferratt and Short, 1986; Myers, 1989). Her conclusions are basically a validation of Couger and Zawacki's work and provide a reasonable explanation of the variations in the results of the studies.

Another interesting work that makes use of the JDS includes Thomsett's work (Thomsett, 1990); it combines both the MBTI and JDS instruments as well as Belbin's roles. Thomsett presents an analysis based on these three items (MBTI, JDS, and Belbin) and concludes that using the MBTI and Belbin's roles as management tools improves productivity. Because of the importance of Thomsett's work to this research, it is presented later in Section 2.4.

### **2.1.3 Management**

The background material for the management aspects of this research cover several significant elements: general management information, identification and management of software development employees using MBTI information, and managing software developers. One of the keystones of this research lies in the general area of management studies, namely, work by Belbin (Belbin, 1981, 1993). Since Belbin's work is such an important issue for this research, it is fully presented in a separate section, but as a general overview, Belbin experimented with management teams to develop a set of roles that must be present in a team in order for the team to work effectively. Other general management information is contained in some of Tjosvold's work. In one book, he discusses the various aspects of being the leader of a team: envisioning the strength of teamwork, uniting members in innovative ways, empowering employees, exploring opposing views to find the best solution, and reflecting on the strengths and weaknesses of a project in order to direct improvement (Tjosvold, 1991a). Tjosvold's insights express the importance of investigating leadership attributes of a team. One issue he presents repeatedly is that openness and diversity are keys to successful teams. Another of Tjosvold's works presents a questionnaire and interview form to evaluate teams (Tjosvold, 1991b). Some of the information in these should be applicable to the current investigation.

Another group of work involves the MBTI, which enjoys popularity in the management literature. Some of the work simply presents distribution information and intuitive explanations for the type distributions for various professions. Lyons describes the statistical distributions of “computer professionals” in a multi-national study (Lyons, 1985). Bush and Schkade present similar information for programmer analysts of a U.S. aerospace firm (Bush and Schkade, 1985); Sitton and Chmelir present very similar results for a set of Texas state computer Programmers (Sitton and Chmelir, 1984). Unfortunately, both of these analyses are superficial and only discuss the top personality type as a whole, e.g. ENTP<sup>1</sup>, instead of presenting each of the four scales separately. One important point that Bush makes concerns hiring practices: “Generally speaking, managers hire people with whom they are comfortable - people they like” (Bush and Schkade, 1985). This generally means that they hire their own MBTI type or as Lyons puts it “in their own image” (Lyons, 1985), and teams made up of members who are all alike does not make a successful team. Not only does a team need diversity, but a good MBTI management type probably is **not** a good software developer type. Similarly, Hastings provides some insight into general types that might not be beneficial to the team, “... technically brilliant specialists who are loners and introverts should not be promoted into core team membership or leadership” (Hastings et al., 1986), which is reminiscent of the Peter Principle (Peter and Hull, 1969). Similar to the MBTI work is Couger and Zawacki’s investigation, considered seminal by some, using the JDS (Couger and Zawacki, 1980). The JDS allows managers and researchers to determine characteristics of work positions that can be used in motivating and managing employees. Their work describes computer personnel and their various jobs.

Other notable research is by Anderson and West (Anderson and West, 1994; West and Anderson, 1992), who developed an instrument to measure the “climate” of a team. Reichers and Schneider define climate in the following way:

Climate is widely defined as the shared perception of ‘the way things are around here’. More precisely, climate is shared perceptions of

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<sup>1</sup> The various personality types are described later, in Section 2.3.1.

organizational policies, practices, and procedures, both formal and informal... Multiple climates are thought to exist in organizations. (Reichers and Schneider, 1990)

This work is important because it could be used as an independent measure of the “quality” of a team as part of the industry study. Also, climate can affect the satisfaction of employees, which in turn affects employee turnover, as discussed in the introduction.

#### **2.1.4 Psychology**

The discipline of psychology contains some general information as well as two specific considerations useful to this research. The following subsections address the general issues, personality characteristics, and a specific psychology topic that is necessary as background material, role theory.

##### ***2.1.4.1 General Issues***

The discipline of psychology initially was investigated to find general areas that might be of applicable to research on teams. This examination uncovered broad areas such as mental representations (Holt et al., 1987) and cognitive styles (White, 1984) and distributed cognition (Flor, 1991), which are interesting but have no direct impact on this research.

Another general psychology topic of particular interest for this research is team psychology. *Group psychology* has been investigated for many years (Hackman, 1990; Biddle, 1979), but more recently the concept of **teams** has entered the domain. Groups are defined as “a set of two or more persons who are linked through interaction” (Biddle, 1979). Hackman distinguishes teams from simple groups in that they must meet the following three criteria (Hackman, 1990):

1. They are intact social systems, complete with boundaries, interdependence among members, and differentiated member roles.
2. They have one or more tasks to perform.
3. They operate within an organizational context.

Based on this definition, software development teams are indeed teams, and psychological research on teams can be applied.

#### *2.1.4.2 Personality Characteristics*

One aspect of the social sciences that is integral to this investigation has been the subject of intensive research and interest: individual characteristics, also called individual differences. There are a number of popular measures for personality characteristics (Watkins and Campbell, 1990; Cattell et al., 1970; Herson and Bellack, 1988; Myers, 1980; Harary and Donahue, 1994; Keirsey, 1984; Goldstein and Hersen, 1990), which is a subset of individual differences. Personality tests have already been used in other fields to predict success (Rice and Lindecamp, 1989). Shaw presents a discussion of personality characteristics of group members that is applicable to this research (Shaw, 1971). He points out that while a large number of different personality measures have been used in studies, over five hundred, fewer than a quarter of these have been used in more than one investigation. He concludes that researchers must be measuring the same attribute and calling it different names. He then creates five broad categories of personality characteristics and presents a literature review of previously-identified “characteristics” and associated behaviors, e.g. paranoid schizothymia correlating to friendliness (.57 correlation for these). Unfortunately, most of these behaviors and characteristics are not directly applicable to this research, although they do provide a significant list of characteristics to be considered.

The most important items found in the psychology discipline are the Myers-Briggs Type Indicator (MBTI) (Myers, 1980, 1987; Myers and McCaulley, 1985) and the associated Keirsey Temperament Sorter (Keirsey, 1984, 1987), which forms part of the foundation for this research. The MBTI has been used to analyze the success of retailers (Rice and Lindecamp, 1989), help individuals in corporate environments work better together (Moore, 1987; Lyons, 1985; Bush and Schkade, 1985; Sitton and Chmelir, 1984), and to analyze software developers and information systems personnel (Buie, 1985, 1988; Bostrom and Kaiser, 1981; Thomsett, 1990; White, 1984), just to mention a few of its uses. A test that provides information similar to the MBTI is the Keirsey Temperament Sorter; it is used to collect the data for this research and is discussed later in the Personality Types section. Section 2.1.1.2 presents an analysis

showing that the MBTI and the Keirsey Temperament Sorter present similar information. See Appendix A for a copy of the Keirsey Sorter.

Another personality characteristic that appears in the literature is competitiveness (Spence, 1983; Johnson, 1992; Tutko and Bruns, 1976). Quantitative research has shown that competitiveness is inversely correlated to “success,” as measured by several various factors such as income and number of citations for professors (Spence, 1983; Johnson, 1992), i.e. higher competitiveness is related to lower success. Competitiveness has been identified as an important attribute to the current investigation.

Other attributes that are of varying degrees of interest to this investigation consists of dominance, sociability, independence, empathy, impulsivity, conformity, imagination, self-sufficiency, self-discipline, flexibility, persistence, practicalness, insight, idealism, friendliness, patience, persuasiveness, responsibility, understanding, analytical ability, cautiousness, creativity, intuitive abilities, conformity, sensitivity, and methodicalness (Watkins and Campbell, 1990). Watkins and Campbell present a collection of psychometrics, each of which measures a few of the attributes in the succeeding list. One final noteworthy attribute is interdependence, for which Shonk has developed a questionnaire (Shonk, 1992).

#### ***2.1.4.3 Role Theory***

Roles, functions of roles, and role theory in general are important to this research, being key to two of the goals. Therefore, it is necessary to present some of the fundamental concepts of role theory, as well as introduce background information that indicates that personality characteristics and roles have been previously linked.

*Role theory* is defined in different ways by various authors; for example Biddle, from whom much of this discussion is drawn, describes it as “behaviors characteristic of one or more persons in a context” (Biddle, 1979). Sarbin takes a particularly innovative view of role theory because he specifically includes personality in his description: role theory “is an interdisciplinary theory in that its variables are drawn from studies of culture, society, and personality” (Sarbin, 1954). Role theory is founded in the meeting of two different theoretical trends in sociology: symbolic interactionism and structural-

functionalism. The former is unimportant to this research, but structural-functionalism concerns the idea that “actions are patterned into coherent and ordered systems that govern both interpersonal interaction and societal functioning” (Knowles, 1982), which introduces the idea of functions.

The characteristic behaviors mentioned above can be defined as *functions* associated with a given role. Biddle states that role functions are a “behavioral repertoire characteristic of a person or position” (Biddle, 1979), in other words, a role. He further states that roles can be examined in terms of their consequences, which are their “characteristic effects, or functions, within a societal system” (Biddle, 1979).

Furthermore, one of the goals of this research is concerned with team members’ awareness and understanding of the team roles that they can or should fill. Role theory contains the concept of *overt structures*, which the author feels are related to this goal. Overt structures are

structured elements within social systems that can be observed directly... most social systems that are defined by overt structures are not planned; rather they occur ‘naturally’ within a given society in response to pressures that are indigenous to that society... that does not mean that we are always aware of the overt components of a social system. (Biddle, 1979)

The fact that individuals do not need to be aware of the structures is similar to one of the interests of this research: Should team members be aware of role theory and the team role(s) that they fill? Does such knowledge affect their team performance?

Two other terms in role theory are *functional requisite* and *role complement*, which are essentially the foundation of Belbin’s work (Belbin, 1981) that is an essential component of this research and is presented in Section 3.3. Functional requisites are “functions that are necessary for the survival or maintenance of a social system” (Biddle, 1979), and the survival of a team can be considered its degree of success or effectiveness. Role complement is a set of roles defined for a given context. These two concepts combine to form the functional requisites that are embodied by Belbin’s roles, which is a team complement.

In addition to Sarbin's description of role theory described above, there is other support for using personality characteristics to investigate roles. Biddle presents a list of underlying propositions upon which role theory is based: roles, social positions, expectation, functions, and the nurtured nature of roles (Biddle, 1979). He then states that different disciplines within the social sciences have different perspectives of role theory. For example, "psychoanalysts would stress the unconscious determinants of behavior." Obviously, this supports investigations of roles based on personality types.

### **2.1.5 Computer Science**

Information from the computer science discipline that has psychological underpinnings similar to this investigation is presented in this section. Certainly, work that is labeled as both computer science and psychology should contain useful information, such as work by Weinberg (Weinberg, 1986) and Shneiderman (Schneiderman, 1980). Unfortunately, many of their presentations are intuitive or anecdotal. Shneiderman includes a section on "Personality Factors" in which he describes "some personality issues and conjectures about their relationship to programming." These include assertiveness/passiveness, introversion/extroversion, among others. One issue presented by Shneiderman that is particularly important, partially because Curtis also presents the same issue (Curtis, 1990b), concerns ambiguity and precision. "The early stages of program design and composition may require a higher tolerance for ambiguity. ... The later stages of program composition require a precise attention to details..." (Shneiderman, 1980). Curtis discusses this in terms of a team having a "common mental model of an application" (Curtis, 1990b). He discusses the *advantages* of having diverse mental models *early* in design and emphasizes that team members' mental models must *converge* as the design moves into implementation; otherwise "an individual's ability to contribute to the current state of the design" is *reduced*. Tjosvold adds that "controversy, when discussed in a cooperative context, stimulates elaboration of views, the search for new information and ideas, and the integration of apparently opposing positions" (Tjosvold, 1991b). Therefore, a diversity of views or approaches can present the opportunity for investigating a greater number of

solutions. This diversity element adds direct support to having diverse personality types on teams.

Zahniser presents a very hands-on, practical paper on group techniques that improve software development performance, by as much as 75% (Zahniser, 1990). He describes “modes of working on software” that consists of levels of involvement, i.e. how many individuals are interacting in a given group? His premise is that employees need to be aware of when fewer people are better than many and vice versa.

Other computer science work focuses more specifically on personality traits. Von Mayerhauser examines two programming team structures, the Chief Programmer Team and the Egoless Programming Team, and analyzes them in terms of personality traits such as interpersonal skill and management skills (von Mayrhauser, 1984). Other work more closely related to the current research makes use of the MBTI. For example, Lyons describes “computer professionals” in a multi-national study that includes some managers (Lyons, 1985); Bush and Schkade describes programmers at an aerospace firm (Bush and Schkade, 1985); Sitton and Chmelir report a similar analysis of Texas state programmers (Sitton and Chmelir, 1984); Bostrom and Kaiser present MIS users and programmers who develop systems (Bostrom and Kaiser, 1981). The Lyons study and the Bostrom and Kaiser study present distribution information for each of the four scales in the MBTI, which is used later to compare their results to the various data sets for this research. The Bush and Schkade study and the Sitton and Chmelir study present only the major composite types, e.g. INTP, so that their results cannot be compared to the current work.

Other MBTI work in computer science focuses on analyzing the “Why?” factors. White presents a case study in which she draws the conclusion that MBTI Feeler types<sup>2</sup> add the personal touch to a team (White, 1984). In her study that involved only two teams, one team did not take into account users’ needs; they “got caught up in technical details” (White, 1984), and the project failed. The other team is described as listeners, “they really heard what I had to say” (White, 1984); this team produced a successful

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<sup>1</sup> The various personality types are described later, in Section 2.3.1.

product. Buie also examines the effects of types on software teams (Buie, 1985, 1988). She finds that software development teams need mostly Thinker types<sup>1</sup>, but Feeler types<sup>1</sup> are necessary, especially for communication with the outside world, similar to White's impressions. Buie "suspects that Sensing and Intuitive types<sup>1</sup> tend to choose different application areas - the former, commercial and industrial environments, and the later, scientific and systems work" (Buie, 1985), so that not only can personality type influence choices of profession (Myers and McCaulley, 1985) but possibly particular sub-areas within a profession.

## **2.2 Personality and Role Measures**

This section provides detailed information on the specific tests or questionnaires used in this research to gather data. It also presents two general results determined as part of this investigation. These results are presented here because they form a foundation for later results. The two tests used in this research are the Keirsey Temperament Sorter and the Belbin Self-Perception Inventory, and they comprise the following subsections.

### **2.2.1 Myers-Briggs Types and The Keirsey Temperament Sorter**

The cornerstone of this research is a measure of personality characteristics. Initial work for this research began with the Myers-Briggs Type Indicator (MBTI) (Myers, 1980, 1987; Myers and McCaulley, 1985). As indicated in the motivation section, other investigations also have been performed in this area. The instrument used to collect data for this research, the Keirsey Temperament Sorter, provides the same sort of information as the MBTI. To understand the personality types of the Keirsey test, it is easiest to start with Jung's work and the MBTI. The MBTI is a psychometric test that, like some other personality tests, is based on a specific theory of personality types, namely C. G. Jung's theory of personality types. Psychometrics is "the measurement of mental traits, abilities, and processes" (Flexner, 1993). The MBTI provides measures of the types defined by Jung (Myers and McCaulley, 1985). The Keirsey Temperament Sorter is a shorter test that provides similar information to the MBTI. The primary difference is that the MBTI

is based strictly on Jung's types, which are based on internal motivations, whereas the Keirsey types are based on behavioral characteristics. For example, White used the MBTI to investigate the differences in the internal cognitive styles of teams (White, 1984), whereas this research is focused primarily on exhibited behaviors.

Jung's theory is based on the idea that individuals, in general, have a fundamental preference for each of a set of functions. This preference is similar to having a natural preference to being left- or right-handed. Jung's types deal with our preference for how we function, view a situation, or use our minds. Each individual can be categorized into a very limited set of types, namely one of sixteen types. A person is *typed* based on four scales or dimensions: Extrovert/Introvert (E/I), Sensing/Intuition (S/N), Thinking/Feeling (T/F), and Judging/Perceiving (J/P). Note that each of these dimensions is typically denoted by the first letter of the appropriate types, except for Intuition, which is denoted by an "N." A type is designated by one attribute from each of the four pairs. An individual might be categorized as a ENTP, viz. Extrovert, Intuition, Thinking, and Perceiving. An individual is either an Extrovert or an Introvert, a Sensor or an Intuitionalist, a Thinker or a Feeler, and a Judger or a Perceiver. See Appendix B for descriptions of all sixteen types.

Each of these four scales is bipolar. For example, for Extrovert/Introvert, Extrovert is at the top of the scale, whereas Introvert is at the bottom of the same scale. When scoring the Keirsey Temperament Sorter, the person ends up with an Extrovert/Introvert score; how high their score is determines whether the individual is an Extrovert or an Introvert. For the Keirsey Temperament Sorter, the Extrovert/Introvert scale is from zero to ten (0-10), and the other three scales are from zero to twenty (0-20): zero indicates an extreme Introvert and a ten indicates an extreme Extrovert.

### ***2.2.1.1 Detailed Overview***

This section presents each of the four bipolar scales: Extrovert/Introvert (E/I), Sensing/Intuition (S/N), Thinking/Feeling (T/F), and Judging/Perceiving (J/P). Since each of these terms is a rather common word, the natural question arises, "What do these terms mean with regard to classifying or typing people?" In a psychological context,

standard definitions do not provide suitable definitions for these terms. The Extroversion/ Introversion dimension deals primarily with one's attitude toward the outer or inner worlds. For example, where does the individual get his or her energy, being alone or being around others? One example of a significant difference between an extrovert and an introvert is that an introvert may feel more alone in a room full of strangers than if he or she were truly alone in the room, whereas an extrovert would probably feel more alive and energized simply by being surrounded by so many people. The Extrovert/Introvert scale primarily indicates whether the person's attention is focused inward or outward.

The basic difference between the Sensing and Intuition types deals with the balance between perceiving the present realities or envisioning future possibilities. A person described as a Sensing type is primarily concerned with the perception of the senses, whereas an Intuition type is more concerned with perception based on insight, viz. meanings, associations, or possibilities. A Sensing type might describe someone else's house as "large, old, aqua with rust trim, Victorian, with a deck added in back that has a hot tub," and a Intuition type might describe the same house as "moody, dark, church-like, ready to fall down." A better way of interpreting this scale, for the purposes of this research, is in terms of an individual's decision-making process. A Sensing type has a propensity to base decisions on facts, past experiences, or concrete details; Intuition types tend to make decisions based on their intuition.

For the Thinking/Feeling scale, the difference between the two is based on the type of decisions that an individual is more comfortable making. The Thinking individual prefers making decisions based on logic, whereas the Feeling individual prefers making decisions that are based on personal values or feelings. For example, one question on the Keirsey Sorter that determines if one is a Thinker or Feeler is "Are you more inclined to be: a) cool headed, b) warm hearted" (Kiersey, 1984). That is not to say that these two types of decisions cannot be exchanged; some decisions must be made on personal preferences, e.g. What would you like to eat tonight? Other decisions naturally tend to be based on logic, e.g. What is the fastest way to get from point A to point B? But the fact remains that some individuals are more comfortable making decisions of one type or the other.

The final scale, Judgment versus Perception, is the most often misunderstood component of the type scales. Most people assume that Judgment types are judgmental and Perception type individuals are very understanding, open people; thus, Judgment types receive a very negative connotation. The real meanings of these terms is based on the individual's view of closure. A Judgment type strives to achieve closure on unresolved issues, whereas a Perception type wishes to leave issues open in order to continue to collect data/information as long and as much as possible before making a decision and achieving closure on an issue. For example, a Perception type individual when making a major purchase would research and research the manufacturers and various models, always hoping to get new information that would "finish" the decision. A Judgment type might just purchase the first item that meets the basic requirements that were established.

### ***2.2.1.2 Agreement between Keirsey Temperament Sorter and the MBTI***

Previous studies have discussed the significance of the distributions of the Myers-Briggs types for software developers (Buie, 1985; Lyons, 1985). As described above, these studies discuss why developers might be distributed in the way that they are. A test that provides information similar to the MBTI is the Keirsey Temperament Sorter. The Sorter is used for this research instead of the MBTI for several reasons:

1. Administration - the MBTI can be administered only by a trained professional, which due to availability of administrators, and cost to a minor degree, adds great complexity to data gathering.
2. Distribution - Some of the participants are located around the country; collecting the data would not have been possible for many of the participants. This also added to the amount of data collected because of the ease to the participants of providing the data.
3. Recommendation - the Keirsey test was recommended by the Director of the Counseling Center at Virginia Tech, Dr. Warren<sup>3</sup>, as a simple, equivalent replacement for the MBTI.

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<sup>3</sup> Personal interview with Dr. Warren in August 1996.

4. Consistency - although the participants for the controlled study described in Chapter 3 are all in one location, some of the participants for the other studies described in this section are distributed around the country, therefore some of the data needed to be collected using the Keirsey test and consistency among the data sets for this investigation necessitated that all data use the same test.
5. Cost - the MBTI costs money, whereas the Keirsey test is free.

In order to compare previous results to the results of the various studies that comprise this research effort, it is necessary to determine that the Keirsey test and the MBTI do indeed provide similar information. To demonstrate this, the participants in the controlled experiments described in the previous chapter completed both the Keirsey Sorter and the MBTI. Then, the agreement of these two tests is compared using a Kappa Test for Agreement. This test indicates how well two sets of data agree. In this case for example, the statistic indicates that 87.5% of the time when the Keirsey test indicates an Introvert, the MBTI also indicates an Introvert, similarly for Extrovert. As shown in Table 2.1, the p-values for three of the scales is significant; the two tests agree. For the fourth scale, Thinking/Feeling, the percent agreement and p-value are weak. Generally, this indicates that one can accept the two tests for comparison purposes.

**Table 2.1: Agreement of Myers-Briggs Types to Keirsey Types**

<b>Type</b>	<b>% Agreement (p-value)</b>
Extrovert/Introvert	<b>87.5%</b> (0.0002)
Sensing/iNtuition	<b>87.5%</b> (0.0002)
Thinking/Feeling	<b>58.33%</b> (0.0934)
Judgment/Perception	<b>79.17%</b> (0.0014)

The agreement between the MBTI and the Keirsey Sorter is acceptable, and with this result, it is reasonable to compare the distributions of the four types using MBTI data from a previous study (Lyons, 1985) and to use Keirsey data for the current data sets. This result is used later, in Section 4.3, to compare the Keirsey data gathered for this research to MBTI data from previous studies, thus addressing Goal 1 of this research.

