Leadership Skills Development for Engineers

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Abstract: Leadership must be a key element advancing for the engineering profession to remain relevant and connected in an era of heightened outsourcing and global competition. Companies intent on maintaining a competitive edge are calling upon educators to produce engineers capable of leading multidisciplinary teams, combine technical ingenuity with business acumen, and produce graduates who have a passion for lifelong learning. Industry is also challenging universities to broaden curricula beyond the intellectual endeavors of design and scientific inquiry to the greater domain of professional leadership and entrepreneurship. Managers in industry are similarly challenged to cultivate key leadership attributes in junior engineers. This article explores the changing nature of engineering in a globally competitive environment and addresses why leadership must become a key issue in the career progression of engineers. We will present a literature review of leadership models along with some proposed solutions for cultivating leadership skills as part of the career development process. Lastly, we will present specific recommendations on how to cultivate leadership attributes throughout an engineering career.

Keywords: Leadership Education; Leadership; Lifelong Learning; Leadership Development; Self Actualization

EMJ Focus Areas: Development Engineering Management Professionals; Engineering Management: Past, Present, Future

In the last 50 years, three publications are considered seminal papers in the field of engineering education: The Grinter Report (1955), The Green Report (1994), and Educating the Engineer of 2020 (National Academy of Engineering or NAE, 2005). The Grinter Report in essence is the foundation of modern engineering education and calls for strengthening the basic sciences and the inclusion of six engineering sciences (mechanics of solids, fluid mechanics, thermodynamics, transfer and rate mechanisms, electrical theory, and nature and properties of materials) for all engineering curricula. This 50-plus year old report is still the framework for modern engineering education and accreditation. The Green Report emphasized education that is relevant, attractive, and connected, and recommended that education reform be accelerated to include:

- Team skills, including collaborative, active learning;
- Communication skills;
- Leadership;
- A systems perspective;
- An understanding and appreciation of the diversity of students, faculty, and staff;
- An appreciation of different cultures and business practices, and the understanding that the practice of engineering is now global;
- Integration of knowledge throughout the curriculum;
- A multi-disciplinary perspective;
- A commitment to quality, timeliness, and continuous improvement;
- undergraduate research and engineering work experience;
- Understanding of the societal, economic and environmental impacts of engineering decisions; and
- Ethics.

Unfortunately, many of these skills have been taught under the guise of senior design while the basic and engineering sciences advocated by the Grinter Report have remained literally unchanged in engineering curricula for over 50 years.

The NAE fell short of making specific recommendations on curriculum reform and missed an opportunity to make significant contributions in reforming engineering education; however, the report did recognize that the global marketplace is the key to the future of engineering. The report states that "Technical excellence is the essential attribute of engineering graduates, but those graduates should also possess team communication, ethical reasoning, and societal and global contextual analysis skills as well as understanding work strategies." Few outside of academics will argue that globalization is now a major disruptive force behind engineering, and we must better train engineers at all levels to be agile leaders and entrepreneurs.

Any practicing engineer will argue that "an engineer is hired for her or his technical skills, fired for poor people skills, and promoted for leadership and management skills" (Russell and Yao, 1997). Against this backdrop, engineering academicians of the 20th century have been justly criticized for having increasingly emphasized scientific theory over practice and productivity, knowledge production over applied critical thinking, and mechanical analysis over market realities. Colleges stand indicted (especially by practicing professionals) for producing engineers who are intellectually and technically gifted, but are, nevertheless, too narrowly trained for real-world engineering (Bakos, 1997; Nair, 1987). Although these grievances can be categorized as sweeping generalizations, contemporary engineering literature reveals a growing call for undergraduate engineering reforms to better prepare college graduates for the marketplace. Against this backdrop, we must early in their careers also instill the need for lifelong learning and the pursuit of leadership and entrepreneurial skills to be not only successful but also relevant in the global market.

