

Teaching Engineers to Form and Share Vision

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Abstract

This paper reports a project teaching engineering students the leadership skills of forming and sharing vision. We describe the skills of forming and sharing vision, review related learning outcomes, and describe six teaching modules delivered in a senior capstone course sequence in the 2020-21 and 2021-22 academic years at the University of Texas at El Paso, a Hispanic-serving R1 university. To assess the modules, changes in the students' self-perceptions of vision skills were assessed quantitatively in the 2020-21 course sequence, and students' perceptions of pedagogical effectiveness of the modules were qualitatively assessed in the 2021-22 course sequence. The pilot study, with six participants, suggested that the modules did, in fact, lead students to see that their leadership vision skills had improved. The fuller qualitative study, with 17 participants, indicated that the students used concepts related to forming vision more frequently than concepts related to sharing vision, which may be due to the study's small-team context. A large majority of students reported that their team used its vision in working on its project. Analysis of students' recall of the modules' concepts indicates that the level of recall per concept ranged from 47% to 100%, with a mean of 76%. The project's learning outcomes and PowerPoint-based modules are available for use.

Introduction

We conducted this study in an engineering department at the University of Texas at El Paso, a Hispanic-serving R1 university. In response to a survey, our department's stakeholders, including advisory-board members, capstone-project sponsors, and alumni advised us that leadership vision was an important skill for our graduates and that this is an area in which our program could do better. Indeed, contemporary models of engineering education [e.g., 1] nearly universally include leadership, and notable models [e.g., 2] include creating and realizing vision as an essential element. Inspiring a shared vision is one of the five practices of exemplary leadership [3]. A leader's vision (1) provides followers, and the group as a whole, with a sense of identity and meaning, (2) motivates followers by providing a shared positive image of the future, (3) provides a path for resolving current problems or crises, and (4) enables the creation of a shared culture and norms [4].

In a project over the last two years, we developed six modules, within two themes, for an engineering capstone-design course sequence that are intended to develop leadership skills related to vision. The core idea is that effective leaders articulate vision that produces feelings of affiliation and that followers perceive as useful. Effective leaders *form* and *share* this vision, and these constitute the two themes for the modules. Accordingly, this paper reviews the theoretical and pedagogical frameworks for teaching vision in leadership, particularly in the context of a program in engineering, proposes learning outcomes based these frameworks, presents the six

modules, and describes a two-part study assessing the modules' effectiveness, and presents the study's results.

Related Work

This section briefly surveys the research literature relating to the role of vision in leadership, reviews instruments for assessing vision in leadership, and discusses some of the pedagogy that informed the design of the modules.

Role of Vision in Leadership

Inspiring a shared vision is one of the five practices of exemplary leadership [5]. This involves envisaging an uplifting, exciting, meaningful future and enlisting others in a common vision by appealing to their values, interests, hopes, and dreams. A leader's vision (1) provides followers, and the group as a whole, with a sense of identity and meaning, (2) motivates followers by providing a shared positive image of the future, (3) provides a path for resolving current problems or crises, and (4) enables the creation of a shared culture and norms [6]. This reflects Bass's [6] model of transformational leadership, which includes, among its seven elements, setting clear goals, stirs people's emotions, gets people to look beyond their self-interest, and inspires people to reach for the improbable. The effectiveness of vision, though, depends on both this affective reaction and also perceived utility: affective reaction reflects the extent to which followers would find the plan to be attractive, leading them to want to be affiliated with the organization, and perceived utility reflects the extent to which followers believe a plan would lead to effective organizational change [5]. Regardless of the extent that feelings of affiliation increase, the perceived utility will be stronger to the extent that followers see the vision as useful not only for the organization but for them personally, too. Because transformational leadership both articulates a vision and provides responsibility and support to followers, which leads to higher levels of identification with and commitment to the organizational goals these leaders set, this approach helps followers to perceive that the goals are attainable [7], thus increasing perceived utility.