## 2.2.2 Belbin Roles

Because management approach is being applied to software development teams, some background from the management discipline needs to be presented. The following sections describe the set of roles identified by R. Meredith Belbin and the test he developed to measure and identify these roles in individuals. An overview of the roles is provided and then a description of the Belbin Self-Perception Inventory.

### 2.2.2.1 Overview

R. Meredith Belbin conducted a series of experiments that produced results that provide a foundation for this investigation. His results consist of a model of **management teams** based on roles that need to be present for the team to be successful. He started with a simple idea that different types of people interact in different ways. Initially, he investigated teams composed of members who were all very similar. Next, he conceived various other types through extensive observation of teams at work. For example, one type was labeled a “Plant” because this type of team member appeared to sit in the corners and not interact a lot, like a house plant, but would produce the most innovative plans and ideas when she or he did interact. Eventually, through observation, hypothesis testing, and experimentation, Belbin defined eight roles based on these observed types that he felt were necessary for a team to be successful: Chairman, Shaper, Plant, Monitor-Evaluator, Resource Investigator, Team Worker, Company Worker, and Completer-Finisher. Table 2.2 provides a brief description of all of the Belbin roles; it is directly from his original presentation of the work (Belbin, 1981).

It is important to note that Belbin has a different view of roles than the traditional one described in Section 2.1.4.3 as part of role theory. He believes that team members have two *types* of roles. The first type is a typical functional role, as described as part of role theory. The second type is a *team role or roles*, which comes from the set of roles described in the previous paragraph. Investigating how these types of roles affect team performance is germane this investigation. For a particular individual, the functional type of role might be a typist on a programming team, whereas the second type might be a Company Worker and a Team Worker. Individual members can fill more than one team

role. The team role describes how the individual fits into the team, not what particular function he or she performs. The remainder of this discussion is based on Belbin's original presentation of the material (Belbin, 1983), including all quotes unless otherwise indicated.

**Table 2.2: Brief Descriptions of Belbin Roles (Belbin, 1981)**

<i>Name</i>	<i>Symbol</i>	<i>Typical Features</i>	<i>Positive Qualities</i>	<i>Allowable Weaknesses</i>
Chairman	CH	Calm, self-confident, controlled	A capacity for treating and welcoming all potential contributors on their merits and without prejudice. Strong sense of objectiveness	No more than ordinary in terms of intellect or creative ability
Shaper	SH	Highly strung	Drive and a readiness to challenge inertia, ineffectiveness, complacency or self-deception	Proneness to provocation, irritation and impatience
Plant	PL	Individualistic, serious-minded, unorthodox	Genius, imagination, intellect, knowledge	Up in the clouds, inclined to disregard practical details or protocol
Resource Investigator	RI	Extroverted, enthusiastic, curious, communicative	A capacity for contacting people and exploring anything new. An ability to respond to challenge	Liable to lose interest once the initial fascination has passed
Monitor-Evaluator	ME	Sober, unemotional, prudent	Judgement, discretion, hard-headedness	Lacks inspiration or the ability to motivate others
Company Worker	CW	Conservative, dutiful, predictable	Organizing ability, practical common sense, hard-working, self-discipline	Lack of flexibility, unresponsiveness to unproven ideas
Team Worker	TW	Socially oriented, mild, sensitive	Ability to respond to people and to situations, & to promote team spirit	Indecisiveness at moments of crisis
Completer-Finisher	CF	Painstaking, orderly, conscientious, anxious	A capacity for follow-through, perfectionism	A tendency to worry about small things, a reluctance to "let go"

A **Chairman** is an individual who controls the team in a typical head-of-the-table manner. This role guides the team toward what he or she perceives as the team's objectives in the best manner he or she can determine. A Chairman is calm and listens to other team members well, having a natural ability to get the most and best out of everyone's potential. Additionally, he or she is very aware of the strengths and weaknesses of the team as a whole. The Chairman is one type of team leader.

The second role, **Shaper**, is also a leader type but has a completely different personality and managerial style from that of a Chairman. A Shaper is a slave driver, questioning members to find the best approaches to problems. This role leads the team by stimulating the members to “challenge inertia, ineffectiveness, and complacency” (Belbin, 1983). Shapers tend to be nervous, extroverted, competitive, and argumentative, just to name a few of their stronger characteristics.

The question arises of who leads the team if individuals of both roles are present in a team. The answer is that either they cooperate in their leadership, trading off at designated appropriate times, or they produce a great deal of conflict in the team and can make the team less successful. Ideally, both roles are present on a team, and they complement each other. The Chairman of the team tries to keep progress moving in a steady, conservative fashion, and the Shaper likes to incite conflict and question complacency to make sure that all possibilities are being considered. For each of the eight roles, a similar relationship exists -- there is a complement of some sort for each role.

The third role is the **Plant**, noted in the introduction of this section. The Plant is the innovator of the team; he or she advances new approaches and ideas with special attention to major issues. A Plant is typically introverted, unorthodox, imaginative, and intelligent but “inclined to disregard practical details or protocols” (Belbin, 1983). The Plants are the brainchildren who must be nurtured and occasionally drawn back into the real world because they tend to have their heads in the clouds. They are considered one of the intellectual types in a team.

The complementary role to the Plant is the **Monitor-Evaluator**, the other intellectual. The Monitor-Evaluator is the analyzer of the team; the member who evaluates all of the alternatives for all decisions, methods, and approaches so that the team is positioned as competitively as possible. This role can be under-appreciated because members that fill this role tend to be unemotional, dry, over-critical, hard-headed, and unmotivational to others; this is unfortunate because the role is necessary for the team to succeed. The Monitor-Evaluator plays counterbalance to the Plant: Plants

come up with esoteric, innovative ideas and the Monitor-Evaluator is the only role that can debate successfully with a Plant to make correct choices.

The fifth role is **Resource Investigator**, who is considered one of the negotiator types of roles. In one aspect, Resource Investigators are very similar to Plants, although not considered complements. Both of these roles are seen as creative members who bring innovation to the team. The difference is that Resource Investigators get their innovations from sources external to the team, primarily due to their extroverted nature. Other attributes associated with this role are enthusiasm, curiosity, and communication skills. These members also have a tremendous “capacity for contacting people and exploring anything new” (Belbin, 1983). Unfortunately, they tend to lose interest in a problem or situation once the novelty of it wears off. Their strength lies in that they know how to get what they want out of a person.

The complementary negotiator role is the **Team Worker**, who ensures that the team works together toward their goals. Whereas the Resource Investigator negotiates outside of the team to get what the team needs, the Team Worker facilitates or negotiates within the team. For example, no matter how brilliant a Plant may be or how successful a team leader may be, team members need to get along in order for the team to be effective. Further, members may get irritated by the slow, thoughtful decision-making process of the Monitor-Evaluator; members may not let the introverted Plant express herself or himself. Therefore, some member role is necessary to make sure that everyone gets along and is provided the opportunity to accomplish his or her functions. Team Workers tend to be very socially oriented, mild, and sensitive; they have a strong ability to respond, communicate, and deal with people and situations, the ultimate facilitator.

The seventh role that Belbin discusses is the **Company Worker**, who is the meat-and-potatoes member of the team. Company Workers’ primary function is “turning concepts and plans into practical working procedures;” they focus on “carrying out agreed (upon) plans systematically and efficiently” (Belbin, 1983). Company Workers tend to be conservative, dutiful, predictable, good organizers, hard-working, and self-disciplined. On the negative side, they are inflexible and resistant to unproven ideas, views, and approaches; they sometimes support the status quo too much. Although

Company Workers, like all of the roles, tend to exhibit some negative aspects, one should bear in mind that negative aspects are part of what defines the individual who can fulfill the role successfully.

The final role, **Completer-Finisher**, is the complement of the Company Worker in a manager-worker relation. Completer-Finishers focus on a project delivering on-time and within cost estimates; the Company Worker carries out work to accomplish this. Primarily, team members in this role focus on avoiding “mistakes of both omission and commission, actively searching for aspects of work (that) need a more than usual degree of attention” (Belbin, 1983). They stress a sense of urgency to the team in order to meet deadlines and goals. Team members who fill this role are painstaking, orderly, conscientious, and anxious; they demonstrate a strong sense of follow-through and perfectionism.

#### ***2.2.2.2 The Belbin Self-Perception Inventory***

While these roles may be interesting, the question arises How can these roles be measured for an individual? Belbin developed a questionnaire as part of his investigations (Belbin, 1981). This is the instrument used to gather data from individuals to analyze the teams. Similar to psychometrics such as the MBTI, this test provides indicators of an individual’s natural propensity toward filling each role. One aspect of the test that affects how teams are set up concerns the fact that the numbers produced by the test are relative, not absolute. The test consists of several sections; for each section an individual distributes ten points among eight statements, based on how strongly they feel about each statement.

Table 2.3 shows one section of the seven sections of the test. Some participants prefer to assign a lot of the points to a few statements; other participants prefer to spread the points out more evenly. When scoring the test to determine an individual’s potential roles, this needs to be considered. The Belbin Self-Perception Inventory was developed by Belbin at the Administrative Staff College, Henley, by the Industrial Training Research Unit from Cambridge. A copy of the complete test is in Appendix C.

**Table 2.3: Sample Section of Questionnaire for Belbin Roles**

Section 2: If I have a possible shortcoming in teamwork, it could be that:
<input type="checkbox"/> 1. I am not at ease unless meetings are well structured and controlled and generally well conducted.
<input type="checkbox"/> 2. I am inclined to be too generous towards others who have a valid viewpoint that has not been given proper airing.
<input type="checkbox"/> 3. I have a tendency to talk too much once the group gets on to new ideas.
<input type="checkbox"/> 4. My objective outlook makes it difficult for me to join in readily and enthusiastically with colleagues.
<input type="checkbox"/> 5. I am sometimes seen as forceful and authoritarian if there is a need to get something done.
<input type="checkbox"/> 6. I find it difficult to lead from the front, perhaps because I am over-responsive to group atmosphere.
<input type="checkbox"/> 7. I am apt to get caught up in ideas that occur to me and so lose track of what is happening.
<input type="checkbox"/> 8. My colleagues tend to see me as worrying unnecessarily over detail and the possibility that things may go wrong.

### **2.2.3 Correlations of Keirsey Types and Belbin Roles**

Part of the initial approach to investigating team performance of software development teams revolves around the idea of measuring Keirsey types and then transforming that data into Belbin roles. Fortunately, a test to measure the roles directly was discovered (See Appendix C). This is fortunate because after months of trying to formulate regression models out of various sets of data, no significant models could be extracted from the data. The best results that could be excised from the data are the correlations between Belbin's roles and Keirsey's types shown in Table 2.4. These correlations come from an analysis of the data from the 55 student participants in the Object Oriented Design class that is used in later analyses (See Section 4.2).

**Table 2.4: “Significant” Correlations Between Belbin Roles and Keirsey Types**

	E/I	S/N	T/F	J/P
CH	-	+0.2102 .0443	-	-
SH	+0.2474 .0174	-	-	-
PL	-	-0.4205 .0001	-0.1731 .0990	-0.4323 .0001
RI	+0.2915 .0048	-	-	-0.2462 .0180
ME	-0.3228 .0017	-	-	-
CW	-	+0.2280 .0288	-	+0.2763 .0077
TW	-	-	-	-
CF	-	+0.2122 .0423	-	+0.3757 .0002

In Table 2.4, the top number in each cell is the correlation coefficient and the bottom number is the p-value for that coefficient. One should note that while the p-values for the correlations in the table are significant at the .1 level (and most of them at the .05 level), the correlations do not convey much meaning. All that can be inferred from this information is that it indicates a trend for a relationship between the variables. This is very weak. In addition, the correlation coefficients are all rather low, making them further suspect. This might be one indication of why Multiple Linear Regression techniques (Ott, 1993) proved not to be useful in modeling this data. That is not to say that there is not *any* relationship among these variables, but regression models could not be found using this data. One approach to creating models of software development team effectiveness includes finding a relationship between the Keirsey types and the Belbin roles, but since the Belbin roles could be measured directly, this relationship is not crucial to this research.

### **2.3 Using Students in Controlled Experiments**

The subjects in these controlled experiments presented in Section 3 are senior college students. Other investigations examine student programming teams. Henry, for one, evaluates various methods used to set up programming teams for collegiate senior-

level software engineering classes: random, allowing students set up their own teams, grade point, etc. (Henry, 1983) She presents a heuristic for establishing teams that is based on amount of free time, schedule conflicts, and grade point that achieves relatively equivalent teams. Scott and Cross also discuss issues in setting up student programming teams, in an effort to make them relatively equivalent (Scott and Cross, 1995). Some of the issues that they present are academic performance (grades), team and project size, and, interestingly enough, psychological profiles including the MBTI. Unfortunately, their treatment is very superficial; they consider only psychological issues such as a team needing an introvert and an extrovert because the class requires written and oral presentations, and *clearly*, they conclude, “an Extrovert will be more comfortable with an oral presentation, while an Introvert may produce a better written report” (Scott and Cross, 1995).

Finally, the issue of using student programmers in experiments introduces the concern that such research does not apply directly to industry programmers. Holt, et al. demonstrate that advanced students and professional programmers are statistically similar in terms of comparing their mental representation and various performance measures (Holt et al., 1987). This provides support for using students in studies, *especially for investigations in which an industry validation is to be conducted*, which is true for this research.

## **2.4 Management Team Research Applied to Software Teams**

As presented in previous sections, many studies have been done on software development teams (Jeffery, 1987; Mills, 1983; Bostrom and Kaiser, 1981; Trower and Straub, 1991; Shneiderman, 1980; von Mayrhauser, 1984; Walz et al., 1987; Zahniser, 1990). One study by Rob Thomsett is of particular interest for this investigation because it combines Belbin’s roles and the MBTI. This study presents a qualitative analysis of software teams in Australia using measurement instruments for the models (Thomsett, 1990).

Thomsett distributed his ideas at workshops in Australia on team leadership to approximately 650 computer professionals. As part of the workshops, participants were

presented with the concepts upon which the three models are based. Additionally, instruments for the three models were administered: the MBTI, the JDS, and the Henley Self-Perception Inventory. Thomsett reports that for one company that participated in the workshop, “Immediate productivity increases of 200 percent (were) reported by the senior management of the computing group” (Thomsett, 1990). Thomsett explains this productivity increase with some intuitive reasons that knowledge of fellow employees’ personality profiles increase team productivity. He also states that the MBTI types are distributed the way they are in his data: a ‘cloning’ effect that means that managers hire employees that are similar to themselves, an effect described by others (Bush and Schkade, 1985; Lyons, 1985).

Unfortunately, there are serious deficiencies with this investigation. First of all, the analysis is completely qualitative: nothing he states can be repeated, or even quantitatively substantiated. Further, he actually says that his ‘approach’ was ‘implemented’ by an organization, but he does not describe what the approach is nor what an implementation of it entails. One might infer that this means that employees are made aware of the concepts of the models, tested with the instruments of the models, informed of their particular results for the instruments for the models, and encouraged to take this information into account in interacting with fellow employees. This is an extraordinary inference, which itself is not concrete. Thomsett is fuzzy, at best, on the details. Another problem with this investigation, or at least the description of it, is in its greatest claim: the 200 percent productivity increase. How was this determined or measured? No details are provided about this, and it gives the appearance that a senior manager is trying to justify sending his employees to a workshop.

To summarize, Thomsett presents an interesting study that needs further investigation. He presents general information that appears **very useful** but has only intuitive supporting arguments and no empirical evidence. His implications are that team members who know each others’ personality information work more productively together. His results are encouraging, but quantitative analyses need to be conducted in order to support his ideas.

# Chapter 3

## The Controlled Experiments

The importance of this research lies in the cause-and-effect relationships that can be used to improve extant teams or to form good teams. The effects are observed when some teams are specifically designed to be better than others. Thus, this research demonstrates that teams with certain qualities perform better than teams that do not have those qualities. The foundation for this work lies in the nature of controlled experiments, which are “stud(ies) in which certain independent variables are manipulated, and their effect on one or more dependant variables is determined” (Hicks, 1982).

Cause-and-effect relationships can be inferred from randomized experiments but not from observational studies. The problem with observational studies is that confounding variables – identifiable or not – may be responsible for observed differences. (Ramsey and Schafer, 1997)

This is a serious concern because early studies in this area are only observational. The cause-and-effect relationship is also the reason that it is so important to conduct controlled experiments, making other considerations equivalent using blocking, so that each team is considered equivalent except for the aspect being investigated. This is the basic difference between controlled experiments and observational studies (Ott, 1993) and makes the effects relationship interesting and useful. Other parts of this overall research effort consist of observational studies.

The specific purpose of these experiments is to produce empirical results to support some of the concepts central to the research. Several null hypotheses were proposed to focus the research on issues that could be tested directly. Each of the hypotheses ultimately selected involves investigating the importance of a team containing one of the Belbin roles. Since the subjects for the experiments are only available for 12

sessions of 2 hours each, only 3 of Belbin's 8 roles are examined: the Shaper, the Plant, and the Monitor-Evaluator. The specific hypotheses are:

Experiment 1: Shaper: Leadership

H<sub>0</sub>: Teams containing one and only one "leader" perform equivalently to teams with no leader or multiple leaders.

Experiment 2: Plants: Innovation

H<sub>0</sub>: Teams composed of all Plant team members perform equivalently to teams with no Plants or even a single Plant.

Experiment 3: Monitor Evaluator: Decision Making

H<sub>0</sub>: Teams composed of all Monitor-Evaluator team members perform equivalently to teams that have no Monitor-Evaluator.

These three roles are investigated because of their obvious importance to software development: leadership, innovation, and decision making. First of all, each team obviously needs clear leadership. Secondly, innovative ideas are very important for development teams to insure that the best approaches to solutions are discovered. Third, a team must be able to decide which general approach, hopefully one of several, is best for a team to succeed, as well as which specific choices among alternatives would advance the team best. That is not to say that other factors, such as experience or even other roles, are not important. In controlled experiments such as these, other factors that affect team performance are either factored out by making them equivalent among the teams, i.e. blocking, or are considered to be assigned randomly to teams. In this way, one attempts to isolate one characteristic at a time to study in a controlled manner. See Section 4.4 for distribution information on the Belbin roles, which lends further support for selecting these roles for the experiments.

For these experiments, the dependant variable being studied is team effectiveness. The primary aspect of effectiveness that is the focus for these experiments is team *performance*. For a quantitative analysis, some objective measure of performance needs to be used to provide a "measure of success." In this research, that measure is the time to *correctly complete* a programming problem, viz. the time-to-completion of solutions that produce correct output for a battery of tests. The mean completion time of all of the teams expected to perform well are compared to the mean completion time of the teams expected not to perform well. A statistical comparison of these means determines

whether there is a significant difference between the means. One certainly could argue that time-to-completion is a small measure of success, but this measure is chosen because it is objective, quantitative, and easy to collect. A solution is not accepted until it is correct, so no measure of correctness is used. Although a correctness measure could be evaluated by using expert evaluators, such a measure would have the deficiency of being subjective, and the focus of this study is on more quantitative measures. Similarly, rating the “quality” of the code would be completely subjective. Thus, this part of the research demonstrates that teams that contain the specified roles perform better, i.e. finish sooner on the average, than teams that do not possess those roles.

### **3.1 Establishing Teams**

To understand how the experiments are conducted, the terms *team* and *group* must be identified as distinct for the purposes of this experiment. Each *team* is composed of three members who indicate a certain role characteristic under observation. Each *team* is placed in a experimental *group* that is being used to test the hypotheses in question. For each experiment, a *group* is designed such that it is expected to perform well on average, i.e. an “successful” group; another *group* is expected to perform on average worse than the “successful” group, i.e. a “unsuccessful” group. These groups clearly correspond to teams that support and oppose the *null hypotheses*.

For example, for the first hypothesis on leadership, two experimental groups are established: a “Leader” (successful) group and a “No Leader” (unsuccessful) group. Then, each team is established to be a “Leader” team or a “No Leader” team in terms of how it is expected to perform in the experiment. In other words, some teams are established with a single, identifiable leader and are in the successful, “Leader” group; other teams are established with no leaders or all leaders and are part of the unsuccessful, “No Leader” group. Using a table like Table 3.1 but including all of the teams, similar groups and teams are formed for each of the hypotheses under test. Tables showing the team and group formation are provided along with the discussions of each of the experiments.

In order to ensure that the role under scrutiny is the reason the groups perform differently, the other roles are made as equivalent as possible across the teams, and the team members' self-rated experience (the last column in Table 3.1) is used as a blocking factor. **All factors**, other than the Belbin roles under investigation, are either made equivalent across the teams or can be considered randomized. Further, for the second and third experiments, the teams are formed such that none of the members work together on a team for the previous experiment(s).

**Table 3.1: Example of Data for a Single Team**

Group	Team	Member	CH	SH	PL	RI	ME	CW	TW	CF	Exp
1 Leader	Team X										
		1	c3	-	-	-	-	w2	-	f9	5
		2	-	s8	p2	-	m0	-	-	-	4
		3	-	s0	p7	-	m5	w0	-	-	4

As an example, Table 3.1 shows the information used to form the groups and teams. Each row under a team, e.g. Team X, contains the information for one team member. The first column simply lists the groups for the experiment. The second column designates the team names. The third column shows members' numbers. The subsequent columns represent the members' data for the Belbin roles: Chairman (CH), Shaper (SH), Plant (PL), Resource Investigator (RI), Monitor-Evaluator (ME), Company Worker (CW), Team Worker (TW), and Completer-Finisher (CF). The final column shows the members' self-rated experience on a one to five (1-5) scale, low to high, which is used to make the teams equivalent, mitigating the chances that the successful teams simply contained better programmers.

The columns of data for the Belbin roles in the table represent the members' scores on the Belbin Self-Perception Inventory that indicates the Belbin roles. Cells with a dash (-) indicate that the score is not significantly high enough to take into account when forming the teams. One should note that if an individual takes the test and distributes the points as evenly as possible, each cell would have the average of 8.75; therefore, a score of 9 or less is insignificant, and a 10 is weak. Each cell contains a letter and a digit. The letter represents the role, which also is shown by the column header

abbreviations, and the digit indicates the score on the Belbin test. Scores in the range 10 to 19 are indicated with a lower case letter for the role, e.g. c3 and p2 indicate a Chairman score of 13 and a Plant score of 12, respectively. Scores of 20 and above are indicated with a capital letter, e.g. W2 and F9 indicate a Company Worker score of 22 and a Completer-Finisher score of 29, which are very high scores. This scheme is used because it removes extraneous information, making comprehensible the enormous amount of data that is needed to form the teams evenly, except for the role under study.