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Fostered by post-World War II federal funding for basic research to support the space race, Cold War, and the war on terrorism, colleges were increasingly driven to create new knowledge. Unfortunately, basic research emerged pre-eminent in our colleges to the detriment of applied engineering. Indeed, the pursuit of basic research approaches "virtue" whereas applied engineering with industry is a "vice" for educators accustomed to promoting theoretical depth and "intellectual gravity" in coursework and research (Goldberg, 1996). This subsequently reinforced a system, often at odds with corporate employers, where accreditation requirements focused squarely on design and science factors, faculty promotion criteria rest heavily on refereed publication volume and funded basic research, and engineering curricula are packed with technical and theoretical courses to the exclusion of broader leadership and entrepreneurial skills required by practicing engineers. Fortunately, unlike any other profession (lawyers, doctors, architects, etc.), corporate America is a major stakeholder in their education and has been adamant in content reform.

Leadership development in industry can best be described as ad hoc with "on the job training" being the primary mechanism. Engineers at all levels must be more adept at market forces and business realities, developing large scale systems, and working with people from other disciplines and cultures. Industry leaders are calling upon educators to provide a holistic education applying systems thinking and strong interpersonal skills (ASEE Prism, 1995). Loath to wait for universities to accommodate them, many industry leaders are turning to professional in-house training programs (Cherrington, 1995). Except for large corporations, however, few companies offer these formal leadership-training programs. Many offer Executive Leadership Development Programs (ELDP) but they are mainly focused on exposing promising young executives to senior management operational issues. For example, the Department of Defense (DoD, 2007) states the "participants of ELDP graduate from the program with an increased understanding and appreciation for today's warfighters." Some do offer formal classes to cultivate leadership skills, executive coaching, rotational assignments, senior mentoring, etc.; however, many companies are not willing to invest the resources in developing promising young talent because of turnover and the focus on productivity except for more senior executives.

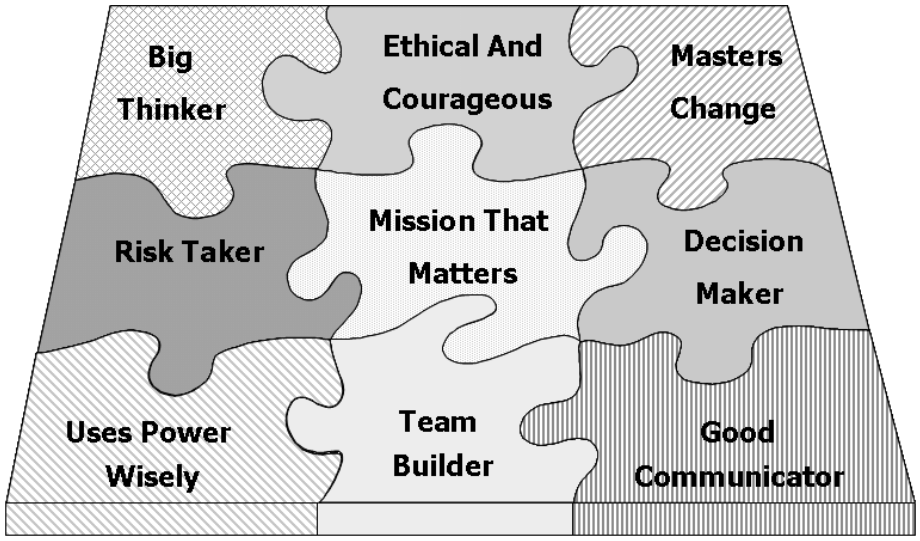
Leadership for engineers is more complicated than most other sectors because, in addition to the traditional skills needed to excel, an additional dimension of technological leadership and governance is required. Engineering managers are hired for their ability to lead in technology based organizations where product cycle times can be weeks not years. Thus, they must continue to remain technologically relevant yet develop the traditional leadership traits. Exhibit 1 shows nine broad and domain independent leader qualities. Note that none of these qualities contains any type of technological knowledge or systems integration skills. Much research needs to be conducted on how to cultivate engineers at all levels for leadership roles in technology-based organizations. The rapid change of technology requires different skills sets than traditional production based organizations.

The Role of the Global Economy

The U.S. economy forms the foundation of our high quality of life, our national security, and our hope that our children and grandchildren will inherit ever-greater opportunities (NAE, 2005b); however, globalization has contributed to a significant portion of the U.S. workforce being in direct competition with lower-wage workers throughout the world. No sector is immune to out sourcing, including engineering. For example, a company can hire eight young professional engineers in India for the cost of one in America (NAE, 2005b). Many leaders in the U.S. are calling for more investment in research and development (R&D) and the training of more engineers and scientists to maintain the technological advantage we have enjoyed since World War II. Others are calling for embracing the global economy and training engineers as innovators, leaders, and entrepreneurs. We believe that both are critical for the U.S. to maintain its position of economic leadership in the global community.