Vision formation requires descriptive mental models, typically acquired through experience, plus reflection, and abstraction of key goals and/or key causes [8]. Presumably a descriptive mental model will be useful to the extent that it fully reflects circumstances, relationships, and exogenous factors. Yet leaders will likely achieve better performance in motivating followers by articulating a vision with fewer schema, fewer cases, and simpler mental models [5]. This suggests that a leader's success in articulating a vision with high perceived utility and high affective reaction is likely a function of the leader's ability to distill complex situations into their essential components.

Every leader's experience is necessarily limited: no-one can have every experience. Thus, leaders effective in forming vision practice continuous learning, which provides them with the benefit of the experience, and knowledge, of others. This means keeping up with the leading-edge developments in one's field. For example, UTEP's College of Engineering obtained the benefit of the experience and insights of national leaders in engineering education through the

college's leaders learning about a model of engineering education that integrates depth with breadth [9, 10], which led to the college's creation of a new undergraduate degree program [11].

The members of a leader's organization also have, individually and especially collectively, vast reservoirs of experience. Indeed, failure to take advantage of the organization's collective experience can result in a leader's imposing a vision and values that destroy dissent and stifle discussion; the effective leader does not simply communicate a strategy to others but creates strategy with others [13]. Participatory approaches have developed successful visions across a range of organizations [e.g., 14]. The core beliefs of UTEP's College of Engineering (<https://www.utep.edu/engineering/about-us/core-beliefs.html>) were developed through a participatory process. The Delphi method [14], in particular, can help organizations develop vision through broad participation of stakeholders [e.g., 15, 16]. Moreover, servant leaders who practice truly inclusive, participatory leadership can develop a pluralistic leadership that more fully engages and empowers diverse people [17].

While participatory development can partly "pre-share" vision and values, sharing vision requires the leader to communicate actively. "A vision is little more than an empty dream until it is widely shared and accepted. Only then does it acquire the force necessary to change an organization and move it in the right direction" [18, p. 134]. The leader has the lead role, so to speak, in sharing the vision. Leaders who "flatten" the communication hierarchy are more likely to achieve shared vision [19]. At the extreme, for organizations with transformational leaders, using face-to-face dialogue to communicate the vision increases the attractiveness of the organizational vision [20].

Pedagogy for Vision in Leadership

Some scholars have rejected teaching vision in leadership, arguing that the very notion of a leader inspiring followers to a shared vision represents a "systems-control orthodoxy" [21, p. 145], typical of models such as transformational leadership, that derives from modernist and universalistic aspirations to maximize control over subordinates. However, contemporary models of engineering education [e.g., 1] nearly universally include leadership, and leading models [e.g., 22] include creating and realizing vision as an essential element. Indeed, many engineering leadership programs typically have at least a nominal commitment to vision as a component of leadership, [e.g., 23, 24], although available materials may not articulate the program's pedagogy for vision in leadership. In some programs, vision is incorporated with the notion of teamwork [25].

Because a leader's capacity to develop vision derives, at least in part, from experience, the classroom does not serve as an optimal context for learning to develop and share effective vision. Indeed, this is likely true for education across all facets of leadership, so understanding and practicing leadership may be more effective in the context of actual work [26]. Short of moving university students and courses into working organizations, there are a few pedagogical approaches that may address this problem at least partially. One such approach is to help the students understand both the upstream and downstream elements of the engineering process, so that they can see their work in broader contexts [25]; this likely, in the leadership vision framework of Partlow, Medeiros, and Mumford [4], provides teams of students with a sense of identity and meaning and motivates them by providing a shared positive image of the future.

Another approach involves approximating the context of actual work by having student teams engage in capstone projects with real customers. In this approach, beyond issues of traditional engineering design, students face problems of business context, customer satisfaction, and environmental constraint that amount to a “a quasi-real-world environment” [27, p. 5]. One of the five learning outcomes of our capstone design course is “to consider, develop and apply key aspects of individual and team leadership.”