To determine each member's potential roles, several factors need to be taken into consideration:

1. An individual fills more than one role by having significant scores for multiple roles, typically two or three roles.
2. Although an individual might have a number that appears to make them fill that role, they may not fill that role because they have a stronger tendency to fill other roles. For example, in Table 3.1, member 1 probably does not fill the Chairman role.
3. Other fellow members can keep a member from filling a role in the case that the fellow member is stronger in the role. This is true particularly if the member has other roles that are stronger. For example, member 3 in Table 3.1 would not fill the Shaper role because of his or her other stronger roles as well as member 2 being such a strong Shaper.
4. Because the scores are relative, not absolute, sometimes a score of ten (10) or eleven (11) is significant, sometimes not. If a person has "high" scores of 12 in two roles and 10 in another role, then the 10 would be considered significant, because the individual has a tendency to assign a few points to all of the statements in the test. Member 1 Table 3.1 is a good example of a low score of 11 **not being** significant.

Part of the basic assumption of this research is that some roles can conflict within a team, such that a team is "better" with only one of that role type on the team. This appears to be true for some roles, such as Shaper, where leadership conflicts can occur. Other roles appear not to demonstrate this effect, such as Plants, where the team improves by having more members who are innovative.

## 3.2 Conducting the Experiments

The teams and groups are formed prior to the commencement of the experiments, and the participants show up in a laboratory where there are nine computers used in the experiment. The 24 student participants are formed into eight teams prior to the experiment, and each team acquires one computer on which to work. One computer is used by the experimenter to test and accept problem solutions. Each participant is given a copy of the problem to be solved that day. The problems are intended to be solved in a little over an hour, although some teams end up requiring up to two hours. In order to make the teams as equivalent as possible, each team can only work on one workstation and are told that they could use whatever editors, compilers, and utilities they wish. All of the facilities on the machines are equivalent. The teams can use any of the compilers available for C. Teams are instructed to email their solutions to the experimenter as soon as they feel that they have a correct solution, and the experimenter tests the solutions with his/her own acceptance data, which is not shown to the participants. A completion time for each team is recorded only when a submitted solution tests *correctly* against the acceptance data. Although the problem statements include some test data, the teams are informed that they must create test data themselves in order to have their solution pass all of the acceptance tests.

Each experiment to test one of the hypotheses consists of four problems that are solved in four separate lab sessions. During the four sessions, the teams are given one problem at a time to complete during that lab session. The means of all four problems for each group are calculated and compared in the following analysis.

## 3.3 Quantitative Results

The following sections detail the quantitative results of the experiments. This discussion is divided into two parts: performance and viability. The performance sections present the results in terms of time-to-completion. The groups are compared to determine whether there is a statistical difference between their means. The basic hypothesis is that the mean of the completion times for the “successful” group in each of

the experiments is significantly lower than for the “unsuccessful” group. In other words, on average, bad teams should take longer to solve the problems.

The second section presents results for the viability data. Basically, the issue of interest with this data concerns whether the “successful” teams are more viable than the “unsuccessful” ones. For example, how good was the inter-member coordination of your team? ... the cooperation? ... the cohesion? How well was each member’s technical abilities used? *How willing would you be to work with this team again?* Each member is asked to rate his or her team on each of these issues on a scale of one to six, poor to good. This data is analyzed to determine if one can distinguish between the groups.

### 3.3.1 Performance Data: Mean Time to Completion

As described in Section 3.1, each *team* is placed in a *group* that is being used to test the hypotheses in question. In the following sections, each of the “successful” and “unsuccessful” groups that are designed for each experiment are described, along with the three specific null and attendant alternative hypotheses.

The analysis of the controlled experiments focuses on the first part of the definition of the effectiveness of a team, i.e. performance. The groups are compared to determine if one group is better in terms of a statistically smaller mean time-to-completion. The raw data for this analysis can be found in Appendix D.

The following are the three null hypotheses and attendant alternative hypotheses used in the three experiments:

#### Experiment 1: Shaper: Leadership

H<sub>0</sub>: Teams containing one and only one “leader” perform equivalently to teams with no leader or multiple leaders.

H<sub>1</sub>: Teams containing one and only one “leader” **do not** perform equivalently to teams with no leader or multiple leaders.

#### Experiment 2: Plants: Innovation

H<sub>0</sub>: Teams composed of all Plant team members perform equivalently to teams with no Plants or even a single Plant.

H<sub>1</sub>: Teams composed of all Plants **do not** perform equivalently to teams with no Plants or even a single Plant.

### Experiment 3: Monitor Evaluator: Decision-Making

H<sub>0</sub>: Teams composed of all Monitor-Evaluator team members perform equivalently to teams that have no Monitor-Evaluator.

H<sub>1</sub>: Teams composed of all Monitor-Evaluator team members **do not** perform equivalently to teams that have no Monitor-Evaluator.

#### *3.3.1.1 Experiment 1: Leadership*

The first experiment demonstrates that teams with a single, recognized leader perform better than those with no leader. The groups for this experiment are, as used as an example in Section 4.1: “Leader” and “No Leader.” The “Leader” teams are established with a single, recognized leader on each team with the other factors roughly equivalent; the “No Leader” teams consists of teams that either have **no** leader type present or have no **clear leader**, i.e. two or all three members are leader types, which creates conflicts regarding who is in charge and which “direction” the team should pursue. The basic hypothesis is that the mean of the completion times for the teams in the “Leader” group is significantly lower than for the “No Leader” group. In other words on the average, leaderless teams should take longer to solve the problems.

This experiment on leadership of a team has a null hypothesis and alternative hypothesis of:

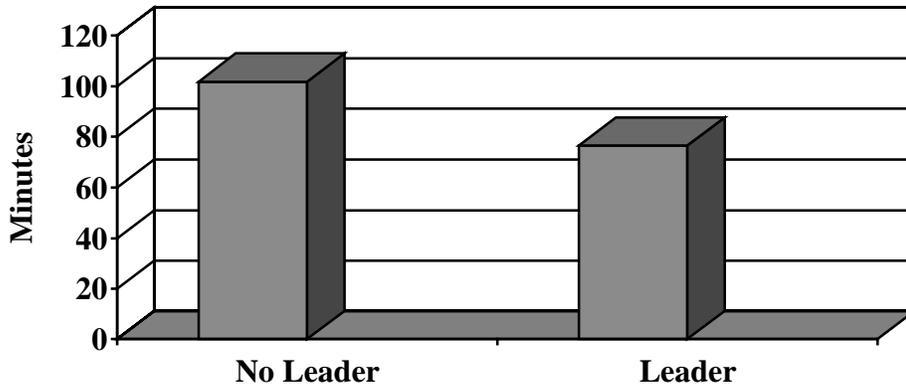
H<sub>0</sub>: Teams containing one and only one “leader” perform equivalently to teams with no leader or multiple leaders

H<sub>1</sub>: Teams containing one and only one “leader” **do not** perform equivalently to teams with no leader or multiple leaders

Again, note that the teams are balanced by level of programming experience, which is indicated in the last column in Table 3.2.

**Table 3.2: Teams Used in the Leadership Experiment**

Group	Team	Member	CH	SH	PL	RI	ME	CW	TW	CF	Exp	
1 Leader	D											
		1	c3	-	-	-	-	w2	-	f9	5	
		2	-	<b>s4</b>	p2	-	m0	-	-	-	4	
		3	-	s3	p7	-	m3	w0	-	-	4	
	F											
		1	-	<b>s1</b>	-	-	m4	-	-	-	5	
		2	<b>c0</b>	-	p0	-	-	w0	t4	-	5	
		3	-	-	-	-	M0	W5	T0	-	2	
	H											
		1	-	<b>s1</b>	P0	r2	-	-	-	-	4	
		2	-	-	P0	-	-	w1	-	-	4	
		3	-	-	-	-	m1	w1	t8	-	4	
<hr/>												
	G											
		1	<b>c0</b>	-	-	-	<b>m4</b>	<b>w1</b>	-	-	4	
		2	-	-	p0	-	-	w4	t3	f0	3	
	3	-	-	-	-	-	w9	t5	-	6		
<hr/>												
2 No Leader	E											
		1	-	s0	<b>p3</b>	-	-	<b>w1</b>	<b>t6</b>	-	2	
		2	-	-	-	-	-	w4	-	f1	5	
		3	-	-	p3	r0	m1	w4	-	-	5	
	C											
		1	-	<b>s2</b>	-	-	-	w2	-	-	3	
		2	c0	<b>s4</b>	-	-	-	w1	-	f2	6	
		3	<b>c4</b>	-	-	-	-	w5	t4	f2	5	
	B											
		1	-	<b>s2</b>	-	r2	-	w0	-	-	5	
		2	-	<b>s0</b>	p3	-	-	w4	-	-	5	
		3	c0	<b>s2</b>	-	r2	m2	-	-	-	3	
	A											
		1	-	<b>s0</b>	P2	-	-	-	-	f5	5	
		2	-	<b>s3</b>	-	-	m6	w7	-	f0	6	
	3	-	<b>s9</b>	-	-	m3	w3	-	-	2		



**Figure 3.1: Means with Team G in No-Leader Group**

After transforming the data with a log function to form a linear model, the analysis of the data shows a significant difference between the groups. An ANOVA using Proc GLM<sup>4</sup> in SAS (Littell et al., 1991) shows that the two groups are statistically different ( $p=0.0068$ ). The means are 101.81 and 76.63 minutes for the two groups (See Figure 3.1) with standard deviations of 57.97 and 54.54 respectively, and the R-Squared for the model is 0.7665. Therefore, the null hypothesis is rejected, allowing the alternate hypothesis to be accepted; the groups are not equivalent. Because the groups are not equivalent and the mean completion time of the “Leader” group is better, this is interpreted as teams with a single, recognized leader perform better than the teams with no clear leader.

The “Leader” group consists of Teams D, F, and H (above the bold line in Table 3.2) and contain a single leader. These teams form the “successful” group. Teams A, B, and C contain multiple leader roles, who tend to introduce conflict into the teams composition, reducing the effectiveness of the team. Teams E and G have no obvious leader who can be identified by Belbin’s roles, although as described below, the member on Team G with a Chairman score of c0 indeed acts as a leader. The information in Figure 3.1 is generated using Teams A, B, C, E, and G as the “No Leader” teams. These

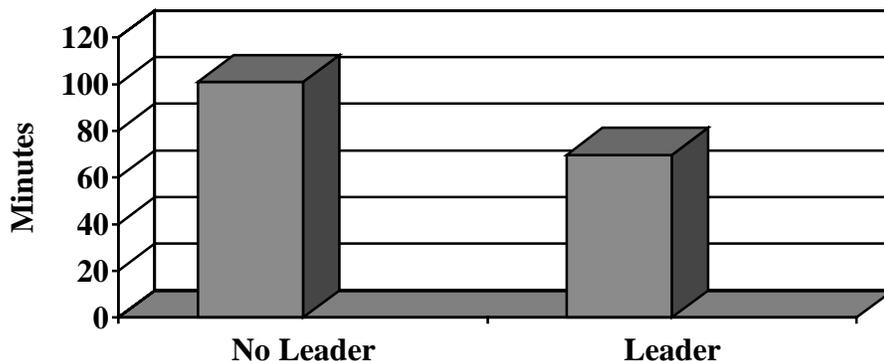
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<sup>4</sup> GLM means General Linear Model, a standard statistical procedure.

include both the no-leader teams as well as the multiple leader teams. The reason that the member on Team G acts as a leader can be explained, *post hoc*, by the following:

1. The individual has a weak measure of the leadership role,
2. The other two roles that the individual should fill are not sufficiently stronger than the Chairman role,
3. The Chairman role needs to be filled by someone on this team.

Typically, when examining the roles in order to set up the teams, only the top two roles are used for each individual. Figure 3.2 shows the results of an analysis of the data putting Team G in the “Leader” group, because Team G has a single leader although it is not obvious from the Belbin data. This analysis has an even stronger conclusion, as shown by a decreased p-value ( $p=0.0034$ ) for the overall test of group significance using an F-test in an ANOVA. As shown in Figure 3.2 the means of the groups are 100.90 and



**Figure 3.2: Means with Team G in the Leader Group**

69.75 minutes with standard deviations of 64.81 and 34.40 respectively. The R-Squared is 0.7665.

Some subjective observations are recorded by the experimenter both during and immediately after each lab session. Some notes about the teams with leaders include: “The team obviously works well together.” “One person (is) at the helm, with the other two supporting technically, non-passively; the leader listens fairly well but is not the bright one.” “Passive-aggressive leader is bright and doesn’t listen well but listens well

enough to get the good ideas from the other members; he tends to become almost too focused sometimes.” By the fourth (and last) problem for this experiment, Team F stated that they “had it down” in terms of coordinating together. Some comments from, and about, the leaderless teams include: “...very separated group,” “two dominant individuals with the third being very passive; one member takes the leadership role but only to argue with the other dominant member over everything, although the leader did make attempts to listen to the quiet one.” By the fourth (and last) problem Team E had “completely given up, apparently feeling that their team had been ‘set up’ not to work well together.”

Other comments directly from the teams themselves include the following: “I (the leader) dominated the design as well as the coding.” Another leader took charge by taking charge of the keyboard, “which was fine with me - I like immediate action - planning out algorithms is dull.” One of this leader’s team members identifies “the team communication” as the best feature of the team. For the teams that are designed to be unsuccessful, some of the teams noted “serious communication problems.” Two of the teams identified the major deficiency of the team as the fact that members “tended to work separately after we had identified the problem” and “many times we were unfocused and un-teamlike.”

One might note that the two Belbin roles Chairman and Shaper are two different types of leaders. They *can* be complementary roles, where the Chairman observes the team, knows the strengths and weaknesses of each member (and hence the team), and knows how to take maximal advantage of the team’s resources. The Shaper plays more of an active part in the team, pushing the team members by questioning opinions and decisions and making members take extra effort in their work. Chairmen tend to be introverted and thoughtful; Shapers tend to be extroverted, confrontational, and motivating, making members extend their capabilities. “The ‘Chairman’ of (three-person) team(s) would be something of a misnomer” (Belbin, 1981) and does not have a significant impact on the team because coordinating the resources of two subordinates is not significant. Therefore, this experiment focuses on the Shaper types of leaders; further cause for not considering Chairman leaders is the virtual dearth of Chairman types in the data of the study.

### **3.3.1.2 Experiment 2: Innovation**

The second experiment demonstrates the importance of innovative Plant members to a team. For this experiment three *groups* are defined: “All Plants,” “Some Plants,” and “No Plants.” As outlined in Section 3.1, the teams are placed into these distinct groups to test the hypothesis. These groups are based on how many members of a team indicate the Plant role with the Belbin Test, which is described in Section 2.2. Some teams have **all** members who are Plants (Group 1, All Plants); some teams have **one or two** Plant members (Group 2, Some Plants); and some teams have **no** members who are Plants (Group 3, No Plants). As can be seen in Table 3.3, Teams A and H form Group 1 “All Plants”; Teams C, D, and E form Group 2 “Some Plants”; and Teams B, F, and G form Group 3 “No Plants.”

**Table 3.3: Teams Used in the Innovation Experiment**

Group	Team	Member	CH	SH	PL	RI	ME	CW	TW	CF		GPA	
1 All Plants	A												
		1	-	s1	P0	r2	-	-	-	-		3.2	
		2	-	-	p3	r0	m1	w4	-	-		2.7	
	3	c0	-	p0	-	-	w0	t4	-		3.4		
	H												
		1	-	s0	P2	-	-	-	-	f5		3.5	
2		-	s0	p3	-	-	w1	t6	-		2.6		
3	-	-	p0	-	-	w4	t3	f0		3.6			
3 No Plants	B												
		1	-	-	-	-	m1	w1	t8	-		3.0	
		2	-	-	-	-	M0	W5	T0	-		4.0	
	3	c0	s2	-	r2	m2	-	-	-		2.6		
	F												
		1	-	s1	-	-	m4	-	-	-		3.0	
		2	-	-	-	-	-	w9	t5	-		3.3	
	3	c3	-	-	-	-	W2	-	f9		3.1		
	G												
		1	-	s2	-	-	-	w2	-	-		2.7	
		2	-	-	-	-	-	w4	-	f1		3.4	
	3	c0	-	-	-	-	m4	w1	-	-		3.4	
2 Some Plants	C												
		1	-	s2	-	r2	-	w0	-	-		2.8	
		2	-	s3	p7	-	m3	w0	-	-		2.9	
	3	c4	-	-	-	-	w5	t4	f2		3.5		
	D												
		1	-	s0	p3	-	-	w4	-	-		2.9	
		2	-	s4	p2	-	m0	-	-	-		3.3	
	3	-	s9	-	-	m3	w3	-	-		3.0		
	E												
1		c0	s4	-	-	-	w1	-	f2		3.6		
2		-	-	P0	-	-	w1	-	-		3.5		
3	-	s3	-	-	m6	w7	-	f0		3.0			

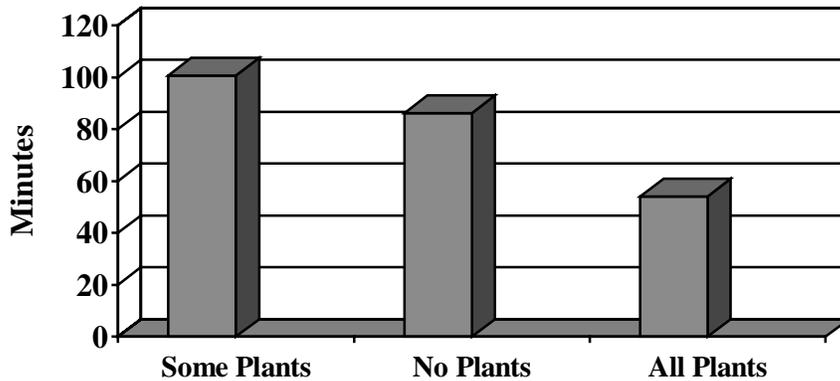
The initial intent was that all three of the groups would be statistically distinguishable, having statistically different means. However, the experiment indicates only that teams composed of all Plant members perform better than teams with one or two Plants, i.e. “Some Plants.” The results are inconclusive on distinguishing between the No Plants group and the other two groups. In other words, the overall mean of the mean-time-to-completion, including all teams for all lab sessions, for the “All Plant” group is statistically different than the “Some Plants” group, but there is not enough evidence to distinguish the “No Plant” group from the “All Plant” or the “Some Plants” groups. Subsequently, this experiment on innovation on a team has a null hypothesis and attendant hypothesis of:

H<sub>0</sub>: Teams composed of all Plant team members perform equivalent to teams with no Plants or even a single Plant.

H<sub>1</sub>: Teams composed of all Plants **do not** perform equivalent to teams with no Plants or even a single Plant.

Note that the teams are balanced by computer science grade point average, which is indicated in the last column in Table 3.3.

An ANOVA using Proc GLM in SAS (Littell et al., 1991) shows that the groups



**Figure 3.3: Means of the Groups by Number of Plants on the Team**

are statistically different by F-test ( $p=0.0412$ ); the means are 100.75, 86.25, and 54.13 for group 2, 3, and 1 respectively (See Figure 4.3) with standard deviations of 55.81, 56.77, and 26.43 respectively. The R-Squared is 0.5024. This allows the null hypothesis to be rejected, indicating that the groups are different. Then, Duncan's New Multiple Range Test (Ott, 1993) is used to determine differences among the group means. For two of the groups, "Some Plants" and "All Plants," the data shows a significant difference between the groups.

This raises several questions about why the "All Plants" group might appear to perform better than the "Some Plants" group but not better than teams with "No Plants." The easiest issue to question is the size of the sample, in other words, the number of teams in the study. Another possible explanation could be that the teams with all Plants are "on the same wavelength," the members simply think more alike than mixed teams. Because all of the members are innovators, they have a tendency not only to come up

with many different ideas, but to understand other's ideas more easily. This is an obvious shortcoming of some of the other teams, as indicated by other team members on the post-experiment questionnaire.

Some subjective observations from the participants as well as the experimenter, who took notes both during and immediately after each lab session, include positive and negative perceptions. Notes about the teams predicted to perform well include: "No negative aspects to this team; everyone worked well together." "The coordination within the group worked very well; the work was divided up very well. (Person 1) figured out the algorithm quickly. (Persons 2 and 3) would quickly produce an initial implementation. (Person 2) would then incredibly quickly type it in, while (Persons 1 and 3) looked for bugs in the algorithm and make sure that (Person 2) wasn't making typos." All three members of this team identify team coordination and "functional roles" as the key to their success. Some comments from, and about, the "unsuccessful" teams include: "Motivation wasn't all that ... (sic) present;" the team "couldn't think of many good solutions." The "quiet/reserved team member didn't participate much," which is very unfortunate since this person is a *very* strong Plant. "Sometimes good ideas were ignored because they 'almost had it' even though the other solution would have been better;" "We thought in different ways. This made coming up with a single, well-understood, and good solution next to impossible." Further comments include "no motivation, no division of labor" and "some ego problems caused good decisions and ideas from all members to get tossed out the window."

### ***3.3.1.3 Experiment 3: Decision Making***

The third experiment attempts to demonstrate the importance of the decision making Monitor-Evaluator members to a team. For this experiment two *groups* are defined: "Decision" and "Not Decision" teams. Some teams are established with at least one strong Monitor-Evaluator on the team; the other teams are established with *no* significant Monitor-Evaluator on the team. The intention of this experiment is to demonstrate that the Monitor-Evaluator is an important member of the team who provides a "decision making" aspect for the team. In terms of basic functions, the Monitor-Evaluator analyzes the abilities of the team members and evaluates all of the



H<sub>0</sub>: Teams containing at least one Monitor-Evaluator team member perform equivalently to teams that have **no** significant Monitor-Evaluator.

H<sub>1</sub>: Teams containing at least one Monitor-Evaluator team member **do not** perform equivalently to teams that have **no** significant Monitor-Evaluator.

It seems that this would be an absolutely necessary part of a team, but the statistical analysis, using Proc GLM in SAS (Littell et al., 1991), fails to reject the null hypothesis ( $p=0.2269$ ). Therefore, one cannot conclude that teams with Monitor-Evaluators perform better than those without. The reasons for this could be one or several of many:

1. The sample size, i.e. the number of teams in the study,
2. The fact that most software engineers tend to be very analytical, but do not indicate this Belbin role, which would simply mean that the teams are roughly equivalent regardless of the Monitor-Evaluator indicator,
3. The experiment includes the assumption that this Belbin role is not *mutually exclusive*. Some Belbin roles appear to strengthen a team when a single member on a team demonstrates that role; other roles appear to improve a team if all the members indicate the role. For this experiment, the teams are set up so that one **or more** Monitor-Evaluators on a team is hypothetically beneficial to the team.
4. Although this is counter-intuitive, it might be possible that Monitor-Evaluators simply are not a benefit to software development teams.