Investing in R&D and recruiting more K-12 students into engineering are national issues.; however, companies which employ engineers that are responding to market conditions are calling for graduates now who are not merely experts in design and analysis, but who possess the leadership skills to apply their technical expertise and to capitalize on emerging science

Exhibit 1. Nine Leadership Attributes (from Farr et al., 1997)



and technologies to bring to the market new if not disruptive products. In this globally competitive business environment requiring companies to "hold the line" on costs, minimize risk, meet schedules, and to maximize productivity, it is viewed as wasteful to accept inefficient on-the-job management training as the first step in leadership development.

A Leadership Development Model

Leader development is, unfortunately, mainly an individual process. Academia and businesses may set up programs and make training accessible, but in the end, it is fundamentally an individual endeavor. Equally important is the understanding that each leader brings to the situation a unique level of prior development attained by genetics, childhood upbringing, and adult experiences. Leadership scholar Bruce Avolio (2005) refers to this concept of each individual having a different path of development as their individual and unique "life stream." If the life stream is the path of an individual's development, then the path is determined by a leadership equation. The innate skills and attributes an individual brings to their life stream can be seen as the denominator in their leadership equation. What individuals do with these innate skills, what they learn in life, and how they adapt to changes in their life stream changes their individual equation by adding to the numerator and hence to their development. In this model of development, all focus is on the numerator, the part of the equation that the individual can and does influence. We understand and acknowledge that each individual brings to the situation traits and attributes that are relatively stable and unlikely to be changed; however the focus on leader development as discussed here is in what Avolio (2005) refers to as the numerator – the skills and adaptations that each individual adds to their life stream. This focus on building strengths and skills sees in each individual the ability to become a better and more effective leader. It is a moot discussion to debate whether leaders are born or made – rather they are all born with varying abilities, and some are developed better and hone those abilities more than others.

Many ELDP focus on a specific skill set or competency that will enable a student or young engineer to better negotiate a particular new position or a specific new challenge. While these programs might be effective in the short term, very few models incorporate development across a broad spectrum of situations and developmental levels. What follows is a discussion of one such model. This discussion is based on the leader development framework developed by the Center for Creative Leadership (McCauley and Van Velsor, 2004). The foundation of this model was derived from the result of hundreds of developmental sessions with executives, educators, business managers, and military officers. Their work provides a skeleton for understanding the impact of various developmental programs and for beginning to integrate these initiatives into a coherent whole.

The Center for Creative Leadership (CCL) defines leader development as the "expansion of a person's capacity to be effective in leadership roles and processes" (McCauley and Van Velsor, 2004). Like Avolio, the focus is on the growth of those innate and already learned behaviors. This definition is especially applicable to students in technical fields because the emphasis is on the individual—it seeks to increase capacity, not meet a pre-established set point—and finally because it acknowledges that there are many leadership roles along the route from follower to chief executive officer. The expansion of a person's capacity can relate to any type of development, from technical expertise to leadership skills. Their framework is quite simple and is based primarily on three components: assessment, challenge, and support.

Assessment

The first step of assessment is to become self aware. Self-awareness is an individual assessment. Quite simply, self-awareness involves developing a clear picture of oneself through self-assessment, peer and superior feedback, and formal and informal 360-degree assessment tools. Personality inventories, critical thinking tests, and emotional intelligence quizzes are all examples of self-awareness tools that are available online and can be used as part of the learning and assessment process. Through the self-assessment process, students determine where they are in terms of their current self and where they would like to be in terms of their ideal or desired self (Markus and Wurf, 1987). While self-assessment tools are valuable, the ability to gather 360-degree feedback from peers, supervisors, and subordinates is equally important. To be truly self aware, one must determine both where they think they are as well as where others think they are. In this way an individual can identify gaps that they would like to address. They can then develop a personal action plan for working to close the gaps. Often this plan will include attempting new behaviors and determining if they fit better with their ideal self. Such attempts, if successful, can help to boost self confidence and a desire for further growth and development. A great discussion of this personal action plan as it relates to self awareness can be found in the Goleman, Boyatzis, and McKee (2002) work entitled *Primal Leadership: Realizing the Power of Emotional Intelligence*.