Teaching Modules

To implement the teaching of leadership vision for engineering students, we developed a set of three modules for forming vision and three modules for sharing vision, all of which integrate developing and disseminating vision as integral parts of team-project activities within a two-semester capstone-design course sequence with real customers. The modules were delivered in the 2020-21 and 2021-22 course sequences.

Our approach to teaching vision for leaders, following [5], involves approximating the context of actual work by having student teams engage in capstone projects with real clients, typically major corporations. In this approach, in addition to traditional engineering design issues, students face problems of business context, customer satisfaction, and environmental constraint that amount to a quasi-real-world environment. Based on the insights from a review of literature on crafting effective visions discussed above, we articulated thirteen learning outcomes for forming vision and ten learning outcomes for sharing vision; the number of outcomes for forming and sharing differed because they reflected the extend of concepts expressed in the research literature. Consistent with Bloom’s taxonomy, we expressed the outcomes at the levels of knowledge and comprehension, application and analysis, and synthesis and evaluation. These modules comprise brief lectures, group and individual active-learning activities, with associated assignments that include observation and reflection. Topics include

- The purpose of vision in leadership
- The factors that contribute to developing vision
- The role of continuous learning in developing vision
- Crafting vision appropriate to the organizational context
- Participatory development of vision and values
- The Delphi method
- Affective reaction and perceived utility
- Being clear
- Communicating a simple mental model
- Using content and style appropriate to the audience
- Articulating a clear sense of purpose and direction for an organization's future
- Communicating values that transcend the leader’s self-interests and material success
- Leading by example

The complete sets of learning outcomes and PowerPoint presentations for the modules are available at <https://bit.ly/3vzECaO>.

Methodology

We assessed the effectiveness of the teaching modules across two academic years in two ways. In 2020-21, we conducted a quantitative pilot study that assessed changes in students' self-perception of their leadership vision skills, and in 2021-22 we conducted a fuller qualitative study of the effectiveness of the modules. In this section, we present these two methodologies.

Assessing Vision Skills

While several instruments have been proposed and validated for assessment of leadership, particularly with respect to servant leadership [e.g., 28], there appears to be only one instrument [29] that includes vision as a component. The Page and Wong [29] instrument is a self-assessment, also in the context of servant leadership, that covers twelve components of leadership: integrity, humility, servanthood, caring for others, empowering others, developing others, visioning, goal setting, leading, modeling, team-building, and shared decision-making. Of these, eight related to visioning.

Page and Wong's [29] pilot study of the instrument (N=24) indicated that the overall survey had high internal consistency (Chronbach's $\alpha = 0.937$) but that the section on visioning had lower internal consistency (Chronbach's $\alpha = 0.569$). Dennis and Winston [30] conducted a factor analysis (N=529) of the Page and Wong survey, from which factor loadings of the items of the scale produced three factors, which Dennis and Winston labeled empowerment, service, and vision. This produced a slightly different grouping of items in the survey with respect to vision, but with high internal consistency (Chronbach's $\alpha = 0.94$). The eight items in Dennis and Winston's service factor, expressed here in the style of Page and Wong's statements, were

1. I have a sense of a higher calling.
2. My leadership is driven by values that transcend self-interests and material success.
3. I firmly believe that that every organization needs a higher purpose.
4. I am able to articulate a clear sense of purpose and direction for my organization's future.
5. I know what I want my organization to become or do for society.
6. I am able to inspire others with my enthusiasm and confidence for what can be accomplished.
7. I am very focused and disciplined at work.
8. I lead by example.

In the pilot study, we asked participants to respond to these prompts, using a seven-point Likert scale, in both a pre-survey before the modules were delivered and a post-survey after the modules were delivered. In the survey, the even-numbered items were expressed in the negative and then reverse-coded in the analysis. Our key hypothesis was that, comparing pre- and post-tests, participants' scores on the vision leadership scale will increase.