Although the final statistical analysis fails to reject the null hypothesis, early subjective indications during the course of the study were very promising. For example, for the first problem of the four for this experiment, the first two teams to complete the problem with the correct solution belong to the “Decision” group, leading the experimenter to be optimistic. Further, the two teams to finish last belong to the “Not Decision” group, finishing relatively long after all of the other teams. One comment from the participants states that “We (the team) sometimes followed blind alleys,” but no other comments elicited from the teams provide much insight to reasons that the groups are not distinguishable.

### 3.3.2 Team Viability Data

At the end of each of the three experiments discussed in the succeeding sections, the participants fill out a questionnaire concerned primarily with the viability of their teams. The general subject of the questions on the questionnaire concerns how well the team works together and how much they would like to work together again. See Appendix E for a copy of the questionnaire. Team members answer a series of questions asking them to rate their team on a scale of one to six (1-6), 1 being poor and 6 being good. For data analysis, all three team members' scores are averaged to provide a "team score." Using Proc GLM in SAS (Littell et al., 1991) again, an F-test is used on these means to determine whether the groups can be distinguished. This section presents quantitative and qualitative analyses of the viability data from the questionnaires. Since the results of the viability data are sparse, the results for all three experiments are presented in this single section.

A questionnaire is used at the end of each experiment to allow the team members evaluate the viability of their team. The results in Table 3.5 show that some factors indicate that teams composed for the performance experiments also exhibited viability differences between the *groups*.

**Table 3.5: Significant Viability Questions**

Leadership Experiment	Means (1-6 scale)		P-value for Group Difference	P-value with Performance Covariate
	1	2		
How willing would you be to work with this team again?	5.67	4.5	0.0102	ns covariance
<b>Plant Experiment</b>				
Rate the overall quality of the team.	5.67	3.78	0.0181	ns covariance
How good was the quality of the decision making for your team?	5.33	3.44	0.0464	ns covariance
How well was each member's technical abilities used?	5.5	4.11	0.0172	ns covariance
How willing would you be to work with this team again?	5.83	3.89	0.0440	ns covariance
How motivated was your team?	5.33	4.56	0.0025	0.0338

In Table 3.5, the first column contains the significant questions. The second column contains the means of the groups that can be distinguished. The third column

contains the probability-values *without* taking into account any covariance between the performance measure and the viability measures, and the last column contains the probability-values taking into account any covariance between the performance measure and the viability measures. An “ns” in the last column indicates that the covariance between the performance measure and the viability question is not significant. It is natural to question whether these viability issues are significant simply because the team performed well in terms of the time-to-completion performance measure. In other words, are teams more willing to work together again if they performed better? This is addressed by the covariance between these viability questions and the performance measure. Covariance is a statistical measure of the *linear* relationship between two random variables measured in the same mean time period; it is basically a measure of whether the two variables are redundant due to their relationship. As indicated in the last column of Table 3.5, only one questions is covariate, the first five factors in the table are not significantly (ns) covariate with the performance measures used in the previous sections for the controlled studies. The only viability question covariate with the performance measure is the “How motivated was your team?” question, and even accounting for the mean-time-to-completion performance measure, this viability factor is still significantly different between the groups ( $p=0.0338$ ). For this motivation measure, this result indicates that the viability question significantly distinguishes between the groups, but only when the mean-time-to-completion is also taken into account. For all of the other questions in the table, the viability data is not related linearly to the mean-time-to-completion, which can be interpreted as the groups can be distinguished using **just** the viability data. In other words, teams do not want to work together again only because they perform well together; or, teams do not want to work together again because they do not perform well together.

For the Monitor-Evaluator Experiment, a few of the questions are marginally significant, p-values in the .05 - .10 range, but all of these are covariant with the performance measure, mean-time-to-completion. With the weak p-values and the covariance, these results are not significant enough to present.

# Chapter 4

## Additional Analyses

This chapter presents a series of results that addresses specific goals of this research, lending support to, and extending, the general concepts addressed by the controlled experiments in the previous chapter. First, qualitative analyses are presented for the data that is used as part of quantitative analyses later in this chapter. Namely, Section 4.1 presents a qualitative analysis of the data from 1996 ACM Mid-Atlantic Regional Programming Competition. In Section 4.2, a second qualitative analysis is presented, as a partial validation of the controlled experiments, for data collected from a sophomore level programming class in which teams are used for programming projects. Next, since the agreement of the MBTI (Myers, 1980, 1987) and the Keirsey Temperament Sorter (Keirsey, 1984, 1987) is established in Section 2.2.3, this chapter presents a comparison of the data sets for this research to a previous study and to the general population. Finally, for the sake of completeness and for future comparisons, descriptive statistics are presented for the various sets of data collected using the Belbin Self-Perception Inventory (Belbin, 1981).

### 4.1 Programming Competition Data

This section provides a description of data collected from the 1996 ACM Mid-Atlantic Regional Programming Competition, a collegiate competition. This analysis concerns only Belbin data collected from the participants. Since the participants are asked to provide information with no recompense, it seemed that requesting additional data such as the Keirsey Temperament Sorter would reduce the number of participants willing to volunteer their time and effort. The following is a description of the programming competition followed by a subjective analysis showing noteworthy trends in the data and demonstrating a unique approach to analyzing software development teams.

The following is a description of the programming competition summarized from the ACM International Programming Competition page from the acm.org home page (ACM, 1997). For the programming competition, each team consists of up to three contestants, all are students carrying at least a half-time load and enrolled in a degree program at the sponsoring institution. At most one contestant of each team may hold a baccalaureate degree. No contestant may have completed two years of post-baccalaureate studies or hold a graduate degree. Contestants may bring resource materials such as books, manuals, and program listings. Contestants may not bring any machine-readable versions of software or data. The programming languages of the contest include Pascal, C, and C++. Each team uses a single workstation, all of which are reasonably equivalent. Solutions to problems that are submitted for judging are called runs. Each run is tested by a judge and accepted or rejected, and the team is notified of the results. Solutions to problems may be submitted as many times as it takes to complete the problem by getting a correct, accepted solution. Contestants cannot converse with anyone except members of their team and personnel designated by the regional contest director. The contest is scheduled for five hours and consists of at least six problems; for the contest analyzed for this study, there are eight problems. So far as possible, problems avoid dependence on detailed knowledge of a particular applications area or particular contest language. Teams are *ranked* according to the most problems solved and a completion “time.” Teams that solve the same number of problems are ranked by least *total time*. The total time is the sum of the time consumed for each problem solved, which is the time elapsed from the beginning of the contest to the submittal of the accepted run, plus a 20 minute penalty for every rejected run for that problem regardless of submittal time. There is no time consumed for a problem that is not solved, therefore problems that are never correctly solved do not penalize a team.

This is clearly an observational study. An observational study is an analysis of data that is collected where no control is imposed to form specific sets of circumstances for scientific observation; studies where circumstances are imposed are called controlled studies, as described in Chapter 3, which details a controlled study.

The teams in this study consist of the teams from the contest for which *all of the team members* provide Belbin data. Of the 93 teams in the contest, only 33 teams

provide complete data. The raw data for this analysis is provided in Appendix F. This analysis compares two *groups* of teams:

1. Group 1 teams are defined as the teams that finish five to eight problems, ranking in the top eighteen (1-18<sup>th</sup>) teams;
2. Group 2 teams are defined as the teams that finish one or fewer problems, ranking at the bottom of all of the teams, 68<sup>th</sup> to 93<sup>rd</sup>.

There are seven teams in Group 1 and nine teams in Group 2. This method of comparison is used to point out the differences between dramatically differently performing teams because it is very difficult to distinguish less dramatic differences between too similar groups. In other words, it is easier to identify distinguishing features of groups of teams that are grossly different.

The major qualitative differences that distinguish features of the groups include:

1. In terms of having a complement of roles, the average number of unfilled roles differs between the groups. Group 1 averages fewer than two unfilled roles whereas Group 2 averages approximately 3.5.
2. Group 1 only has one probable leadership conflict, as described for Experiment 1 in Chapter 3, whereas **all** of the teams in Group 2 has probable leadership conflicts or no leader.
3. All of the teams in Group 1 have at least one Company Worker, whereas only 44% of the teams in Group 2 have any Company Workers.
4. 71% of the teams in Group 1 have a Resource Investigator, whereas only 22% of the teams in Group 2 have one.
5. 71% of the teams in Group 1 have a Team Worker, whereas only 33% of the teams in Group 2 contain a Team Worker.

Percentages for the other roles are too similar to be noteworthy. To reiterate information in Chapter 3, Company Workers are individuals whose primary function is “turning concepts and plans into practical working procedures;” they focus on “carrying out agreed (upon) plans systematically and efficiently” (Belbin, 1981). Resource Investigators are members who have a tremendous “capacity for contacting people and exploring anything new.” Team Workers are members who facilitate or negotiate within the team; they make sure that team members all get along and are provided the opportunity to accomplish their functions.

Most of these five results are not astonishing, if one examines the data using Belbin's view of team roles. Although no direct experimentation of the role complement has been performed as part of this research, Belbin's work speaks strongly of its importance, which is indicated by the first result. The second result is also not surprising based on the results of the first of the controlled experiments on team leadership in Chapter 3. The significance of the Company Worker is also an obvious result; having members who implement agreed-upon plans is essential, so that having members who focus on this aspect would obviously improve a team. The fourth result is striking because one would not think that having members who have "a strong capacity for contacting people" (Belbin, 1981) would have such a significant effect on team performance for teams such as these in a fairly closed environment like this contest. Finally, the significance of the Team Worker should not be under-emphasized. Members who enable a team to function as a team, as opposed to a group of individuals, clearly create a synergy that strengthens the team.

## **4.2 Student Data - OOP Spring 1997**

This section presents a partial validation of the results from Chapter 3 by applying the Belbin role concepts to a sophomore-level college programming class. The class is Object Oriented Software Design and Construction at Virginia Tech, and the students reflect a broad range of abilities and general interests but have by this point in their academic careers committed to being software developers. The students are asked to provide data by filling out a Keirseey Temperament Sort and a Belbin Self-Perception Inventory.

For this OOP class, the students typically are allowed to choose their own teammates, and the professor acquiesced to letting students who *do not desire to participate in this study* to select their own teams. Other students are willing to participate but do not provide data by filling out a Belbin Self-Perception Inventory. Therefore, the teams are divided into three groups for the analyses:

1. Teams formed by the experimenter to be roughly equivalent in terms of the Belbin roles;

2. Teams formed by the experimenter randomly because the members did not provide Belbin data;
3. Teams formed by the team members themselves with no knowledge of the Belbin roles.

The project for this analysis is the second project for the class; therefore, all the members had some experience working with others on a programming project. Unfortunately, most of the teams in Group 3, who formed their own teams, formed the teams using knowledge about who worked well together gained from the first project. One might expect the teams in Group 3 to perform better than the other two groups because the team members are more familiar with one another. This concern is addressed in Section 4.2.2.

There are several different analyses presented for this data. First, an ANOVA result shows that the teams from Groups 1 and 2 have significantly different means for their grades for the project. Next, another ANOVA result presents a distinction between the groups based on how many Completer-Finishers are on a team. Finally, some qualitative results are presented similar to the type of results in the previous section. Additional correlation analysis of this data is presented in Section 2.4 because it provides information concerning the relationships between the Keirsey Sorter and the Belbin Inventory. This data is also included as part of the analyses in Sections 4.3.2 and 4.4, which presents distribution data descriptions for several data sets for Keirsey/MBTI data and Belbin data, respectively. The data for these teams is provided in Appendix G.

#### **4.2.1 Improvement of Project Grades**

As noted above, there is a difference in performance of the groups in terms of the means of the project grades for the groups. To begin with, there is a concern about the teams in Group 3 having an unfair advantage because the members may have worked together on the first project for the class. To test whether the groups are equivalent in terms of their project grade, an ANOVA is used to compare the groups, with the Null and Alternate Hypotheses of:

H<sub>0</sub>: Teams that have worked together previously for these class projects perform equivalent to teams set up using Belbin roles and teams set up randomly.

H<sub>1</sub>: Teams that have worked together previously for these class projects **do not** perform equivalent to teams set up using Belbin roles and teams set up randomly.

An ANOVA using Proc GLM<sup>5</sup> in SAS (Littell et al., 1991) shows that the three groups, which are described at the beginning of this section, are **not** statistically different by F-test ( $p=0.1182$ ); therefore, the Null Hypothesis is not rejected. This indicates that the groups perform the same statistically, i.e. the groups cannot be distinguished by their means. The means are 96.657 for Group 1 (the Belbin teams), 91.164 for Group 2 (the random teams), and 94.623 for Group 3 (the self-selected teams) with standard deviations of 3.34, 5.31, and 5.64 respectively.

Since the teams in Group 3 are self-selected, an “a priori contrast” of the other two groups was thought to be meaningful, and therefore this next analysis compares just Group 1 and Group 2, which are the groups of teams formed using Belbin roles and the random teams, respectively. The Null and Alternate Hypotheses to compare these groups are:

H<sub>0</sub>: Teams formed by the experimenter using knowledge of the Belbin roles perform equivalent to teams set up randomly.

H<sub>1</sub>: Teams formed by the experimenter using knowledge of the Belbin roles **do not** perform equivalent to teams set up randomly.

The means are the same as above: 96.657 for Group 1 and 91.164 for Group 2. The p-value for the F-test in the ANOVA is 0.0264, and the Null Hypothesis is rejected, signifying that the means of the two groups are *different*. Since the mean of the Belbin groups is higher, one can conclude that teams formed using knowledge of the Belbin roles perform better than teams formed randomly.

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<sup>5</sup> GLM means General Linear Model, which is a standard statistical procedure.

#### 4.2.2 Effect of Completer-Finisher

Another question of interest concerns the ability to distinguish between the groups based on the presence of the various Belbin roles. For example, do teams perform better if there are Completer-Finishers on the team? For this analysis, new **groups** are defined based on the number of Completer-Finishers on a team. The 26 teams for this analysis come from the ones for which there is complete Belbin data. Again, this analysis is from observational data. Therefore, the groups are not set up in a controlled way, and this analysis simply explains existing characteristics of the groups and the teams within them. To test the Completer-Finisher question, the Null and Alternate Hypotheses are:

- H<sub>0</sub>: Teams containing members who indicate the Completer-Finisher role perform equivalent to team with no Completer-Finishers.
- H<sub>1</sub>: Teams containing members who indicate the Completer-Finisher role **do not** perform equivalent to teams with no Completer-Finishers.

Since the study is observational, the teams are not evenly distributed between the groups, nor are *all* of the “cases” of groups realized. Specifically, there is no group that contains members who are all Completer-Finishers. There are three groups that contain zero, one, and two members who are Completer-Finishers. To avoid confusion, they are referred to as Group 0, Group 1, and Group 2, respectively. An ANOVA using a Proc GLM<sup>6</sup> in SAS (Littell et al., 1991) shows that the groups are statistically different by F-test ( $p=0.0441$ ); the means for the groups are 84.0, 92.941, and 93.333, respectively. A Duncan’s New Multiple Range Test (Ott, 1993) is used to determine which means are actually different among the three. The test shows that the means of Groups 1 and 2 are not statistically different, but the mean of Group 0 is significantly different from both Group 1 and 2. Therefore, one can conclude in favor of the Alternate Hypothesis, H<sub>1</sub>: the teams that contain Completer-Finishers perform better than teams that do not.

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<sup>6</sup> GLM means General Linear Model, which is a standard statistical procedure.

### 4.2.3 Qualitative Analyses of OOP Class Data

This section provides a qualitative analysis of the data from the OOP class, similar to the analysis in Section 4.1 on the programming competition data. For this analysis, 26 teams are used because those teams provide sufficient data for this analysis. Unlike the groups used in the two previous analyses, the teams are rank ordered by project grades, with the best grades at the top and the worst grades at the bottom. When all of the teams are used in a comparison, with 13 in the top half and 13 in the bottom half, the following observations are made:

1. Leadership is better in the top half than in the bottom half. In the top half, ten teams have single, strong leaders, whereas in the lower half, only six teams have single, strong leaders, and one team in the lower half has **all** strong leaders.
2. There are more strong Monitor-Evaluators, with a score greater than 14, on teams in the lower half. The top teams include only two, and the bottom teams include six.
3. When examining all of the roles, the top contains a greater number of very strong roles, with a score greater than 20. The top teams include nine, and the bottom teams include four.

The first result supports the findings from the first controlled experiment: leadership is very important to team success. Although this analysis does not have statistical support, the indications are clear that this result supports the controlled experiments. The second result also follows another of the controlled experiments: the utility of the Monitor-Evaluator on software development teams is questionable. This is counter-intuitive; it would seem that having a member who focuses on analyzing possibilities and evaluating decisions would be important, but this result indicates, as the third controlled experiment in Chapter 3 implies, that Monitor-Evaluators may not be desirable team members. This clearly requires further study. The third result, while interesting for its purely numerary value, is not directly usable. Does it indicate that individuals who score very high on one or more of the role indicators has a particularly strong or clear predilection for their roles? This is not clear.

As described in Section 4.1, it is easier to see distinguishing features of groups of teams that are grossly different. So, when the top seven teams are compared to the bottom seven teams, the following are observed:

1. When examining the leadership roles, six of the seven teams have a strong leader, with a score greater than 14; whereas in the bottom seven teams, only two of the seven teams have a strong leader.
2. When examining the Monitor-Evaluator, only one of the seven teams has a strong Monitor-Evaluator, with a score greater than 14; whereas in the bottom seven teams, six of the seven have strong Monitor-Evaluators.

Both of these are stronger numerically than the previous results and declare stronger differences between the groups. The conclusions one can draw from these two observations are the same as the previous conclusions: leadership is important and Monitor-Evaluators probably do not make a positive overall contribution to their teams.

### **4.3 Keirsey Type Distributions**

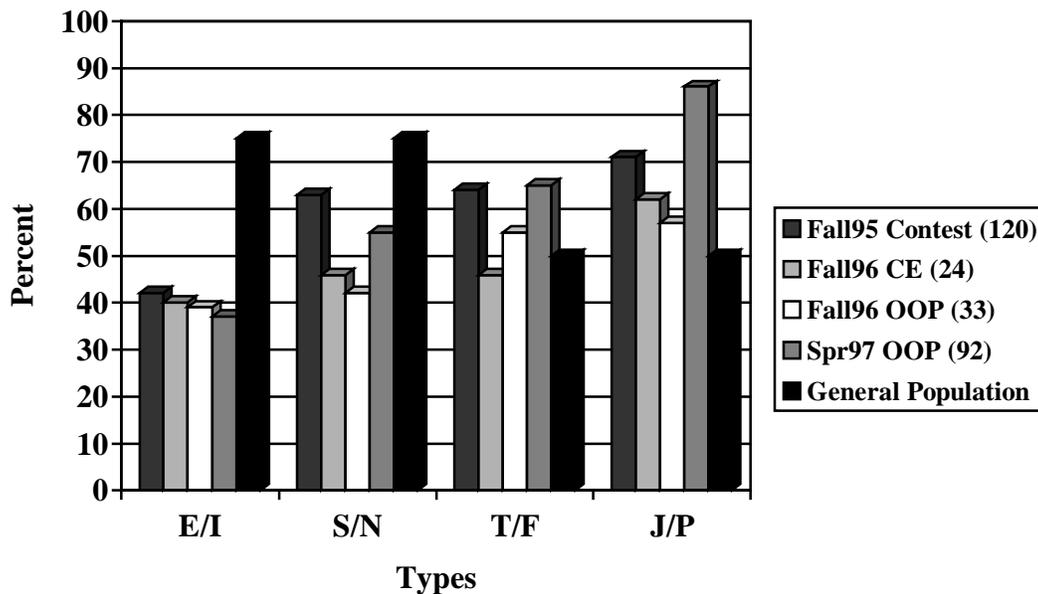
Because the agreement between the Keirsey Temperament Sorter (Keirsey, 1984, 1987) and the MBTI (Myers, 1980, 1987) is established in Section 2.2.3, it is reasonable to compare previous data sets that use the MBTI and the data sets gathered as part of this research that use the Keirsey Sorter. Because the tests that are used for the data sets are different, some variability should be expected and can be accounted for by that difference.

Figure 4.1 shows the distributions of the four sets of data gathered as various parts of this research and the general population.

1. Fall95 Contest - data from the very first study for this research, done as a preliminary investigation to discern if there might be some relationship between personality information and team performance. The data is from the ACM Mid-Atlantic Regional Programming Competition in 1995.
2. Fall96 CE - data from the controlled studies of Chapter 3.

3. Fall96 OOP - data from a sophomore-level, object-oriented design, computer science class in the fall of 1996 at Virginia Tech that is described in Section 4.2.
4. Spr97 OOP - data from another section of the object-oriented class in the spring of 1997.

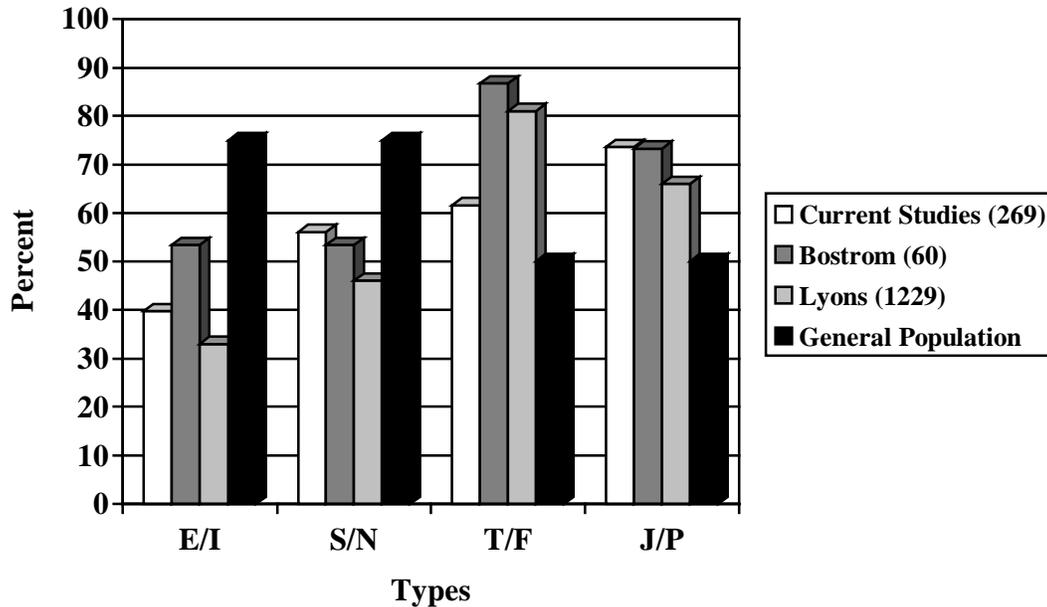
The general population data is provided by Keirse (Keirse, 1984). The legend for the graph includes a number in parentheses indicating the number of individuals in the data set, for example 120 for the “Fall95 Contest” data.