Challenge

A second key component of leader development is challenging experiences. Engineers must be directed or encouraged to undertake experiences that will challenge them and push them out of their comfort zone, experiences from which they will grow and develop. A runner will never get faster if they only run at a comfortable pace. They may stay in shape and maintain good cardio fitness, but will never get faster if they do not push and challenge their ability by going faster and faster on training runs. The same principle holds true for leadership. An engineer will never improve their interpersonal, communication, managerial, etc., skills if they only stick to aspects of the project with which they feel comfortable. For example, if an engineer focuses only on design and production, and never accepts the challenge to speak with other group members or the customer, they will never grow in the area of communication. Too often engineers remain in their technical comfort zone and do not cultivate other elements of the "whole" leader.

Leaders develop by taking on stretch assignments, situations, and experiences that offer them a challenge outside their comfort zone. These are not assignments that are completely outside their area of expertise—a runner does not attempt to improve by learning to scuba dive—nor would we want an engineering student to attempt the stretch assignment of public relations. The challenging experiences should be based on what the individual determines to be a gap in their development during the assessment phase. Truly challenging experiences make an individual uncomfortable and create a disequilibrium that they must resolve. They are forced to develop and try new skills when their tried and true favorites don't work. This is true for all areas of development and especially true for leadership development.

Leaders in technical organizations and students in technical programs must be encouraged and rewarded for seeking out challenging leadership experiences.

Support

Support comes in many forms. Universities, corporations, etc., must recognize the need for this development and allow students the time and resources required. In academics, this may necessitate restructuring graded requirements in pre-existing courses or developing entirely new course goals and objectives. In corporations this might involve formal mentoring, rotational training, professional coaching, and professional development activities.

Another form of support comes from those surrounding the leadership student. A leader must have a person or group of individuals to whom they can turn in order to help them make sense of the experiences they have had and the feedback they have received. Far too often young engineers live through a challenging experience and simply throw it into their files, never to be seen or evaluated again. These valuable experiences are real and are part of their life stream, but without reflection no growth takes place, and, as a result, the experiences are not significant in their development. The real promise for growth and development is in the processing of that experience, either alone or with the help of a trusted friend, peer, or mentor. In these after action reviews which look at the student's actions, inactions, decisions, and interactions are rich learning opportunities that will expand their capacity to do the same or better the next time they are presented with a similar issue. In our fast paced, just-in-time culture, it is often difficult to take time out to reflect on our experiences and seize developmental opportunities. We must recognize this tendency and purposefully set aside time and resources to enable and assist our young engineers to make the best of each growth opportunity.

Along with support must come the freedom to fail. Teachers, peers, mentors, coaches, and superiors must understand that not all challenging experiences will be met with complete success. What truly matters from a developmental perspective are the lessons that the students of leadership take away from the experience and their ability to own that experience and the lessons learned. As stakeholders in the development of engineers, we all must set up our students of leadership to learn and provide the support to make all of their outcomes opportunities for growth.

The assessment—challenge—support model of leader development can be used to increase capacity in these critical attributes. Engineering curricula can be easily adapted by including aspects of these qualities in courses and course projects.