Assessing Vision Pedagogy

The fuller study, conducted in the 2021-2022 academic year, focused on strengths and weaknesses of our approach to teaching engineers the leadership skills of forming and sharing vision. After the modules were delivered, students responded to a survey that asked students:

- (1) For each of the 14 topics listed above in the Teaching Modules section “define in your own words what it means and provide an example of how you applied it (or say that you did not apply it);”
- (2) Whether their team used its vision? If so, how? If not, why?’ and
- (3) Please share any other comments on the course content on forming and sharing vision for engineering leaders. Were any of the elements of course content difficult to understand? Were any of the elements especially interesting or engaging? Why?

We applied thematic content analysis [31] to the participants’ survey responses with a view to understanding:

- The extent to which the teams used the modules’ concepts for forming and sharing vision.
- The extent to which the teams used their team visions in their projects
- The extent to which the students understood the modules’ content

The investigators generated a codebook with which to assess the themes in the participants’ responses. Each participant’s survey responses were coded independently by two investigators, and conflicts were resolved by agreement.

Results

For the quantitative pilot study of changes in self-perception of leadership vision skills, ten students were enrolled in the course sequence, six of whom completed both the pre- and post-surveys. The mean self-perception in the pre-survey was 5.38 (scale 1-7, stdev = 1.61). The mean self-perception in the post-survey was 5.63 (scale 1-7, stdev = 1.51). Hedge’s G was 0.16, indicating a small effect. However, the difference between the participants’ pre- and post-scores approached significance ($p = 0.058$, paired one-tailed t test), which was notable given that $N = 6$. Interestingly, two of the six subjects reported slight *decreases* in their self-perception of leadership vision skills. Figure 1 presents a sorted scatter plot of the differences between the results from pre- and post-surveys. We speculate that the decreases do not reflect the modules’ causing a student’s vision skills to decline but rather the possibility that the student’s newly acquired knowledge of leadership vision skills led to a more realistic self-perception. Anecdotally, one of the participants later said that he wished we had introduced this material earlier because his team found its vision statement so useful in keeping their project on track.

In the qualitative study of the pedagogy, 17 of the 20 students in the Capstone Design sequence completed the survey (some students were out for reasons related to the pandemic). The first result relates to the extent to which the team’s forming and sharing of their visions were informed by the factors listed in the learning outcomes. As presented in Figure 2, the data

indicate that the materials relating to forming vision were used more than the materials relating to sharing vision. We think that the relatively low use of the materials relating to sharing vision may have occurred because the teams were small (four students each) and all the members of each team participated in developing the team's vision. Consequently, each team's vision was effectively "pre-communicated." This suggests that other approaches to application of skills may be needed to instill skills of sharing vision. For example, the twin concepts of affective reaction and perceived utility, which went largely unused by the teams, would be important for students when they lead larger organizations. While the teams' use of the Delphi method was moderate, we were actually encouraged by the fact that they used this relatively complex approach at all.

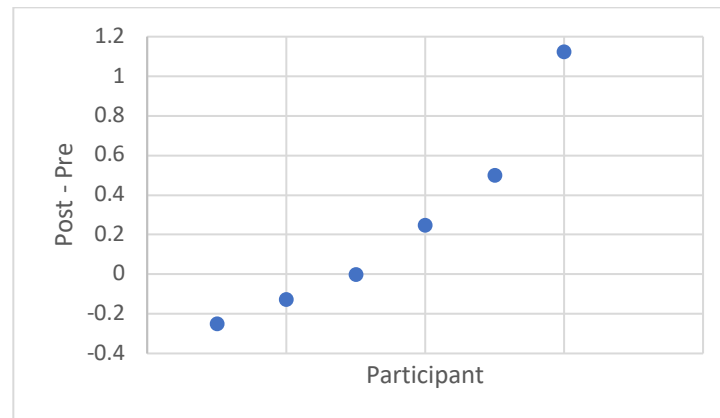


Figure 1. Difference, by participant, between post- and pre-survey self-perception of leadership-vision skills.