**Figure 4.1: Comparison of Type Distributions**

As Figure 4.1 clearly shows, there is a distinct difference between the data for this research and the general population for each of the four scales. For the Extrovert/Introvert scale, the general population contains more Extroverts (75%) than Introverts, whereas the data samples for this research all show a marked propensity toward Introvert. For the Sensing/Intuition scale, again the general population contains a great majority of Sensors (again, 75%), whereas the data for this research shows a significantly lower propensity. For the Thinking/Feeling scale, most of the data sets show a higher percentage of Thinkers than the general population. For the final scale, Judgement/Perception, the data sets show an obvious trend toward Judgers than the general population.

Figure 4.2 eliminates some of the confusion of Figure 4.1 by averaging the data for all of the sets of data gathered for the various studies of this research effort and comparing them to the general population and to two previous studies (Lyons, 1985;



**Figure 4.2: Summary Comparison of Type Distributions**

Bostrom and Kaiser, 1981). All four of the scales show a clear trend that differentiates the general population from the computer science data sets, including the data sets for this research and both of the previous studies. For the Extrovert/Introvert scale, the Bostrom and Kaiser data (Bostrom and Kaiser, 1981) shows a slight preference toward Extrovert, but both of the studies from the literature (Bostrom and Kaiser, 1981; Lyons, 1985) and the data for this research are appear significantly different than the general population, clearly indicating more of a preference towards Introversion. For both the Sensing/Intuition and Judgement/ Perception scales in Figure 4.2, the percentages are very similar for the current studies and the previous ones. The Thinking/Feeling scale is not quite as consistent among the studies, but clearly demonstrates a significant difference between the general population and the computer science population.

Note that for these first three scales in Figure 4.2, the data for this research lies between the general population and the Lyons data. This might be explained by the fact

that the Lyons data comes from large business-oriented firms, which do not have personality profiles the same as, for example, aerospace or engineering programmers. The data for this research comes from a more general computer science population; in fact, since the participants are students, it is not known what sorts of computer science sub-fields these individuals will eventually pursue. This concept of sub-fields, which demonstrate different profiles for the four scales, is a direct extension of the basic ideas that Myers and McCaulley present (Myers and McCaulley, 1985).

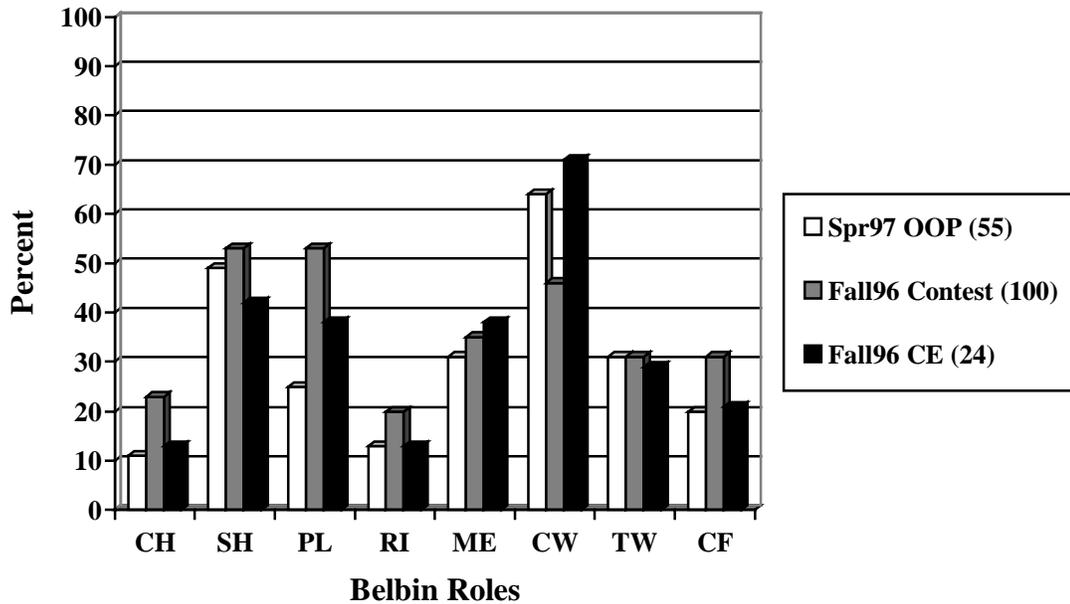
Further pertinent information is derived from the object-oriented design class from the spring of 1997 (Spr97 OOP in Figure 4.1). The means of the Keirsey types of the data sample are Extrovert/Introvert 4.43, Sensing/Intuition 10.73, Thinking/Feeling 11.64, and Judgement/Perception 12.86. See Section 2.2.1 for descriptions of these terms because they do not denote their standard definitions. These means indicate the same trends as Figure 4.1: computer science students have a tendency toward being Keirsey Introverts, Sensors, Thinkers, and Judgers.

#### **4.4 Belbin Statistics**

Since this is groundbreaking research, others might be interested in some basic statistical data description for the Belbin roles. Therefore, some data descriptions are provided for the Belbin data collected, along with some general observations that can be inferred from a fundamental analysis.

The means of the Belbin roles of the data sample from the object-oriented design class from the spring of 1997 (Spr97 OOP in Figure 4.1) are Chairman 6.93, Shaper 9.84, Plant 9.28, Resource Investigator 6.38, Monitor-Evaluator 8.51, Company Worker 11.67, Team Worker 8.51, Completer-Finisher 7.85. Note that if an individual could take the Belbin Self-Perception Inventory and make all of the roles equal, then all of the means would all be 8.75. Therefore, one can see that software programmers have a tendency toward **not** being Chairmen, Resource Investigators, and Completer-Finishers. They do have a tendency toward being Shapers, Plants, and Company Workers.

Figure 4.3 shows the distribution of each of the sets of data gathered for the various studies of this investigation. The “Spr97 OOP” data is again from the object-oriented design class in the Spring 1997, which is described in Section 4.2. The “Fall96 Contest” data is from the programming competition that is described in Section 4.1. The “Fall96 CE” data is from the controlled experiments that are extensively described in Chapter 4. For most of the Belbin roles, the data demonstrates consistency among the sets



**Figure 4.3: Belbin Distributions**

of data. There are very few Chairmen, Resource Investigators, and Completer-Finishers; a moderate percentage of Monitor-Evaluators; and a relatively high percentage of Plants, Shapers, and Company Workers.

More specifically, Figure 4.3 shows several interesting trends. The percentage of Chairmen in all of the data sets are rather low. The Shaper role also shows some consistency across the data sets. The Plant role is not as consistent; the Programming Contest data shows a higher percentage of Plants than the other two sets of data, which are data drawn from college classes. This could be due to the nature of the programming

contest. One would think that this type of competition would attract individuals who are good at problem solving, hence the increase in the percentage of Plants.

The Resource Investigator and Monitor-Evaluator percentages are also very similar across the data sets. The Company Worker role is not so consistent; the Contest data set has a lower percentage than the other two data sets. Again, this might easily be due to the nature of the programming contest; such a competition probably does not attract individuals who have a natural propensity toward “simply” implementing agreed upon solutions. The Team Worker role is very consistent across the data sets. The final role, Completer-Finisher, is fairly consistent across the data sets, but the Contest data has a slightly elevated percentage. This again could be explained by the nature of the competition; Completer-Finishers focus on the details of a project and on meeting completion deadlines. Competitions would seem to attract individuals who have such tendencies.

# Chapter 5

## Industry Analyses

This chapter presents analyses of data collected from software development teams from within the software development industry. The first section provides qualitative analyses of five teams. The second section provides a description of the distribution of the data for the Belbin roles, adding the data from the industry teams to the data description for the student data examined in Section 4.4.

### 5.1 Qualitative Analysis of Industry Teams

The following sections present analyses of software development teams in the private industry sector. The team sizes vary from three members up to nine members, demonstrating the utility of this type of information to various sizes of teams. The procedure used in these analyses consists of:

1. Finding teams that indicate a commitment to, or interest in, participating in an analysis of their team;
2. Having all team members fill out the Belbin Self-Perception Inventory (Belbin, 1983) in order to gather data for analysis;
3. Interviewing the leader of the team in order to obtain an independent analysis and verification of the Self-Perception data;
4. Analyzing the Self-Perception data, looking for trends in the data from which subjective assessments can be made;
5. Comparing the Belbin analysis with the interview information, identifying similarities and differences between the two, thus providing verification of the Belbin analysis.

Part of the analysis uses six problem areas that Belbin identifies (Belbin, 1981):

1. Setting Goals & Identifying Needs
2. Innovation & Finding Ideas
3. Decision Making & Formulating Plans
4. Getting Along with Each Other & Making Contacts

5. Turning Plans into Reality & Establishing Organization
6. Following Through & Attention to Details

These problem areas can be used to assess how well the roles are being filled

The following subsections provide information on industry teams following this general structure: first, each team's Belbin data is analyzed; then, information gathered through an interview with a leader from each team is presented; finally, the significant observations from the Belbin analysis is compared to the interview information. The subject teams consist of:

1. A four-person team from a major industry leader in telecommunications;
2. A nine-person team from a small regional company focusing on software development;
3. A five-person team from a year long symposium on proper software development techniques that produces a viable product;
4. A four-person team from a large, international manufacturing company that does specialized software development for their products;
5. A three-person team from a medium-sized manufacturing company that does specialized software development for their products.

### **5.1.1 Telecommunication Team**

This section provides a qualitative analysis of a software development team working on a Hardware-Software Interface (HSI) program at a major telecommunications company. The end product is used only within the company; in other words, it is an internal product. Technically speaking, there are four individuals on the development team, although a fifth member, the manager of the team, used to be an integral part of the team and still attempts to be an active player on the team. This particular team uses scenarios to develop their product, which is written in Smalltalk. Currently, they are continuing to extend the design with major features. Member 5, the team's manager, was the sole initial designer and has a hardware background. As he developed the product, he needed additional manpower. So, Member 1, Member 2, and Member 3 were brought on board in the course of approximately a year because of their software development experience. Finally, Member 4 was added as a part-time consultant because he is a

specialist in a technical area that the team required, work development environments. Member 5 was then promoted into a project management position for the team. The following analysis addresses the team without Member 5 as a member, i.e. the current team, as well as how the removal of Member 5, an integral member, has affected the team.

#### ***5.1.1.1 Belbin Analysis of Telecommunication Team***

This section presents the Belbin data for the team and an analysis of the data. As shown in Table 5.1, the team contains an unusually strong indication of Plants, which, from the controlled experiments described previously in Chapter 4, is a very positive quality for a team to display. Unfortunately, the current team, excluding Member 5, does not indicate a very strong leader. Member 1 and Member 3 both show some leadership indication with their Shaper and Chairman roles, respectively. However, Member 1's results from the Belbin test indicate scores that are fairly evenly distributed, so that his Shaper designation is questionable. Member 3's Chairman designation is similarly tenuous but consists of a much stronger indication of the Team Worker role and secondary weaker roles of Chairman and Plant. Neither of these two members should be expected to take the leadership role, although, because Member 3 has been with the team almost as long as Member 5, she might step into this role. One final part of this analysis concerns whether the team covers all of the complement of Belbin roles. If one considers that Member 4 is only a part-time consultant, making it difficult or impossible for him to truly fill some of the needs of a Company Worker, there is a clear deficiency for that role in the current team.

**Table 5.1: Belbin Data for Telecommunications Team**

	CH	SH	PL	RI	ME	CW	TW	CF
Member 1	-	11	11	12	12	-	-	12
Member 2	-	-	18	-	-	-	13	20
Member 3	10	-	10	-	-	-	17	-
Member 4	-	-	16	-	13	18	-	-
Member 5	-	17	-	-	-	12	-	-

To summarize, the team should have excellent rapport and plenty of innovative ideas because all of the members are Plants. Because of the deficiency in the leadership roles and the Company Worker role, the team may have problems with leadership and with the practical, nuts-and-bolts development previously accomplished with the team, as long as Member 5 remains a less than active member. On the other hand, before Member 5 was promoted, these deficiencies should not have been a problem. The team with Member 5 as an active member shows the complement of Belbin roles filled. In this case, Member 5 is a rather strong Shaper type leader, yet also fills the Company Worker role. This at first seems an odd combination, but it does work well in this instance.

### ***5.1.1.2 Interview with Telecommunications Team***

In addition to the background information presented at the beginning of the section for this team, the following observational, subjective information is used to assess the team and validate the analysis of the Belbin data. This information has been extracted from an interview with Member 5. To begin with, Member 5 has always sought to fit the person to the job, allowing people to work on what they like or are most comfortable. In his words, he “fills in the gaps” on the team; he is a “utility player.” Member 2 shows attention to detail. Member 1’s skills are related strictly to software, which limits the scope of Member 1’s understanding since the product is a Hardware-Software Interface. Member 3 is an overall good “team person,” although very introverted, and he is very analytical, possibly indicating a Monitor-Evaluator. Member 1 is labeled by Member 5 as the “Code Leader.” All of the team members are “self-initiating.”

For each of these areas, Member 5 indicates that the team is “great,” with the exception of “Getting Along with Each Other & Making Contacts.” He says that “everyone on the team is very introverted (and) individual. They get along because they all tend not to need lots of personal contact, not much external (to the team) contact is needed or desired.” This indicates that the team has a potential deficiency with external contacts, but none are really necessary, so the team functions well for what is required of them. In terms of long term and short term goals, Member 5 indicates that the team, as a whole, meets all of its goals in a reasonable manner.

When asked to identify the major strengths and weaknesses of the team, Member 5 said

The team now lacks a utility player, someone who will do whatever needs to be done for the success of the project. Logistics are not well taken care of. Documentation is lacking. Human Factors is a problem. The demand for the product is growing faster than we can easily handle it. There’s talk of creating a class to teach how to use it. All of the team members are very introverted (and) individual. They get along because they all tend not to need lots of personal contact, not much external (to the team) contact is needed or desired.

From the interview, one can gather the following information: Member 5 is clearly the leader of the team, to some degree, even after being promoted “out” of the team. Member 3, partly because she has been with the team second longest, takes leadership of the group in some instances. Member 1 has some leadership in the team because he is the “Code Leader.”

### ***5.1.1.3 Comparison: Telecommunication Team***

Two key parts of the analysis correspond directly to the controlled experiments. First, Member 5 is clearly the single, accepted leader of the team, with a strong Shaper role indicated. Member 1 would clearly subordinate himself, due to his lack of experience (on the project compared to Member 5), but with Member 5’s promotion, he does naturally fill, at least partially, the leadership role. Member 3, being a weak Chairman and a very strong Team Worker, might work *with* Member 1 as a complimentary Chairman to Member 1’s rather weak Shaper.

The second part of the analysis concerns the fact that the current team, with Member 5 as a manager, consists of all Plants. The conclusion of the second controlled experiment on innovation directly applies. Teams with a strong set of Plants perform well. This is certainly true for this team. The team appears to function quite well from all indications during the interview, in both the performance as well as the viability of the team.

The primary deficiency that Member 5 identifies in the team is a lack of a “utility player,” which he filled when he was an active member of the team. He is now in a project management position, so there is a clear void in the Company Worker role that addresses the assiduity of the practical coding effort, implementing agreed upon details in order for the team to be successful.

The significant observations from the interview agree with the analysis of the Belbin data. The team composition of all Plants, a strong leader, and complement of roles when Member 5 was with the team, making a very strong team. Member 5 indicates that the team is still “great” even without his membership, but he recognizes its deficiencies without him. Overall the team performs “great,” which is also indicated by the Belbin analysis. The Company Worker deficiency will probably become more of a problem as development continues and Member 5’s membership is further removed. As with many promotions out of a team, Member 5 can still provide some effort to the team. Undoubtedly, he still spends some time supporting the project, however, as the development progresses, his knowledge will become obsolete, making it more difficult for him to contribute. This is when the Company Worker deficiency will become much more apparent.

### **5.1.2 Regional Team**

This second industry team is a larger team developing a very ambitious document management application. The company for which the team works is a small company employing on the order of thirty employees. The team itself consists of nine members. The project was initiated with two software developers, Member 1 and Member 2, who now function as the Project Manager and Technical Lead, sometimes sharing both roles.

These two developers produced a prototype two years ago, which, of course, became the first release of the product. Six months after this release, two additional developers were added to the project. With a clear understanding and a strict adherence to the precepts laid out in the *Mythical Man Month* (Brooks, 1995), as a release date became close, two more developers were added to the project to meet scheduling deadlines; the deadlines were utterly missed. After a several more months, even more developers were brought onto the project in order to meet a more realistic schedule that had features prioritized. This brought the team to a total of nine developers. The product did indeed meet the subsequent deadline, and the current state of the project is stable, as the team focuses on adding features and fixing bugs. The team members express a general satisfaction with their work, their product, and their employer.

#### ***5.1.2.1 Belbin Analysis of Regional Team***

As one can see in Table 5.2, this team contains a tremendous strength in the Plant role. From the results of the second controlled experiment, this indicates a richness of ideas and should encourage a successful team. Fortunately, this team does not lack the Company Worker role, as the first industry team does. The team has fair coverage of the Belbin role complement, except for the Completer-Finisher role. This could lead the team to having trouble meeting deadlines and not paying enough attention to detail, the key features of the Completer-Finisher role. Further, there could be leadership conflicts on the team because three members indicate Shaper roles and one a Chairman role. One final consideration for this team is the low number of Monitor-Evaluators, which from all previous indications is not generally a positive role to have present on a team.

**Table 5.2 Belbin Data for Regional Team**

	CH	SH	PL	RI	ME	CW	TW	CF
Member 1	-	15	18	-	15	-	-	-
Member 2	-	10	14	10	-	-	-	-
Member 3	-	-	-	-	-	24	11	-
Member 4	14	-	-	-	-	13	11	-
Member 5	-	-	16	-	-	13	-	-
Member 6	-	-	10	-	12	15	-	-
Member 7	-	15	23	13	-	-	-	-
Member 8	-	-	19	-	-	13	-	-
Member 9	-	-	13	12	-	-	17	-

### ***5.1.2.2 Interview with Regional Team***

From an interview with the team leaders, the following information is extracted. The division of the software development features is fairly strongly enforced; in other words, this is not a large project with everyone working on all of the various features. This has a side-effect that teamwork among the members is not terribly significant; there does not *need* to be much interaction among the members. Such interaction, while not necessary, would be somewhat helpful to the team and certainly not deleterious. The primary manner in which new ideas, i.e. innovation, is expressed in the team is through the two leaders “batting around ideas.” The other primary member who is given freedom to design on his own is Member 7. Member 7, while given design freedom, is viewed as a source of problems because he does not take direction very well. Members 3, 5, 6, and 8 are described in terms such as “firefighter,” “move around filling the gaps,” and “workflow/debugging” types of workers. The leaders give a general impression that they enjoy the team but are waiting for it to “gel,” a term coined by DeMarco (DeMarco, 1982). For Belbin’s six “problem area” scales (Belbin, 1981), the leaders rate the team with sevens and eights on a ten-point scale for all of the areas, indicating that they feel the team is good but has a definite need for improvement in most areas, a need that they fully expect to be fulfilled. The best feature of the team that the leaders identify is the brainstorming and innovation of the team. The major deficiency is the interface to

external (to the team) people and lack of organization, and they “are working hard on” their organizational skills.

### ***5.1.2.3 Comparison: Regional Team***

To begin with, the major problems identified by the leaders involve Resource Investigators and Chairman leadership. Both of these roles exist within the team but are subordinated and, clearly, not put into significant use. The member who is in fact a Belbin Chairman demonstrates three important factors that affect his role(s) on the team: very new to the team, clearly not one of the leaders, and is not a native-English speaker. These factors exclude this individual from taking a leadership role within this team, which denies the team the benefits of his natural organizational skills. There are also three potential Resource Investigators, any of whom could address the external interface problems but do not. This can be explained by the fact that the team members’ functions are strongly associated with the code on which they work. There is no significant identification of abilities other than software development skills and experience. Therefore, even though there are two members with significant Resource Investigator indications, the only members who interact with people outside of the team are the leaders, one of whom does show a weak indication of the Resource Investigator role. The two other members who indicate the Resource Investigator would probably function better in this capacity.

Another point of interest with respect to the analysis of the Belbin roles and the interview concerns the leadership of the team. If the members who have been with the project since its inception were not the same as the members who indicate significant Shaper roles, then there would be more of a leadership conflict. The one member who the leaders described as being a problem is Member 7, who incidentally indicates a strong Shaper. The other aspect of the leadership of this team is that the two leaders brainstorm many of the decisions of the team, with additional input from team members who the leaders think are particularly relevant for the discussion. The fact that one of the leaders is a Monitor-Evaluator might be positive in this instance, although previous indications are that Monitor-Evaluators tend to be a negative influence on a team. In the case of

decisions that come out of brainstorming sessions, this leader's Monitor-Evaluator aspect probably proves a useful feature.

The team members who indicate the Company Worker role are also identified by the leaders using terms one would generally associate with members who focus on implementing agreed upon decisions: "firefighter," "move around filling the gaps," and "workflow and debugging." Because the team contains several Company Workers, there are no major problems in turning plans into reality. However, there are problems due to a lack of an attention-to-detail and a drive-to-completion. These are two aspects of the Completer-Finisher role, which is absent from the team profile.

In summary, the team has some significant problems, which they themselves identify, but appear unclear as to how to resolve. Other aspects of the team are quite strong, especially innovation because of the plethora of Plants. These two factors appear to balance slightly on the positive side, as indicated by the leaders ratings for Belbin's problem areas.

### **5.1.3 Symposium Team**

This team consists of members of a "Design Studio" symposium that is part of a Software Engineering Master's degree. The following description is a summary of a description of the symposium (Henry, 1997). The Design Studio is a three-semester "course," provided free of charge, in which those students pursuing their Master's degrees in Software Engineering get to be part of a software development team. As members of this team, students apply what they have learned in their pre-requisite courses (Software Systems Engineering, Software Design, and Software Project Management) to a real-world project.