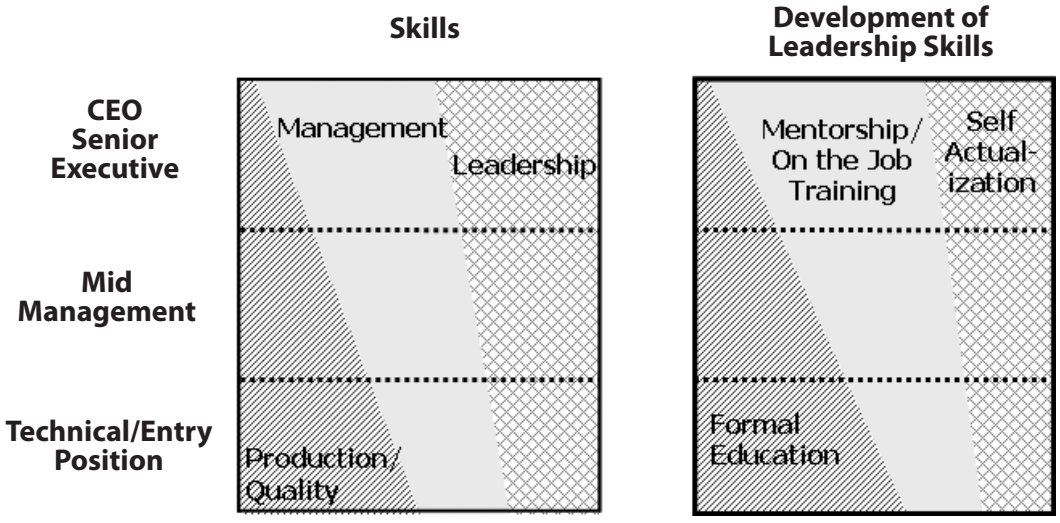
Developing Leadership Skills

As shown in Exhibit 2, the essential leadership attributes shown in Exhibit 1 are developed differently over the course of a career. Formal education dominates the development of leadership skills early in a young engineer's career. Later on the job training combined with mentorship are how these skills are developed. Lastly, self-actualization of leadership skills as a young engineer matures and moves into positions of increasing responsibility dominates development of these skills.

In academics, particularly in developing program content, there is a constant struggle between technical content and what is often considered "soft" skills—subjects such as leadership and entrepreneurship. With few exceptions, technical content as laid out in the Grinter Report, is the winner. At the undergraduate level, the development of key leadership attributes is usually relegated to elements of senior design. This is unfortunate because other opportunities exist to start the development of these attributes within the humanities electives, basic engineering core, and the engineering electives. Unfortunately, even within senior design leadership is ignored. In many cases while academicians understand it is important, they simply do not know how to cultivate leadership attributes within the constraints of academics. Some methods that might be practiced in engineering curricula include:

- In group design, place one student in charge of the group. He/she is solely responsible for meeting deadlines and organizing the effort. Everyone will rotate through this position and will be graded on how they lead the group. Make leadership performance a significant portion of their grade.
- Make outstanding communication a key and necessary part of all courses—especially senior design.
- Find coaches from industry who are successful leaders as well as engineers, and who understand the importance of cultivating young leaders. These leaders should give frequent lectures to talk about the keys to success. These types of lectures would be more valuable to future engineers than any

Exhibit 2. Development of Key Skills Over a Career in Engineering Formal Education



in-depth technical lecture. Internships with industry would be even more valuable.
- Raise the awareness of faculty that leadership skills are important and must be developed. This can best be accomplished by making it an assessed outcome.
- In today's volatile world, change is a constant. Students can conduct a self- or peer-assessment to determine their comfort with addressing and accepting change and seek input from their peers and advisors on the same. Management requirements creep/changes are keys to success for any student of leadership.
- Encourage, support, and recognize leadership in student chapters of professional and honor societies or other peer managed organization.

Leadership development experiences during baccalaureate engineering training must be reinforced by extensive practice in real-world settings early in a young engineer's career. Building in exposure at the undergraduate level may offer the impetus for young engineers to understand the importance of leadership skills. Early direct experience and rewards is the foundation for subsequent career growth.

Mentorship/On-the-Job Training

Most middle and senior managers complain about the ineptness of young technical staff engineers; however, the same managers are typically too busy to coach/mentor young, technically proficient engineers. Often, these young engineers are not told that they need to formally develop key soft skills and the importance of those skills. The prevailing attitude is that entry-level engineers will somehow realize their soft skill deficiencies and remedy them through osmosis. The sad part of this is that most junior members of organizations hunger for knowledge about the business aspects of their firm, long-term vision of the corporation, improving people and communication skills, etc.—everything needed to be a good leader. If young engineers do not want to grow into positions of responsibility, you have done a poor job of hiring.