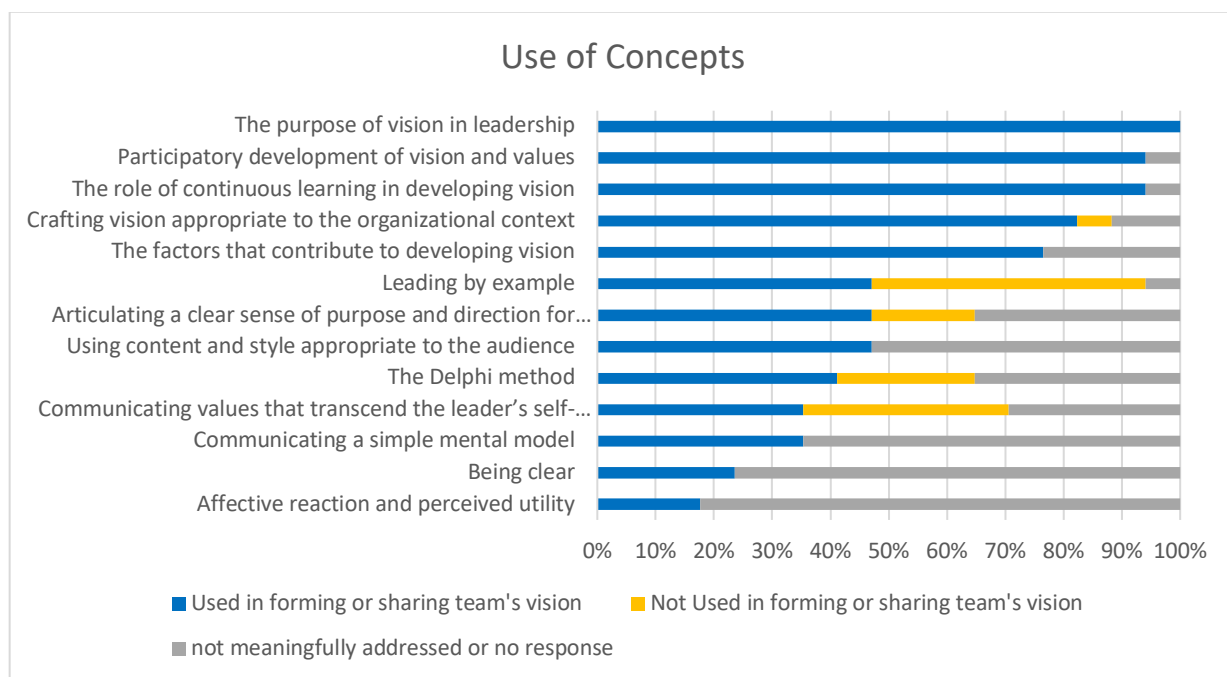


Figure 2. Extent to which students reported using the concept of the modules' topics, listed in the survey, in their projects, ordered from highest to lowest use.

Overall, as presented in Table 1, most of the students reported that their team used its vision in pursuing the team's project. For example, one student responded that "Yes absolutely, we knew where we were heading and we did what was needed to move forward." For students reporting lower or no use of the team's vision, the top reason was that the team's vision was problematic. For example, one student responded that "Our vision was flawed as we saw when we tried to use it or reflect on how we had used it. This helped discuss ways which we could make changes to the vision to something that we could actually use."

Table 1. Extent to which students reported that their team used its vision.

Team used its vision a lot	6
Team used its vision somewhat	9
Team did not use its vision	2

The students were split in assessing the modules' content. Seven respondents reported that the material was easy to understand, while three said that the modules would benefit from (a) more time to absorb the material, (b) more examples, and (c) more analytical skills. One student commented that the lectures "felt convoluted." However, none of the responses identified a particular concept or module as difficult to understand.

Looking at comprehension and recall of the modules' content, the students' responses suggest that they learned the key concepts in each of the modules. The students were asked to define in their own words the meaning of each the main concepts. For each response, we coded the student's primary description, and Figure 3 presents these results. Average recall was 76%. The clearest concept, appropriately enough, was that of being clear. The least-well-described concept, disappointingly, was that of communicating values that transcend the leader's self-interest. Overall, the data suggest that nine of the twelve concepts had at least 70% recall, and the lowest level of recall was 47%. Interestingly, there does not appear to be a meaningful correspondence between recall of concepts and use of concepts. Being clear had 100% recall but 24% use, leading by example had 94% recall but 47% use, while continuous learning had 94% recall and 94% use.