One academic year, 1995-96, the Design Studio teams developed a Windows<sup>TM</sup>-based project management tool that integrates Albrecht's Function Point Analysis with Barry Boehm's COCOMO model. The team worked long and hard to produce a quality product in a relatively short period of time. The team produced approximately 8,000 lines of C++ code, complete design documentation, test plans, user documentation, installation guides and programs, and a comprehensive help facility.

### 5.1.3.1 Belbin Analysis of Symposium Team

As Table 5.3 shows, this team shows a coverage of the complement of Belbin roles, which is certainly a very good indication. Unfortunately, there is not a strong Plant influence on the team; there is only one very strong Plant and another member whose third role is a weak Plant. Fortunately, the team also does not include any significant Monitor-Evaluators, with the **only** member indicating the role being the leader, which might be a positive feature as described in the previous section. Also on the negative side is the virtual lack of Completer-Finishers. The only member indicating this role has it as a third role, and it is extremely weak, making it even more questionable. One final problem with this team is with the leadership: three of the five members indicate the Shaper role. This is potentially a serious problem.

**Table 5.3 Belbin Data for Symposium Team**

	CH	SH	PL	RI	ME	CW	TW	CF
Member 1	-	18	-	-	11	-	12	-
Member 2	-	14	-	-	-	13	-	10
Member 3	-	-	11	12	-	14	-	-
Member 4	10	16	-	-	-	-	9	-
Member 5		-	20	-	-	-	14	-

The low amount of Plant talent on the team raises the question of the importance of innovation on teams that are not working in innovative areas such as research or new technologies, as are the case for the first two industry teams. In areas of software development where maintenance or non-innovative development is being addressed, is there a significant need for a team to include innovative members? This issue is even more apparent in the two following sections that present teams that are working in well-defined areas that are adding features to products or re-engineering extant products to new applications. In a sense, these teams need innovation in terms of coming up with solutions to problems, but it seems obvious that innovative individuals would not be drawn toward, or even interested in, working in this type of “innovative” arena.

### *5.1.3.2 Interview with Symposium Team*

The following information is from an interview of the team leader, who indicates that he is more of a project manager and that the technical lead fell on Member 5, who has more experience than the other members. The division of labor that Member 5 devised is seen as a major positive aspect by the project manager. Member 5 is responsible for presenting designs and various ideas that could be incorporated into the product; Members 3, 4, and 5 make decisions as a (sub-)team. Member 2 is relegated to a very distinct and separate part of the project: documentation and the help facilities. Member 3 is defined as the COCOMO expert, Member 4 as the Function Point expert, and Member 5 as the overall technical leader.

In terms of meeting long- and short-term goals, the project manager indicates that the team is very good with short-term goals, but the members lack the practical experience to maintain a focus on long-term goals. The team members do not have enough experience to realize that certain decisions might be costly in the short term, in terms of time or effort, but the long-term benefits can far outweigh the short term costs. In terms of the six Problem Areas identified by Belbin (Belbin, 1983), the team performs well for most of them, but for the “Getting Along with Each Other & Making Contacts” area, the team performs poorly.

The major deficiency of the team that is identified by the project manager is in the testing of the software, but “Member 3 and Member 4 took up the slack on this,” so that it is not a major problem. The major positive aspect of the team is the “great design decisions” and the process that allowed these decisions to be adopted. The entire design process is well documented, an uncommon feature in software development. Since “multiple ideas (are) written up and decided upon,” this leaves significant documentation and a paper trail of the usually-forgotten answers to why decisions are made. This is indeed a major coup because such concurrent documentation is always espoused by software engineers as necessary but is rarely accomplished.

### ***5.1.3.3 Comparison: Symposium Team***

In comparing the Belbin information to the interview, several aspects show agreement. To begin with, this team “solves” the leadership issue in an interesting manner; the team is basically subdivided so that there is not a conflict for leadership. Member 1 is not really a direct, active member of the team, removing him/her from contention; Member 2 is directed to work almost completely on his/her own, also removing him/her; and this leaves Member 4 as the real leader of the core of the team, which consists of Member 3, Member 4, and Member 5. Further, these three members possess near coverage of the Belbin team complement, also strengthening the team. Another interesting point, if one looks at this “core” team of three members is that two of the three members are Plants, which provides the team with the positive aspect of innovativeness. This team is not doing research; it is not developing new, innovative software; but it does need innovation to address the complex issues that a major development endeavor inherently possesses. Therefore, having two Plant members, one of whom is very strong, is probably sufficient for this level of need for innovation.

The major deficiency is in the testing area, which could be interpreted as a lack of completeness or attention to detail, which can be explained by the dearth of Completer-Finishers on the team. The other deficiency that the project manager identifies is with long-term goals. One explanation of this is that the team lacks the Chairman role who can take a more global view of the project.

One positive aspect of this team, the design decision aspect, is a great boon, but it is difficult to explain with the Belbin data. That the team has a near complement of the roles can explain some of this positive aspect. The fact that the core members have fairly distinct roles in which they are strong also probably has a beneficial effect on the team. This is such a positive aspect of this team that it is no wonder that on the six Belbin Problem Area scales (Belbin, 1981), the team scores high on most of them. The one area where they have problems is with “Making Contacts,” and this deficiency may be easily explained by the fact that only one member has even a mediocre indication for the Resource Investigator role. The focus for this role is to make contacts outside of the team, which for some teams can be very important. External contacts are not particularly

important to this team, so this is not a major problem; it is simply viewed as a minor deficiency that should be addressed.

#### **5.1.4 Large Manufacturing Team**

This section details a software development team from a large, international manufacturing company that does specialized software development for their products, which are gasoline pumps and the associated cash registers. Projects for this company are on a six to twelve month cycle. Other companies contract with this company to produce a set of products with certain specifications that are generally similar to existing products with, typically, minor additions and modifications, but the entire system must be tailored to each customer's needs. Most of the projects for the company are written in Pascal and C; this particular project is approximately 80% Pascal and 20% C. Teams for this company are formed by the team leaders based on who is available, the members' specializations or abilities, and with whom the leader feels "comfortable." The team leaders serve as technical leaders as well as project managers.

The Belbin data in Table 5.4 is provided by the team members shortly before the end of the project, and the interview information is collected a few weeks after the end of the project. Therefore, because the project is completed, the team leader can reflect on the entire life-cycle of the project and **all** of the important events during the project. Additionally, not much time has passed since the completion of the project. Thus, the team leader should not have forgotten the specifics of how the team performs, and the data should be fairly accurate. The timing seems particularly apt for this analysis.

##### ***5.1.4.1 Belbin Analysis of Large Manufacturing Team***

As one can see in Table 5.4, this team has some good features as well as several bad features in terms of the Belbin roles. One good feature is that there is only one strong leader on the team. Only one strong leader on the team is a positive factor, as indicated by the first controlled experiment. Most of the members also indicate the Company Worker role, which appears to be an especially important role for non-innovative teams. The team also includes two rather strong Team Workers. For fast-paced teams, strong Team Workers on a team can relieve, or even prevent, internal strife

and keep the team from wasting time and effort on such problems. This type of efficacy seems particularly important with a short, six to twelve month life-cycle. The final positive aspect might be the coverage of all but two of the Belbin roles, nearly a complement of the Belbin roles. All of the roles except Plant and Completer-Finisher are indicated by members of the team.

**Table 5.4 Belbin Data for Large Manufacturing Team**

	CH	SH	PL	RI	ME	CW	TW	CF
Member 1	-	-	-	-	13	15	15	-
Member 2	10	24	-	-	-	11	-	-
Member 3	-	-	-	-	14	-	16	-
Member 4	-	-	-	13	-	12	-	-

On the negative side, the team contains **no** Plants. This lack of innovative members seems to be a very serious flaw for any team. Further, there are no Completer-Finishers on the team, another serious problem. The major deficiency for this team concerns the leadership role. Although there is only one **very strong** leader on the team, that member is not the “leader” of the team, and the member who is indeed the leader shows no predilection to the leadership roles. This *must* be explained by experience or other factors that override such a strong discrepancy. Finally, there is once again the potential problem of Monitor-Evaluators on the team. Two team members indicate the role, and several of the previous analyses imply that the role can be detrimental to the team, although there is no direct quantitative evidence yet.

#### ***5.1.4.2 Interview with Large Manufacturing Team***

The interview of the individual who is identified as the technical leader and the project manager provides the following information for analysis. Member 1 is the leader of the team that he himself has formed. Members 1 and 2 work together in doing most of the development. Member 4 works on the verification processes and the host simulator, which is a completely independent piece of code. He/she must interface with the customer a great deal for this because it simulates the expected use of the product. Member 3 is the integrator and tester for the team. In terms of team cohesion,

coordination, and trust, the team is rated fairly high by the leader. The one problem area is with meeting established goals; meeting of short term goals is rated fairly high, but the team has some problems maintaining a focus for long term goals. In terms of the six areas defined by Belbin, again, most of them receive a fairly high score by the leader, but two that are deficient are “Innovation and Finding Ideas” and “Organization.” The best feature of the team that is identified by the leader is “the cohesiveness; he (the leader) knows the people and their capabilities” very well. The worst aspect of the team is the lack of “attention to detail, organization, and priorities.”

#### ***5.1.4.3 Comparison: Large Manufacturing Team***

It is interesting that the leader of a team would identify part of his/her function as the primary failing of the team: organization and priorities. Fortunately, it appears that because the leader has significant experience, the lack of organization and of clearly defined priorities is not a *fatal* problem. Further, the leader identifies meeting long term goals as a major problem, also indicating a leadership problem. This all clearly indicates that this “leader” does not function well in this “role,” which agrees with this person’s Belbin roles. One would assume that once Member 2 gains some experience, he/she will take on leadership roles with this company, since she/he indicates such strong potential for leadership with the Belbin roles.

A second role that is clearly deficient in both the Belbin analysis and the interview is the Completer-Finisher. The team has problems with “attention to detail,” which is one of the Completer-Finisher’s main functions. This also can account for some of the problems in meeting long term goals.

A third role that is obviously absent from this team is the Plant. The leader identifies this as a problem when assessing the innovativeness of the team. Although this is a deficiency of the team, one wonders how much of a deficiency this truly is for **this** team, as opposed to other teams that are involved in intensely innovative development. Software development teams that are performing research must include innovative individuals in order to develop new technology, but teams such as this one might perform better if members use innovative methods to solve problems, in general.

### 5.1.5 Medium Manufacturing Team

Information for this team is extremely limited because the only member in contact with the researchers is very circumspect with proprietary information to anyone outside of the company, although she/he has been very helpful. This product is a large, Windows™ 3.1 application that provides an interface to control industrial machinery. This team, similar to the team in Section 5.5.4, develops specialized software for machinery that is the main product of the company. Although the entire company itself is medium-sized, the software development portion of the company is extremely small, consisting of a few small teams. This particular software project is *very* mature, although these developers have been together for only eighteen months. The project is predominantly in the maintenance phase of its life; occasionally, minor features are added, but the vast majority of effort is put into maintaining the code. These three developers have all worked together on previous projects but all three of them have not been on a team together until this team.

#### 5.1.5.1 Belbin Analysis of Medium Manufacturing Team

As Table 5.5 shows, this team, like the previous team, is deficient in a role that seems crucial to software development: Plants. Another role in which this team is deficient is the Monitor Evaluator, which might not be a deficiency, as indicated previously in this chapter. It is quite interesting that the team is extremely strong in both the Company Worker and the Team Worker roles. Both of these strengths should be a huge benefit to the team, particularly the Company Worker role for this maintenance-intensive project. This is important because, whereas innovation might not be needed, members who are willing to implement agreed-upon ideas is extremely important.

**Table 5.5 Belbin Data for Medium Manufacturing Team**

	CH	SH	PL	RI	ME	CW	TW	CF
Member 1	10	-	-	12	-	12	13	-
Member 2	-	12	-	-	-	17	12	-
Member 3	-	-	-	-	-	11	12	12

There is also a positive lack of conflict for the leadership roles. The member who provides information for the team during the interview phase of this analysis is a rather weak Chairman; another member indicates a moderate strength Shaper role. These two roles can, in some instances, complement one another in leading a team. Therefore, the only major deficiency on the team is in the Plant role.

#### ***5.1.5.2 Interview with Medium Manufacturing Team***

Again, the information for this team is very limited. The original designers are no longer with the company, and the product is generally in a maintenance phase. The member with whom the interview is conducted states that there is no leader on the team, and incidentally that the president of the company used to be a programmer, implying that he or she somehow influences the team, either directly or by reputation. These three members are still on this team because they have the most general experience and because of their individual areas of expertise, which is not explained by the interviewee. One of the most significant aspects of the team is the utter lack of innovation on the team; this information is noted by the interviewer immediately after the short description of the product.

The evaluation of the team by this individual is mixed. In terms of the goal keeping and other indicators such as cohesion, coordination, etc., the team rates very high except for long term goals. For short term goals, the team rates very high; for long term goals, the team rates very low. This is interesting because the responses for goal keeping for this team and the previous one, which is also in a maintenance phase, are similar. A mere two instances does not truly demonstrate a trend, but the relationship between long term goals and the life cycle phase might be worthy of further investigation.

The evaluation for the six areas that Belbin identifies as potential Problem Areas (Belbin, 1983) presents a different indication. For two of the areas, “Getting Along with Each Other & Making Contacts” and “Following Through & Attention to Details,” the team is rated very high. For two others, “Setting Goals & Identifying Needs” and “Decision Making & Formulating Plans,” the team rates moderately. Finally, for the last two areas, “Innovation & Finding Ideas” and “Turning Plans into Reality & Establishing

Organization,” the team rates moderately poor. This variety of ratings is confusing because it is so different from the indications for the other measure in the previous paragraph. It begs the question, “How can a team have excellent viability, cohesion, coordination, team vision, etc. but rate moderately poorly on these areas that Belbin identifies?” The answer to this demands further investigation.

For the major strengths and weaknesses of the team, the interviewee indicates that the strength of the team comes from its “small size. All of (them) are very respectful of others, and (they) are all Christians.” The major weaknesses are identified as

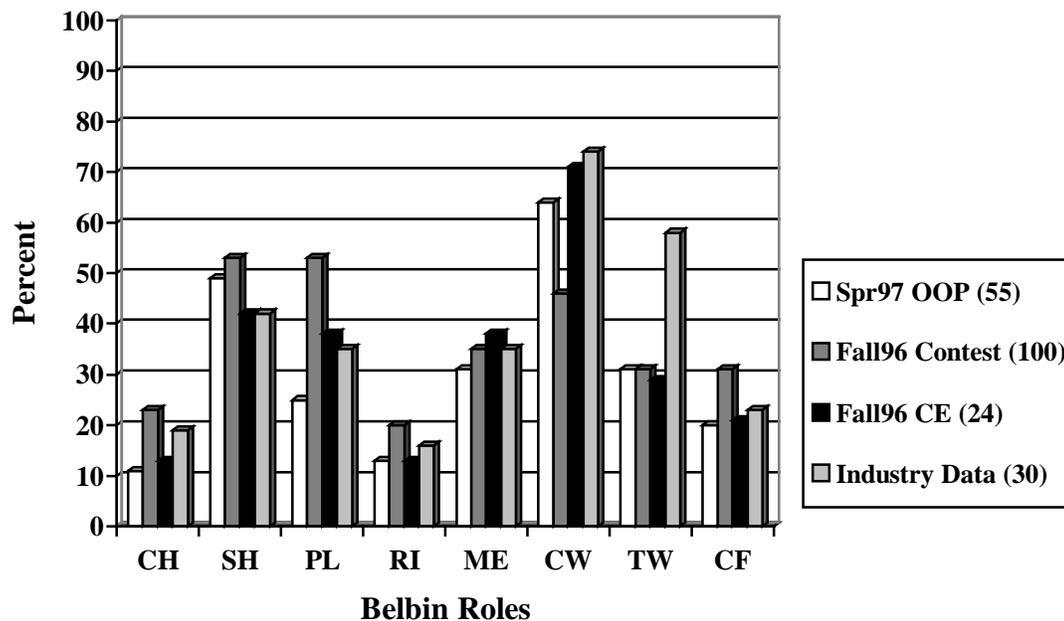
1. The team is “too small in terms of the long term goals, too much maintenance, not enough new stuff,” and
2. The team does “not (have a) complete understanding of all of the subsystems”

#### ***5.1.5.3 Comparison: Medium Manufacturing Team***

Only a couple of points can be compared between the Belbin analysis and the interview. The primary interesting point is the lack of innovation on the team. The interview clearly indicates that the team does not include innovative members; further, the specific Belbin problem area also indicates that the team is weak in terms of team innovation. On the other hand, this is *not* identified in the interview as a deficiency of the team. This indicates that innovation is not crucial to this team. The only other points that can be drawn from the interview is that the team appears to get along very well with one another. In terms of the Belbin Problem Areas (Belbin, 1981), the two areas in which the team is rated highly are affected by the roles in which the team shows strength: Company Worker and Team Worker. For the problem area “Getting Along with Each Other & Making Contacts,” the Team Worker role is indicated by all three members, and the Resource Investigator role, which handles external interfacing, is indicated by one of the members. This shows that the roles that positively affect these areas are filled by team members. The Company Worker role, which is also indicated by all three members, affects the problem area “Following Through & Attention to Details,” for which the team rates highly. The ratings for the other problem areas are not clearly distinguishable in the Belbin Analysis.

## 5.2 Belbin Distributions Including Industry Data

This section provides a description of the Belbin role information for all of the data collected for this research. Section 4.4 provides a similar description for all of the data used in Chapter 4. This section builds on that description, adding the industry data that is used in the preceding sections of this chapter.



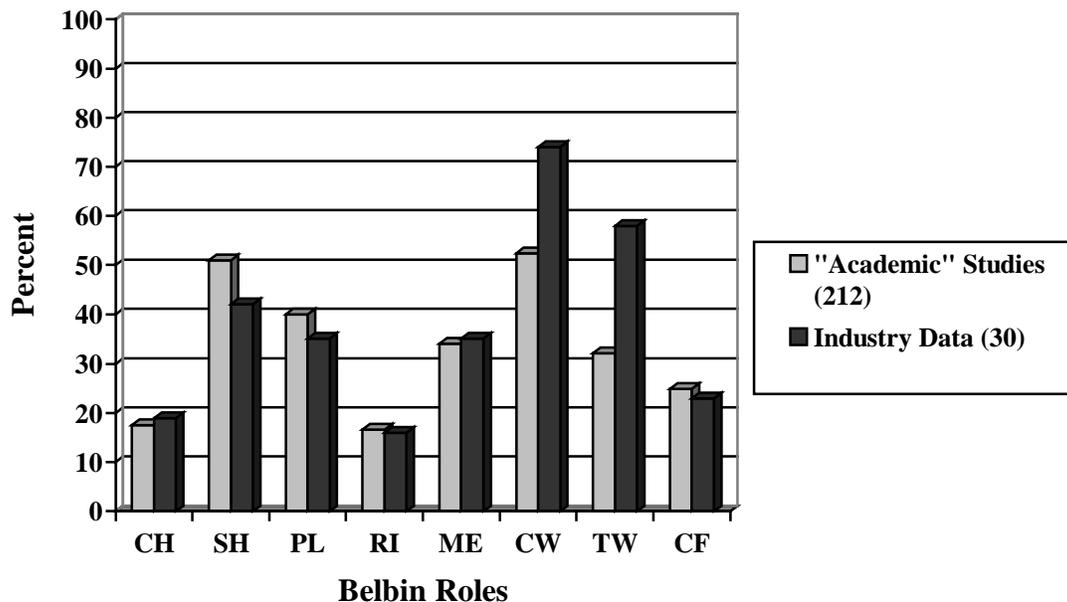
**Figure 5.1: Belbin Distributions Including Industry Data**

Figure 5.1 shows the distribution of each of the three sets of Belbin data gathered for the various studies of this research investigation. The “Spr97 OOP” data is, again, from the object-oriented design class in the Spring 1997, which is described in Section 4.2. The “Fall96 Contest” data is from the programming competition that is described in Section 4.1. The “Fall96 CE” data is from the controlled experiments that are extensively described in Chapter 3. These three are the same as in Figure 4.3. The Industry Data in Figure 5.1 is for the teams used in the analyses in Section 5.1. Figure 5.2 presents a summary of the data in Figure 5.1, averaging the data from the studies from Chapters 3 and 4 so that “academic” data and industry data can be compared. The major differences

between the data sets are with the Company Worker and Team Worker roles. Two interesting points about the Company Worker role in Figure 5.2 are that:

1. It is the highest percentage for the academic data as well as for the industry data;
2. Only the Team Worker role has a greater difference between the academic and industry data.

The Team Worker role is even more inconsistent between academic and industry data samples. This role shows the greatest difference between the academic and industry data samples. However, it also is odd because the academic data has a mean that is not extreme, approximately 30 percent, whereas for the industry data, this role is the second



**Figure 5.2: Summary of Belbin Distributions**

highest percent.

It is very interesting that the team-specific role, Team Worker, is more prevalent in industry teams. Perhaps this is due to members learning the importance of being able to work well together, thus increasing members' scores on the Self-Perception Inventory. Another interesting difference, although slight, is with the Plants. Most of the industry data comes from more common, less highly-technical companies. These types of jobs

may not attract individuals who are interested in innovation. It is even more interesting that the data collected for a team from a major industry innovator does include significantly innovative team members. As shown in the preceding sections, the profiles of the teams that can be extracted from the Belbin data alludes to a great deal.

# Chapter 6

## Conclusions and Future Work

This chapter summarizes the significance of this research and suggests additional investigations for continued research. More specifically, the utility of the application of personality characteristics and roles to a software development environment is described. First, the significance of this research effort is described, then future work is outlined, some of which has been mentioned in the previous chapters.

### 6.1 Goals

This section addresses each of the goals of this research individually, describing how the studies and findings from Chapters 3 through 5 address the goals defined in Chapter 1. Each goal is listed at the beginning of each subsection as a reminder of the goal statement.

#### 6.1.1 Goal 1

Goal 1: Develop quantitative models that can be used in evaluating and in forming software development teams.

The initial attempt to address this goal involved combining the Keirsey personality types to build a general regression model (Ott, 1993). As the investigation continued, Belbin roles were uncovered in the literature. The focus of the investigation turned toward developing a model that would include a combination of the Keirsey types and the Belbin roles and toward defining a mapping scheme from the Keirsey types to the Belbin roles. The mapping, in conjunction with a model developed with the Keirsey types, could have been used to show the utility of the Belbin roles. This initial approach of finding a general model using a mapping is shown to be improbable, or at least weak, in Section 2.2.3; this section shows the relationship between Keirsey types and Belbin roles to be tenuous. Once the Belbin Self-Perception Inventory (See Appendix C) was

discovered to measure the Belbin roles, the investigation focused on the direct applicability of Belbin's roles to software development teams. Finding a *general model* that uses all of the Belbin roles and the Keirseey types appears to be too broad of a problem to solve with a general model; instead, a more cumulative approach is taken to address this goal.