What can managers do to develop their young engineers? The most important contribution is to give them your time. This is not an easy task in a world of deadlines and bottom-lines; however, some simple things you can use to grow young engineers might include:

- Invite young engineers, as part of the training process, to observe or participate in public or important private meetings exposing them to several levels of responsibilities. After the meeting, jointly and constructively discuss the meeting and critique the tactics and skills of the various participants. This can show the young engineer the importance of some of the qualities that a leader must possess as previously presented.
- Encourage young engineers to develop soft skills and reward their efforts. For example, Toastmasters speaking clubs is an excellent way to develop speaking skills. Invest in non-technical education that can be used to improve the skill level of one of the nine leadership qualities shown in Exhibit 1. These are just as important as technical continuing education.
- Involve the working, young engineer on a strategy session for pursuing a contract, a job interview for a new hire, etc. Use these types of interactions as opportunities to share corporate strategy such as focusing or developing relationships with clients. Including a young engineer in such a meeting will also help minimize the amount of time required for coaching/mentoring.
- Have the courage to constructively criticize young engineers' actions and products. Develop plans for addressing weaknesses. Do not rely on the young engineer to figure out that a problem exists and to find a way to fix the problem. This is probably the most important element of junior engineer development.
- Help your young engineer develop a personal and professional development plan. Discuss the requirements necessary to accomplishment their current job but also where they want to be in ten years. Help them develop quarterly and annual targets toward that future development.

Note that the coaching/mentoring process not only develops the young engineer but also rewards the mid level manager; leadership development flows in both directions and is often rewarded with loyalty. Young engineers see problems and issues differently that you do. They will not be bound by your past experiences and will likely astonish you with novel and useful applications. By spending time with you, young engineers will better understand your vision and in turn will be better able to make contributions that directly support your goals.

In leadership development, mentorship is especially important for young female engineers. Often, in the politically correct corporate world, open conversations about the challenges of being female in a male dominated profession are avoided. Mid-level managers must take care to include women in their coaching and mentoring. Recent work by Hyde (2005) suggests that in the leader skill and attribute domain there is more similarity than difference in the abilities of men and women. The differences in career progression can often be accounted for by differences in mentorship and developmental experiences. A deliberate development and mentorship program within your organization will ensure that all young engineers have the opportunity to develop to their potential.

Self-Actualization

Self-actualization is a term used to describe the manifestation (actualization) of our potential as human beings beyond basic survival needs and is a good way to describe lifelong learning. Most senior engineers are successful because they have demonstrated technical excellence and some management ability. To make the transition to respected leader, they must continue to develop and refine the nine qualities of a leader previously presented. All successful leaders are continually learning and adapting. Senior engineers can further develop their leadership skills by:

- Continuing their education in depth but more importantly in breadth. Most engineers at all levels will habitually read their technical specialty journal or trade magazine. Most feel that practical experience is the best teacher for the soft side of business instead of a formal learning process. Instead of just technical development, focus your continuing education in those areas that can have the most effect on your business or industry – the nine qualities shown in Exhibit 1.
- Continue self evaluation and, based upon feedback and advice from others, continue to work on those areas in which you are weak. The use of 360 degree peer assessment has become commonplace in most corporations. As a senior leader in any company, others will scrutinize your every action. You must improve on those very skills that allowed you to advance to your present position and install confidence in the workforce. Do not be afraid to hire an executive coach. You want an experienced professional guiding you in other aspects of your life.

Of all the phases of an engineer's career, your ability to influence your group toward accomplishing its goals is most important at this juncture of your career. You impact the lives of the employees and the welfare of the company. It is more critical than ever at this stage in a career to continue to improve your leadership skills.

Conclusions

This article has set a framework for engineering students of leadership in the global economy. Using these qualities as a framework, specific ideas are presented in how to develop those necessary qualities through the career path taken by most engineers.

Engineers at all levels are often naive about the optimum mixture of technical and non-technical skills needed to be a success. They need to be shown both by word and example that a judicious blend of hard and soft skills is needed to ensure long term success. The earlier the development process is started, the more time is available to grow into a leadership role. The pace and flattening of our global environment is changing the nature of modern engineering; to succeed, young engineers must more quickly grow into this role. Everyone wins when young engineers develop leadership skills early in their careers.

As part of the leadership development process, an important element in the transition from project engineer to management is to honestly and objectively identify those qualities in which they are deficient. No engineer has ever made the transition from a technical staff engineer to executive without polishing many of the skills shown in Exhibit 1. We must learn to assess and challenge ourselves.

Lastly, engineers understand the commitment to a lifetime of learning toward the goal of self actualization; thus, we understand the need for continued professional development in all areas. Once we obtain a senior management position, continually honing our skills is second nature. We must strive to improve all of the nine qualities previously discussed. We must never forget our obligation to younger students of leadership and provide the mentorship needed for success.

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