Conclusion

In this paper, we reviewed the theoretical and pedagogical frameworks for teaching vision in leadership for engineering students, articulated learning outcomes based on these frameworks, presented six modules teaching modules, and presented a two-part study assessing the modules' effectiveness. The project's results provide engineering educators with a ready-to-use set of teaching modules that have been demonstrated to be effective in producing learning outcomes for forming and sharing vision as engineering leaders, which should be useful at scales from the personal, to teams, to larger organizations. The results of our quantitative pilot study suggest that the modules helped students improve their forming and sharing of vision, in terms of self-assessed skills. The results of our fuller qualitative study suggest that the students used concepts related to forming vision more frequently than concepts related to sharing vision, which may be due to the study's small-team context. The results also suggest that the students largely found

their team's vision useful in working on their project. On average, 76% of the content of the 13 thirteen principal concepts conveyed in the modules were correctly recalled by students.

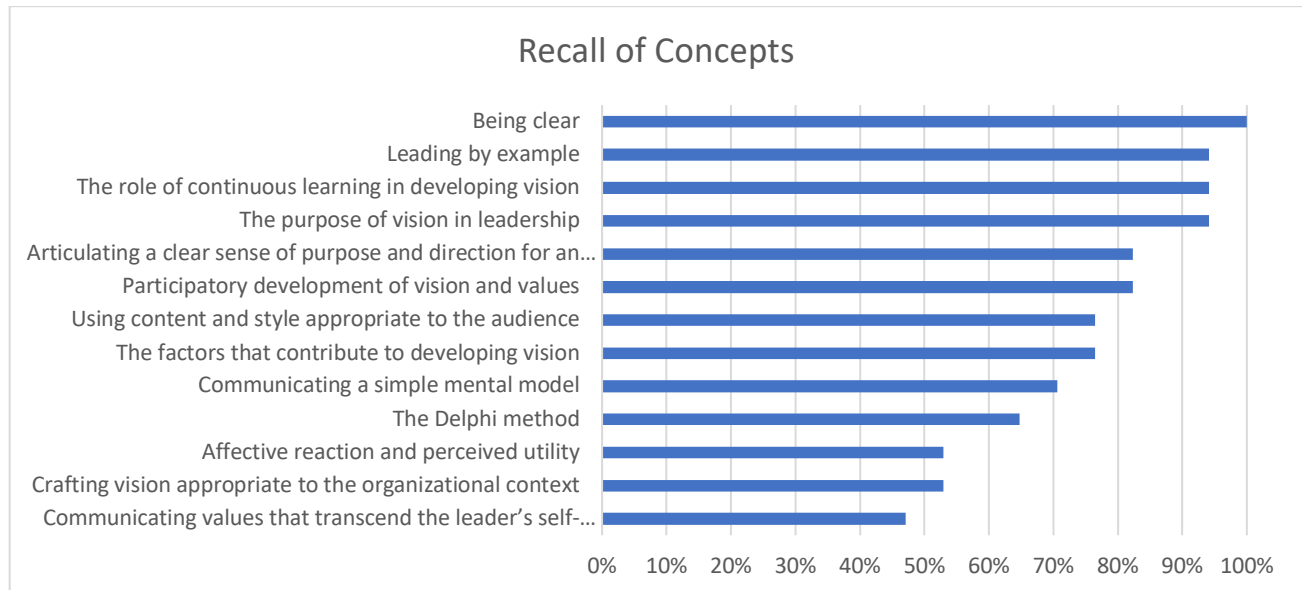


Figure 3. Recall of concepts, listed in the survey, measured by students' primary descriptions, ordered from highest to lowest recall.

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