Goal 1 is addressed by several parts of this investigation. The first studies that focus on this goal are the controlled studies in Chapter 3. The results of these studies create a strong foundation built upon the statistical analyses. They provide some of the basic capability to evaluate and form teams, based on the Belbin roles investigated in these studies. By quantitatively demonstrating that leadership and innovation, indicated by the Shaper and Plant roles, are necessary roles for a software development team, this goal is partially addressed, although the group with no Plants could not be statistically distinguished from the other groups. The controlled studies are expanded in the Programming Competition and Object Oriented Programming studies. The observational study using the programming competition in Section 4.1 indicates clear trends in the importance of:

1. A team having a complement of the Belbin roles.
2. The Company Worker, Resource Investigator, and Team Worker roles,
3. Leadership, through the Shaper role.

The applicability of the Belbin roles in forming software development teams is demonstrated in Section 4.2 with the OOP class: teams formed using the Belbin roles perform better than randomly formed teams.

Further evidence of the utility of the Belbin roles in evaluating teams is demonstrated in Chapter 5 by assessing industry teams. Therefore, this series of studies cumulatively address Goal 1 by demonstrating the applicability of the quantitative results from the controlled studies.

### **6.1.2 Goal 2**

Goal 2: Compare the distribution of the personality type data collected for this study to the general population and to previous studies.

Goal 2 is addressed by presenting comparisons of the data from the current studies to studies from the literature, as well as presenting distribution information for the Belbin data collected for this research. The result in Section 2.2.1.2 demonstrates that the personality types resulting from an MBTI test agrees with the types from a Keirsey Temperament Sorter; thus, these types can be compared. Consequently, in Section 4.3 the various data sets for this research are compared to data from two previous studies (Lyons, 1985; Bostrom and Kaiser, 1981) and to the general population (Keirsey, 1984). Further, the distribution of the eight Belbin roles is also described for all of the data sets used for the various studies in this research, including the industry data. The data distributions for the Belbin roles are described in Section 4.4 for all of the studies except the industry studies. In Section 5.2, the industry information is compared to the data from Section 4.4, providing a comparison of industry to non-industry data. Since no distribution information is currently available for the general population, let alone specific subcategories of the general population, the intention for including this information is so that it may be used for future comparative studies.

### **6.1.3 Goal 3**

Goal 3: Demonstrate that *team roles*, as described by R. Meredith Belbin (Belbin, 1981), can be utilized to improve the effectiveness of software development teams.

This goal is treated in a manner similar to the way Goal 1 is addressed in Section 6.1.3. The approach taken to address Goal 1 ultimately evolved toward the Belbin roles, and the approach to address Goal 3 therefore indicate similar results. The controlled studies in Chapter 3 demonstrate direct evidence that Belbin's roles can be used to form teams to improve performance. The results demonstrate some of the basic capabilities useful to evaluate and form teams using the Belbin roles. From these results, one can see that the Shaper and Plant roles are critical roles for a software development team. Furthermore, the controlled studies are partially validated with the Programming Competition analyses and the OOP analyses. As stated above, the observational study of the Programming Competition in Section 4.1 indicates clear trends showing the importance of a complement of the Belbin roles, the Company Worker, Resource

Investigator, Team Worker, and Shaper roles. The usefulness of the Belbin roles in forming teams is demonstrated in Section 4.2 with the OOP class: teams formed using the Belbin roles perform better than randomly formed teams.

Finally, the industry evaluations in Chapter 5 demonstrate a direct application of the roles to a setting outside of academia, further extending the utility of applying Belbin's roles to software development teams. Thus, this series of studies confirm the usefulness and applicability of Belbin's roles in evaluating and forming software development teams.

#### **6.1.4 Goal 4**

Goal 4: Determine whether the Belbin team roles need to be understood and accepted by the team members.

Although this goal is not *directly* addressed by a specific study within this research effort, several of the studies in this investigation do address this goal. The controlled experiments indeed answer this objective by demonstrating that teams can be successfully formed using Belbin's roles without the participants having any knowledge of the roles. More specifically, the participants had no knowledge of *their* team roles, or even general knowledge about Belbin's work, and the experimenter formed teams using Belbin's roles. The results from the controlled studies clearly indicate that the groups of teams formed are significantly different, and therefore, team members do not *need* to be aware of their roles in order for the roles to affect team performance.

This is not to say that awareness of the roles would not be significant. Other studies have shown that if team members are aware of their fellow team members' personality types, then their communications are improved (Lyons, 1985; Moore, 1987; Bostrom and Kaiser, 1981; White, 1984). This indicates another type of improvement for teams, although no specific studies on this type of effectiveness have been performed to compare teams with knowledge of their personality types against teams with no knowledge of their personality types.

The other qualitative studies in Chapter 4 also show that the Belbin roles affect the teams. Although the participants in the programming competition in Section 4.1 were

unaware of the Belbin roles, the Belbin roles do indicate differences between the top ranking teams and the bottom ranking teams. Furthermore, the participants who volunteered from the OOP class were informed that roles would be used to form their teams, but they had virtually no knowledge of the Belbin roles. The participants had no significant knowledge about Belbin's work and no specific knowledge about their own scores on the Belbin Self-Perception Inventory. Therefore, the participants had no knowledge of the roles that they might fill for their team or of the effect that the roles might play for or against their teams.

In summary, the controlled experiments show that team members do not need to be aware of the Belbin role for the roles to affect team performance. Also, the additional studies from the programming competition and the OOP class indicate that teams demonstrating positive Belbin aspects, such as having a single leader, perform better.

### **6.1.5 Goal 5**

Goal 5: Demonstrate that the Belbin team roles can be applied to industry teams, in a way similar to the studies involving students.

This goal is addressed in Chapter 5. Analyses of software development teams from within the industry demonstrate that Belbin's roles and the Belbin Self-Perception Inventory can be used to recognize important positive and negative features of a team. Thus, positive features can be encouraged, and negative features can be avoided or remedied.

## **6.2 Implications of the Research**

One aspect of this research that has not been enumerated as part of the goals of this research, and yet is very significant, is the cumulative effect of the series of studies. This research does not use *only* students, or *only* maintenance teams, or *only* communications teams, or *only* three member teams. It includes a broad spectrum of types of software development teams of varying sizes. This makes the cumulative results stronger because the sources of the data for this research are so disparate. If all of the studies were very similar, if the teams came from a single source, or if the teams were

very homogeneous, then the final conclusions would not have as broad a base from which to draw.

### 6.3 Future Work

This research effort is only the beginning of investigative research in this area. Further controlled, observational, student, and industry studies must be conducted in order to continue this endeavor.

Additional fundamental controlled experiments need to be conducted to address each of the roles that were not covered specifically by this research. Further controlled experiments should investigate the importance of having a complement of roles on a team. Such studies would support some of the qualitative analyses from Chapter 4. Also, a fundamental assumption of this research is that the roles are independent; is this true or should one consider role groupings? For example, is a member who is a Plant/Monitor-Evaluator significantly different from a Plant/Company Worker? Other studies should explore additional roles that might have specific applications to software development.

Some questions that have arisen during this research question the importance to the team of each of the roles; does the importance vary with the type of team? For example, in the industry analyses for some types of teams, the Company Worker appears to be much more important and the Plant appears much less important. Further, some of the results of this research indicate that the Monitor-Evaluator is not only *unimportant* but that, in fact, it appears to be a detriment to a team. Since the Monitor-Evaluator is the decision maker of the team, one would think that this role is critical to a software development team. Why would the Monitor-Evaluator *ever* be a detriment to a team?

Finally, quantitative analyses of industry teams needs to be performed. The analyses provided in Chapter 5 show clear indications that knowledge of Belbin's roles can be used to identify positive and negative aspects of industry teams. This part of the investigation should be continued and extended. Quantitative analyses need to be conducted on industry data to demonstrate empirically that the Belbin roles can be used to assess software development teams in industry.

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# Appendix A:

## The Keirsey Temperament Sorter

The questionnaire is from  
Please Understand Me, Character & Temperament Types,  
by David Keirsey and Marilyn Bates (Keirsey and Bates, 1984),  
ISBN 0-9606954-0-0  
Get the book if you want more detailed information.  
This program is based on  
mb.pl by Jonathan Magid (jem@sunsite.unc.edu)  
His test is located at  
<http://sunsite.unc.edu/jembin/mb.pl>

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1. Are you more attracted to
  - imaginative people
  - sensible people
2. Do you
  - speak easily and at length with strangers
  - find little to say to strangers
3. Is it preferable mostly to
  - just let things happen
  - make sure things are arranged
4. Do you want things
  - settled and decided
  - unsettled and undecided
5. Are you drawn more to
  - overtones
  - fundamentals
6. Is it harder for you to
  - identify with others
  - utilize others
7. Are you more
  - leisurely
  - punctual
8. Are you more impressed by
  - principles
  - emotions

9. Do you see yourself as basically
  - soft-hearted
  - hard-headed
10. Which rules you more
  - your head
  - your heart
11. Do you value in yourself more that you are
  - devoted
  - unwavering
12. Common sense is
  - rarely questionable
  - frequently questionable
13. Are you more frequently
  - a fanciful sort of person
  - a practical sort of person
14. Are you more inclined to be
  - easy to approach
  - somewhat reserved
15. Are you more comfortable
  - before a decision
  - after a decision
16. In doing ordinary things are you more likely to
  - do it the usual way
  - do it your own way
17. Are you a person that is more
  - whimsical than routinized
  - routinized than whimsical
18. In relationships should most things be
  - renegotiable
  - random and circumstantial
19. Are you more interested in
  - design and research
  - production and distribution
20. Are you more
  - realistic than speculative
  - speculative than realistic

21. Which person is more to be complimented: one of
- strong feeling
  - clear reason
22. At parties do you
- stay late, with increasing energy
  - leave early, with decreased energy
23. In judging others are you more swayed by
- circumstances than laws
  - laws than circumstances
24. Do you tend to be more
- deliberate than spontaneous
  - spontaneous than deliberate
25. Which is more satisfying
- to arrive at agreement on an issue
  - to discuss an issue thoroughly
26. Which is the greater fault:
- being indiscriminate
  - being critical
27. Are you more comfortable with work that is
- done on a casual basis
  - contracted
28. Are visionaries
- somewhat annoying
  - rather fascinating
29. At a party do you
- interact with few, known to you
  - interact with many, including strangers
30. Are you inclined more to be
- fair-minded
  - sympathetic
31. Are you more often
- a warm-hearted person
  - a cool-headed person
32. Does it bother you more having things
- incomplete
  - completed

33. Facts
- illustrate principles
  - 'speak for themselves'
34. Do you feel better about
- having purchased
  - having the option to buy
35. Are you more likely to trust your
- hunch
  - experience
36. In phoning do you
- rarely question that it will all be said
  - rehearse what you'll say
37. Do you put more value on the
- open-ended
  - definite
38. Do you feel
- more practical than ingenious
  - more ingenious than practical
39. In company do you
- wait to be approached
  - initiate conversations
40. Are you more likely to
- see how others are useful
  - see how others see
41. Are you more comfortable in making
- value judgments
  - logical judgments
42. In approaching others is your inclination to be somewhat
- objective
  - personal
43. Do you tend to choose
- somewhat impulsively
  - rather carefully
44. Are you more interested in
- what is actual
  - what is possible

45. Would you say you are more
- easy-going
  - serious and determined
46. Do you tend to look for
- the orderly
  - whatever turns up
47. Do you prefer the
- unplanned event
  - planned event
48. Do you more often prefer the
- final and unalterable statement
  - tentative and preliminary statement
49. In your social groups do you
- get behind on the news
  - keep abreast of other's happenings
50. Do you prize more in yourself
- a strong sense of reality
  - a vivid imagination
51. Are you more
- gentle than firm
  - firm than gentle
52. Do you prefer to work
- to deadlines
  - just 'whenever'
53. When the phone rings do you
- hope someone else will answer
  - hasten to get to it first
54. Which situation appeals to you more:
- the structured and scheduled
  - the unstructured and unscheduled
55. Which do you wish more for yourself
- strength of compassion
  - clarity of reason
56. Which seems the greater error
- to be too passionate
  - to be too objective

57. Do you prefer
- a few friends with more lengthy contact
  - many friends with brief contact
58. Do you go more by
- facts
  - principles
59. Are you more drawn toward the
- touching
  - convincing
60. Which is more admirable:
- the ability to organize and be methodical
  - the ability to adapt and make do
61. In writings do you prefer
- the more figurative
  - the more literal
62. Which is more of a compliment
- 'There is a very logical person'
  - 'There is a very sentimental person'
63. Is it worse to
- be 'in a rut'
  - have your 'head in the clouds'
64. Which appeals to you more
- consistency of thought
  - harmonious human relationships
65. Children often do not
- exercise their fantasy enough
  - make themselves useful enough
66. Does new and non-routine interaction with others
- stimulate and energize you
  - tax your reserves
67. Writers should
- express things more by use of analogy
  - 'say what they mean and mean what they say'
68. In making decisions do you feel more comfortable with
- standards
  - feelings

69. Should one usually let events occur
- randomly and by chance
  - by careful selection and choice
70. Is it worse to be
- unjust
  - merciless

# Appendix B:

## The 16 Keirsey Personality Types

The following descriptions show the Keirsey type, the percent within the general population, and descriptive list of identifying characteristics. These descriptions have been extracted from (Keirsey and Bates, 1984).

ENFJ 5%

leaders; assumes they will be followed; charismatic; expect and give cooperation; people highest priority; responsible for others; caring; concerning; nurturing and supportive; over-idealizes relationships; not critical; trustworthy; fluent in communication; influential in groups; empathic; very intuitive; extremely even-tempered, to a fault; reliable in meeting commitments; like complex situations; social without dominance; values harmony; independent of others valuations

INFJ 1%

possibilities; decisive; think in terms of values; values the welfare of others; depth of personality; are complicated; can deal with complex issues and people; very empathic; very intuitive; achievers and very creative; over-perfectionism; puts too much into a task; subtly influential; reserved; private; consistent; value integrity; prefer to agree with others; dislike conflict; needs to intuit; handles others well; enjoys problem solving; aware of individuals' and groups' feelings; good listeners; once a decision is made, they implement it; good at public relations; value harmony; crushed by criticism; like praise and uses approval; can not handle conflict

ENFP 5%

everything is significant; sense the motivations of others; greatly impact others; strive towards authentic, which others find attractive; self-berating because they are so conscious of self; intense emotion is vital; feel endangered from losing touch with their real feelings; keen and penetrating observers; attention always directed; looks for 'hidden motives' tending toward the negative; perceptions tend to be correct, but their conclusions about such perception tend to be incorrect; hypersensitive; hyper-alert; bore easily; resist repeating events; enjoy creating something (concept) but do not follow through; enthusiastic and contagious about it; optimistic; ingenious; imaginative; problem solvers (particularly with people); enjoy inventing new ways of doing things; difficulty in picking up on others' creativeness (views); extensive use of intuition; needs interaction; difficulty with rules, regulations, and standard operating procedures; can be impatient

INFP 1%

idealistic; to the outside world, appears calm, pleasant, reticent, and shy, although they really are deeply caring, passionately so; profound sense of honor; willing to make unusual sacrifices; values process over logic; a gift for interpreting symbols and creating them; takes deliberate liberty with logic; may at times assume an unwarranted familiarity with a domain; may have difficulty with conditional frameworks; impatient with the hypothetical; adaptable; welcomes new ideas; aware of other's feelings; works well alone as well with others; patient with the complicated and impatient with the routine; deep commitment; avoids conflict; sensitive to others; strong capacity for devotion; sympathy and adaptability in their relationships

ENTJ 5%

commandant; need to lead; urge to give structure; empirical; objective; extroverted thinking; tendency to plan using policy and goals as opposed to regulations and procedures; dislikes inefficiency; impatient with repeated errors; must always have a reason for doing something; holds team vision; 'cannot not lead;' organize units keeping long- and short-term objectives in mind; seek and can see effectiveness in personnel; prefer decisions based on impersonal data; rise to positions of responsibility; tend to work in organizational structures; take charge at home

INTJ 1%

builder; self confident; introspective; focusing on possibilities; decisions end the question; look to the future; authority has no significance; tend to conform if it is useful; supreme pragmatists, who see reality as something that is quite arbitrary and made-up; no idea is too far-fetched to entertained; natural brainstormer; always open to new concepts seeking them aggressively; keen eye for consequences of the application of the ideas or positions; theories that cannot be made to work are discarded; better at generalizing, classifying, adducing evidence, proving, and demonstrating than at pure reason; drive to completion; difficulties are stimulating; loves responding to challenges that require creativity; tend to build data and human systems; generates a plethora of implementations for ideas (concepts); can be very single-minded; work long and hard; live to see systems become substance; internal and external consistency important; seems demanding; appears to see through coworkers; high achievers; dedicated (to the company, not to individuals); independent; seems cold, etc., but is really hypersensitive to rejection

ENTP 5%

ingenuity, deals imaginatively with relationships; always sensitive to possibilities; good at analysis (especially functional); likes the complex; interest in everything; inspiration to others; easy to please; effervescent; reluctant to conform to the standard way of doing things; looks for a 'better way,' confident in the value of their pursuits; brings fresh new approaches to their work; an expert at directing relationships between means and ends; a design is a means to the end

implementation; can improvise; focuses on competency and the power that it gives; debater/conversationalist; one-up-man; value adaptability and innovation; entrepreneur and cleverly makes do; counts on ingenuity as opposed to planning and being methodical; may neglect necessary preparation; hates routine; loses interest once a project is no longer challenging; competitive; non-conformist; understands politics and may work against the system to be one-up; natural engineer of human relationships; may be unaware that they do not have sufficient knowledge of a situation to ward off dangers

INTP 1%

architect of ideas, systems, and edifices; greatest precision in thought and language; detects contradictions in statements; searches for whatever is relevant and pertinent; good at concentration; unimpressed with authority derived from position; abhors redundancy and incoherence; can be obsessed with analysis; persevere until complex issues completely understood; can generate hostility and defensiveness in others; arrogant; logician' mathematician; philosopher; scientist; must not be allowed to work out implementation; architect, not builder; excellent teachers; takes relationships seriously; deals with the environment primarily through intuition; shy except with close friends; adaptable until one of their principles are violated

ESTJ 13%

responsible; very in touch with the external environment; pillars of strength; organizes orderly procedures, detailing rules and regulations; impatient with those who do not carry out proper procedures with sufficient attention to detail; comfortable in evaluating others; realistic; matter-of-fact; curious about new devices and procedures; loyal; rise to positions of responsibility in their jobs; punctual and expects others to be so; not responsive to views and emotions of others; jumps to conclusions; not willing to patiently listen to the views of others; in tune with established procedures; follows routines well; neat and orderly; do not confuse others by sending double messages; dependable and consistent

ISTJ 6%

dependable and duty; decisive in practical affairs; guardian of time-honored institutions; their word is their bond; quite and serious; persevering and dependable; dedicated; thoroughness, details, justice, practical procedures, and smooth flow of personnel and material; handles difficult and details figures; reliable and stable; excellent supervisors; others fail to see their vulnerability to criticism; patient with their work; not patient with individual goals of individuals; practical and sensible; distaste for and distrust of fanciness; the ostentatious is abhorred; durable clothing is good

ESFJ 13%

harmony; most sociable of all types; energized by interactions with people; idealize whatever or whoever they admire; nurturers of established institutions; promotes harmony and harmonious relations; traditions should be developed, supported, and observed; hurt by indifference; needs to be appreciated; conscious of appearances; takes the opinions of others about social standards very seriously; values; conscientious and orderly; outgoing personalities; good at people-to-people jobs; seldom becomes a source of irritation; complex analysis does not interest them; emotes; outgoing in their emotional reactions; needs to be needed, loved, and appreciated; soft-hearted; sentimental; exhibits a bent towards the pessimistic that can become contagious

ISFJ 6%

must be of service; carries a sense of history, continuity with past events; values traditions and the conservation of resources; the least hedonistic of all of the types; work is good; willing to work long, long hours; assigned tasks will be completed; adheres to established ways of doing things, which is not often questioned; annoyed by others who do not adhere to standard operating procedures; most irritation is turned inwards; super-dependable; extraordinary sense of responsibility; talent for executing routines; devoted and loyal to a boss, identifying with the individual rather than the institution; aware of status; aware of material resources; values saving; prepares for emergencies; dislikes to be in a position of authority; offended by someone 'putting on airs;' frequently misunderstood and undervalued

ESTP 13%

resourceful; individuals of action; have an attractive style; socially sophisticated, suave, and urbane; master manipulators; observes others' motivations; hypersensitive to minimal nonverbal cues, 'selling' to the 'client;' all actions are directed toward the audience; witty, clever, and fun; appear to be extremely empathic, when in fact they are simply using their hypersensitive observations of nonverbal cues; uses information that they gain towards their ends; nerves of steel; ruthless pragmatists, offering the ends and justification for whatever means; do not care to justify their actions to others; initiators of enterprise; invaluable itinerate administrators; can sell an idea or project in a way no other type can; will not follow through on tedious details; unappreciated for their extraordinary talents must have someone else to do the follow-through work; live for the immediate moment; radiates charm; do not establish deep commitments; relationships are conditional, the condition being the consideration of what they have to gain

ESFP 13%

performer; warm and optimistic; smooth, witty, charming, clever, voluble, and open; avoids being alone and can easily find company because they are so entertaining; outstanding conversationalists; has an air of sophistication; generous to a fault; assists one and all; impulsive; vulnerable to psychological seduction; tolerance to anxiety is the lowest of all types; ignores the negative side of a

situation as long as possible; self-indulgent; relies heavily on personal experience and generally shows good common sense; adaptable; gregarious sociability; wants knowledge only for the immediate utility; good at working with people in crisis

ISTP 7%

master of tools; fiercely loyal to 'brothers,' individuals with the same interests; impulsive; fiercely insubordinate, seeing authority as unnecessary; must do their own thing; proud of their ability to make the next move skillfully; fearless, risking injury; likes to pit their technique against chance. odds, or fate; thrive on excitement; hunger for action; very subject to boredom; tool artisan; plays on impulse, taking off at **any** time just because; hangs out with their own kind (climbers, racers, hunters, etc.) in play; companionship is mediated through the tool; little interest in developing verbal skills; can be great leaders if they are on the front line; supreme realism, timing, and sense of expediency allows them to seize the day, to get as much as they can and capitalize on their opponents' deficiencies; battle leaders are duelists; combat is an art, an intellectual game, not in the sense of strategy but in tactics and skill; not interested in clerical, interpretive, and science curricula; usually bored with school; has the attitude, What is there to do *now* that is *worthwhile*?; always very active; stubbornly insistent; has a communality with the other SP types; cheerful, loyal to their equals, uncomplicated, trusting, receptive, generous, and want no obligations, duties, or confining promises

ISFP 5%

gifted artist; tendency not to express themselves directly, but through action; hedonistic; impulsive; not searching for significance, like NF types; no interest in science, like NT types, or in commerce, like SJ types; live Epicurean lives in the here and now; do not plan or prepare, what some might call practice or preparation is actually doing to them; caught up in whatever actions are currently taking place; so absorbed they may be unaware of pain, fatigue, etc. their kindness is unconditional; very empathic; not interested in developing communication skills; reserved and private, due not to ability but to lack of interest; can be optimistic and cheerful, egalitarian, fraternal, and insubordinate; tends to ward off obligations, duties, confinement, can fetters; loves freedom; easily bored; wants excitement, risk, chance, and tests of luck; uncomplicated in motivation, trusting, receptive, and generous; spends rather than saves; retiring, reserved, and even self-effacing

# Appendix C:

## The Belbin Self-Perception Inventory

The following is from Belbin's original work on team roles (Belbin, 1981).

For each of the following sections, **distribute ten (10) points** among the 8 sentences that you think best describe your behavior. These points may be distributed among several sentences: in extreme cases they might be spread among all 8 sentences or ten points may be given to a single sentence. Enter the points in the spaces in front of each sentence. For example, for section 1, you might give five points to statement 2, two points to each statement 4 & 5, and one point to statement 7. (Suggestion: Read all of the sentences, crossing out the ones that are not true or hardly true, then distribute points among those sentences left.)

### I. What I believe I can contribute to the team:

1. \_\_\_ I think I can quickly see and take advantage of new opportunities.
2. \_\_\_ I can work well with a very wide range of people.
3. \_\_\_ Producing ideas is one of my natural assets.
4. \_\_\_ My ability rests in being able to draw people out whenever I detect they have something of value to contribute to group objectives.
5. \_\_\_ My capacity to follow through has much to do with my personal effectiveness.
6. \_\_\_ I am ready to face temporary unpopularity if it leads to worthwhile results in the end.
7. \_\_\_ I can usually sense what is realistic and likely to work.
8. \_\_\_ I can offer a reasoned case for alternate courses of action without introducing bias or prejudice.

### II. If I have a possible shortcoming in teamwork, it could be that:

1. \_\_\_ I am not at ease unless meetings are well structured and controlled and generally well conducted.
2. \_\_\_ I am inclined to be too generous towards others who have a valid viewpoint that has not been given proper airing.
3. \_\_\_ I have a tendency to talk too much once the group gets on to new ideas.
4. \_\_\_ My objective outlook makes it difficult for me to join in readily and enthusiastically with colleagues.
5. \_\_\_ I am sometimes seen as forceful and authoritarian if there is a need to

get something done.

6. \_\_\_ I find it difficult to lead from the front, perhaps because I am over-responsive to group atmosphere.
7. \_\_\_ I am apt to get caught up in ideas that occur to me and so lose track of what is happening.
8. \_\_\_ My colleagues tend to see me as worrying unnecessarily over detail and the possibility that things may go wrong.

III. When involved in a project with other people:

1. \_\_\_ I have an aptitude for influencing people without pressurizing them.
2. \_\_\_ My general vigilance prevents careless mistakes and omissions being made.
3. \_\_\_ I am ready to press for action to make sure that the meeting does not waste time or lose site of the main objective.
4. \_\_\_ I can be counted on to contribute something original.
5. \_\_\_ I am always ready to back a good suggestion in the common interest.
6. \_\_\_ I am keen to look for the latest in new ideas and developments.
7. \_\_\_ I believe my capacity for judgment can help to bring about the right decisions.
8. \_\_\_ I can be relied upon to see that all essential work is organized.

IV. My characteristic approach to group work is that:

1. \_\_\_ I have a quite interest in getting to know colleagues better.
2. \_\_\_ I am not reluctant to challenge the views of others or to hold a minority view myself.
3. \_\_\_ I can usually find a line of argument to refute unsound propositions.
4. \_\_\_ I think I have a talent for making things work once a plan has to be put into operation.
5. \_\_\_ I have a tendency to avoid the obvious and to come out with the unexpected.
6. \_\_\_ I bring a touch of perfectionism to any job I undertake.
7. \_\_\_ I am ready to make use of contacts outside the group itself.
8. \_\_\_ While I am interested in all views I have not hesitation in making up my mind once a decision has to be made.

V. I gain satisfaction in a job because:

1. \_\_\_ I enjoy analyzing situations and weighing up all of the possible choices.
2. \_\_\_ I am interested in finding practical solutions to problems.

3. \_\_\_ I like to feel I am fostering good working relationships.
4. \_\_\_ I can have a strong influence on decisions.
5. \_\_\_ I can meet people who may have something new to offer.
6. \_\_\_ I can get people to agree on a necessary course of action.
7. \_\_\_ I feel in my element where I can give a task my full attention.
8. \_\_\_ I like to find a field that stretches my imagination.

VI. If I am suddenly given a difficult task with limited time and unfamiliar people:

1. \_\_\_ I would feel like retiring to a corner to devise a way out of the impasse before developing a line.
2. \_\_\_ I would be ready to work with the person who showed the most positive approach.
3. \_\_\_ I would find some way of reducing the size of the task by establishing what different individuals might best contribute.
4. \_\_\_ My natural sense of urgency would help to ensure that we did not fall behind schedule.
5. \_\_\_ I believe I would keep cool and maintain my capacity to think straight.
6. \_\_\_ I would retain a steadiness of purpose in spite of the pressures.
7. \_\_\_ I would be prepared to take a positive lead if I felt the group was making no progress.
8. \_\_\_ I would open up discussions with a view to stimulating new thoughts and getting something moving.

VII. With reference to the problems to which I am subject to working in groups:

1. \_\_\_ I am apt to show my impatience with those who are obstructing progress.
2. \_\_\_ Others may criticize me for being too analytical and insufficiently intuitive.
3. \_\_\_ My desire to ensure that work is properly done can hold up proceedings.
4. \_\_\_ I tend to get bored rather easily and rely on one or two stimulating members to spark me off.
5. \_\_\_ I find it difficult to get started unless the goals are clear.
6. \_\_\_ I am sometimes poor at explaining and clarifying complex points that occur to me.
7. \_\_\_ I am conscious of demanding from others the things I cannot do myself.
8. \_\_\_ I hesitate to get my points across when I run up against real opposition

# Appendix D:

## Raw Data from the Controlled Experiments

### Experiment 1: Shapers

OBS	CLASS	TEAM	GROUP	PLACE	TIME
1	1	a	13	2	55
2	1	b	13	8	120
3	1	c	13	4	75
4	1	d	11	1	50
5	1	e	13	7	113
6	1	f	11	6	106
7	1	g	11	3	60
8	1	h	11	5	77
9	2	a	13	6	220
10	2	b	13	5	137
11	2	c	13	3	114
12	2	d	11	4	132
13	2	e	13	7	240
14	2	f	11	1	99
15	2	g	11	8	245
16	2	h	11	2	111
17	3	a	13	5	63
18	3	b	13	6	70
19	3	c	13	7	78
20	3	d	11	4	62
21	3	e	13	8	120
22	3	f	11	3	51
23	3	g	11	1	43
24	3	h	11	2	49
25	4	a	13	6	48
26	4	b	13	7	50
27	4	c	13	5	46
28	4	d	11	1	31
29	4	e	13	8	80
30	4	f	11	3	35
31	4	g	11	4	41
32	4	h	11	2	34

## Experiment 2: Plants

OBS	CLASS	TEAM	GROUP	PLACE	TIME
1	1	a	t1	2	41
2	1	b	t3	8	180
3	1	c	t2	4	120
4	1	d	t2	1	150
5	1	e	t2	7	240
6	1	f	t3	6	56
7	1	g	t3	3	67
8	1	h	t1	5	95
9	2	a	t1	6	87
10	2	b	t3	5	91
11	2	c	t2	3	101
12	2	d	t2	4	83
13	2	e	t2	7	103
14	2	f	t3	1	180
15	2	g	t3	8	146
16	2	h	t1	2	50
17	3	a	t1	5	56
18	3	b	t3	6	39
19	3	c	t2	7	55
20	3	d	t2	4	27
21	3	e	t2	8	41
22	3	f	t3	3	32
23	3	g	t3	1	51
24	3	h	t1	2	57
25	4	a	t1	6	18
26	4	b	t3	7	32
27	4	c	t2	5	62
28	4	d	t2	1	116
29	4	e	t2	8	111
30	4	f	t3	3	46
31	4	g	t3	4	115
32	4	h	t1	2	29

### Experiment 3: Monitor-Evaluators

OBS	CLASS	TEAM	GROUP	PLACE	TIME
1	1	a	t1	1	26
2	1	b	t1	1	35
3	1	c	t1	1	49
4	1	d	t1	1	31
5	1	e	t2	2	36
6	1	f	t2	2	32
7	1	g	t2	2	67
8	1	h	t2	2	135
9	2	a	t1	1	94
10	2	b	t1	1	59
11	2	c	t1	1	75
12	2	d	t1	1	50
13	2	e	t2	2	71
14	2	f	t2	2	52
15	2	g	t2	2	73
16	2	h	t2	2	130
17	3	a	t1	1	130
18	3	b	t1	1	60
19	3	c	t1	1	57
20	3	d	t1	1	76
21	3	e	t2	2	54
22	3	f	t2	2	75
23	3	g	t2	2	41
24	3	h	t2	2	110
25	4	a	t1	1	57
26	4	b	t1	1	21
27	4	c	t1	1	68
28	4	d	t1	1	35
29	4	e	t2	2	38
30	4	f	t2	2	55
31	4	g	t2	2	49
32	4	h	t2	2	53

# Appendix E:

## Viability Questionnaire for Controlled Experiments

All information that you provide on this questionnaire will be kept strictly confidential and will have absolutely no effect on your grade. Circle the number that best addresses the question.

1. Rate the overall quality of the team. poor 1 2 3 4 5 6 great
2. Rate your overall participation as part of the team, regardless of fault  
(Ideally everyone should contribute evenly to the team.  
Do you feel you contributed roughly 1/3 of the effort?) uneven 1 2 3 4 5 6 even
3. How good was the inter-member coordination of your team? poor 1 2 3 4 5 6 great
4. How good was the cooperation within your team? poor 1 2 3 4 5 6 great
5. How good was the quality of decision making? poor 1 2 3 4 5 6 great
6. Rate your overall satisfaction with the team's performance. poor 1 2 3 4 5 6 great
7. How strong was the innovative orientation of the team? weak 1 2 3 4 5 6 strong
8. To what degree did your team have clear norms/standards and roles? not 1 2 3 4 5 6 very
9. How well was each members' abilities used? not 1 2 3 4 5 6 very
10. How cohesive was your team? not 1 2 3 4 5 6 very
11. How motivated was your team? not 1 2 3 4 5 6 very
12. How well was your technical abilities used? not 1 2 3 4 5 6 very
13. other team-member 1? not 1 2 3 4 5 6 very
14. other team-member 2? not 1 2 3 4 5 6 very
15. How willing would you be to work with this team again? not 1 2 3 4 5 6 very

What is the worst aspect (feature) of the team that caused the most problems?

What is the best aspect (feature) of the team?

# Appendix F:

## Programming Competition Data

<i>Team Rank</i>	<i>CH</i>	<i>SH</i>	<i>PL</i>	<i>RI</i>	<i>ME</i>	<i>CW</i>	<i>TW</i>	<i>CF</i>	<i>Number of Problems Solved</i>
[1]									<b>8</b>
	-	10	18	-	-	10	-	-	
	10	-	-	-	16	-	15	-	
	12	13	13	-	15	-	-	-	
[2]									
	-	30	10	-	-	-	-	-	
	-	-	-	-	-	15	14	14	
	-	21	-	14	-	-	-	-	
[3]									
	-	-	10	-	-	19	-	20	
	11	13	11	11	11	-	-	-	
	-	10	-	-	15	10	-	12	
[11]									<b>5</b>
	-	13	-	-	-	24	18	-	
	-	-	17	-	12	12	11	12	
	-	-	20	-	12	13	-	-	
[13]									
	-	-	-	15	-	11	12	11	
	-	-	-	-	-	16	12	12	
	-	15	20	10	10	-	-	-	
[17]									
	-	-	19	14	-	11	-	-	
	-	-	-	-	11	16	-	-	
	-	-	16	-	-	16	-	-	
[18]									
	-	12	12	-	-	13	-	-	
	11	-	19	-	-	-	10	-	
	-	17	-	14	10	-	-	-	
[29]									<b>3</b>
	-	-	14	-	-	18	-	12	
	-	23	-	-	11	-	-	-	
	-	-	18	-	11	-	-	10	
[31]									
	-	16	-	-	-	14	-	13	
	-	11	-	-	-	27	-	-	
	-	11	-	-	-	19	-	13	
[38]									

	-	-	-	10	15	-	-	13	
	-	-	25	-	16	-	-	-	
	-	12	13	-	13	-	-	10	
[39]									
	-	-	18	-	-	-	13	-	
	-	11	-	10	10	10	-	-	
	12	-	-	-	-	13	-	-	
[40]									
	-	-	16	-	-	-	-	11	
	-	-	15	12	-	15	11	-	
	-	15	19	-	10	-	-	-	
[41]									
	16	25	-	-	-	-	-	-	
	-	10	10	11	-	-	-	-	
	-	-	13	-	-	19	-	-	
[42]									
	-	14	-	-	-	10	-	18	
	-	16	11	13	-	-	-	-	
	-	-	12	-	-	-	17	18	
[47]									
	-	26	14	10	-	-	-	-	
	12	14	-	-	-	-	10	-	
	-	13	-	-	-	-	-	17	
[48]									
	-	17	11	-	-	12	-	-	
	-	-	-	-	-	17	20	11	
	-	-	-	-	15	-	24	-	
[55]									<b>2</b>
	10	-	12	-	-	17	10	-	
	-	16	19	12	10	-	-	-	
	-	18	19	-	10	-	-	-	
[56]									
	14	11	-	-	-	11	10	-	
	-	15	-	11	-	-	-	-	
	-	-	14	-	-	19	-	11	
[57]									
	-	-	-	11	-	15	-	-	
	11	-	12	-	-	-	15	-	
	10	-	12	-	-	11	11	12	
[58]									
	-	-	17	-	10	11	10	-	
	-	-	-	-	12	-	13	-	
	-	11	-	-	-	16	11	15	
[61]									
	-	10	-	-	-	14	-	17	
	11	-	-	-	-	-	-	10	

	-	15	-	-	-	13	15	-	
[62]									
	-	-	-	14	-	14	26	-	
	14	13	-	-	-	16	-	-	
	-	-	15	-	12	-	11	-	
[63]									
	-	24	-	-	12	-	-	13	
	-	42	-	-	-	13	-	-	
	11	-	11	-	-	-	15	-	
[67]									
	-	-	12	-	-	15	12	-	
	-	-	14	-	14	11	-	-	
	-	12	17	-	-	14	-	-	
[68]									<b>1</b>
	-	17	17	-	19	-	-	-	
	-	17	16	-	13	-	-	-	
	-	14	-	10	-	-	10	13	
[69]									
	-	-	-	16	-	14	-	-	
	-	-	11	-	-	14	11	18	
	-	-	20	-	10	-	-	15	
[71]									
	-	18	-	-	-	18	-	-	
	15	15	-	-	-	-	-	-	
	-	10	10	-	-	10	10	-	
[72]									
	12	-	-	-	-	-	18	11	
	-	11	-	-	-	-	10	-	
	9	-	10	-	-	-	-	-	
[81]									
	11	-	15	-	11	-	-	-	
	-	10	17	-	-	-	-	-	
	-	13	17	-	-	-	-	-	
[89]									
	11	10	10	-	-	-	-	10	
	22	-	22	-	10	-	-	-	
	-	-	-	-	12	29	11	-	
[90]									<b>0</b>
	-	19	-	-	14	-	-	-	
	-	19	11	-	13	-	-	-	
	-	19	-	-	-	-	-	19	
[92]									
	11	17	-	-	11	11	-	-	
	-	11	14	-	10	-	-	10	
	-	16	-	-	12	14	-	-	
[93]									

	-	18	16	11	-	-	-	-	
	10	-	-	15	-	-	-	-	
	12	-	17	-	-	-	-	11	

# Appendix G:

## OOP Spring 1997 Data

Team 33									104.5
1	-	18	11	-	-	-	-	-	104.5
2	-	16	-	-	-	11	-	13	104.5
3	11	-	18	-	-	-	15	-	104.5
Team 1									102
1	-	15	20	-	-	-	-	-	102
2	-	-	-	-	13	11	-	15	102
3	-	-	-	-	-	-	14	16	102
Team 4									102
1	-	25	13	-	11	-	-	-	102
2	-	11	-	-	-	18	-	-	102
3	-	-	-	-	14	16	-	12	102
Team 13									101
1	-	15	13	-	-	11	11	-	101
2	-	-	11	-	-	15	12	11	101
3	-	-	18	-	12	-	-	-	101
Team 20									101
1	-	10	-	-	-	13	-	11	101
2	18	-	-	-	10	17	-	-	101
3	-	-	11	12	-	-	25	-	101
Team 14									100.5
1	-	14	-	-	-	14	-	19	100.5
2	-	-	18	10	-	-	-	-	100.5
3	-	-	-	-	19	20	-	-	100.5
Team 8									100
1	-	20	-	-	-	-	-	14	100
2	-	-	18	12	-	-	-	-	100
3	14	-	-	-	-	17	-	21	100
Team 21									99.49
1	-	11	-	-	-	13	-	11	99.49
2	13	-	-	-	11	13	-	-	99.49
3	-	-	10	-	-	23	-	-	99.49
Team 6									99
1	-	14	-	-	-	-	12	10	99
2	-	-	13	10	-	-	19	-	99
3	-	-	-	-	-	21	-	16	99
Team 19									99
1	11	11	13	-	-	12	-	-	99
2	18	-	10	-	11	17	-	-	99
3	-	-	15	-	-	-	16	12	99

Team 17									99
1	21	13	-	-	-	12	16	-	99
2	-	-	13	-	17	17	-	-	99
3	-	-	-	12	-	-	-	15	99
Team 3									98.49
1	11	25	-	-	-	-	-	12	98.49
2	-	-	21	13	-	-	-	-	98.49
3	-	-	-	-	15	12	-	10	98.49
Team 2									97
1	-	15	15	11	-	-	11	-	97
2	10	13	-	-	-	17	-	11	97
3	-	-	-	-	-	11	11	-	97
Team 11									97
1	-	16	13	-	-	12	-	-	97
2	-	-	13	-	12	13	12	-	97
3	-	-	19	-	-	-	-	-	97
Team 30									97
1	-	-	19	-	17	16	-	-	97
2	-	12	-	11	19	15	-	-	97
3	11	-	-	-	12	-	17	-	97
Team 5									96.99
1	-	18	-	-	17	-	-	-	96.99
2	-	-	11	18	15	-	-	-	96.99
3	-	-	-	-	-	15	-	19	96.99
Team 32									96.49
1	-	-	-	-	-	12	11	13	96.49
2	12	-	19	-	-	13	-	-	96.49
3	10	14	-	-	-	-	17	-	96.49
Team 36									96
1	-	16	-	-	-	13	-	-	96
2	-	20	-	-	-	-	-	-	96
3	14	-	-	-	13	14	-	15	96
Team 12									95
1	10	16	10	10	-	-	10	-	95
2	-	-	24	18	-	-	-	-	95
3	-	-	16	-	13	-	11	-	95
Team 7									94.49
1	-	14	-	-	11	10	-	14	94.49
2	-	-	11	-	16	17	-	-	94.49
3	-	14	-	-	-	11	-	16	94.49
Team 10									94.49
1	-	16	-	11	-	19	10	-	94.49
2	-	-	15	-	11	-	12	-	94.49
3	14	-	-	12	-	13	-	-	94.49
Team 22									94
1	-	11	-	-	-	25	10	-	94

2	-	-	10	10	-	10	15	-	94
3	-	-	-	-	16	17	-	14	94
Team 16									92
1	10	14	-	-	-	-	-	12	92
2	10	-	10	-	-	12	10	-	92
3	-	-	-	-	16	19	-	-	92
Team 18									89
1	-	13	11	14	-	-	-	11	89
2	12	-	-	-	17	12	-	-	89
3	-	-	17	-	-	-	18	-	89
Team 15									88
1	13	14	-	-	-	14	12	17	88
2	-	-	17	-	-	14	-	-	88
3	-	-	-	-	-	21	-	17	88
Team 9									87
1	10	19	13	-	-	-	-	-	87
2	-	-	18	-	-	18	17	-	87
3	-	-	10	-	10	14	-	13	87

## Vita

Todd Stevens was born and lived his first 18 years in Marion, Ohio. He then underwent a transformation into (arguably) an adult and relocated to Ohio University where he learned and lived for 5 years. He then moved to Columbus, Ohio to work for AT&T, again reforming and re-discovering himself, this time with a disagreeable 8 to 5 requisite schedule imposed on him. Not being satisfied with his education (or an 8 to 5 life), he moved to Blacksburg, Virginia, still trying to figure out this life-thing. After completing a graduate degree and being sated (one might say fed up) with graduate school, he moved to Massachusetts and Wang Labs. This environment was fertile for more self-examination and learning, but once again after a few years, the college bug bit again (the economy, recession, and abysmal state of the computer science job market also played a role). He returned to Blacksburg to live (and incidentally work towards a Ph.D.), still talking to Alfie. He has learned and loved, made tremendous friends, and drank some beer.

Todd is currently in the throws of pursuing an academic position where he can continue this research investigation (since this is just a beginning), enjoy teaching, meet new people, and live happily ever after with someone. I think I need a dog.

“Died on me finally. He had to.

Died doing his bad bugle imitation, calling for the maps, died bellowing orders at everyone, horses included...” (from *Oldest Living Confederate Widow Tells All* by Allan Gurganus, 1989). One of the most interesting openers of a book that I have ever read. And it’s all a lie. Life is like that.