ENGINEERING TEAMWORK: LOW STAKES TEAMBUILDING ACTIVITIES FOR HIGH-IMPACT UNDERGRADUATE EXPERIENCES

NICHOLAS A. CLEGORNE
AMY B. GRUSS
ALBERT M. JIMENEZ
Kennesaw State University, U.S.A.

ABSTRACT

Teamwork has been described as a leadership-coupled professional competency in post-secondary engineering education. It has been listed among the most critical professional skills by engineering industries and professional organizations. Here, a mixed-method case study is reported, which used Visual Thinking Strategies alongside a group project in an elective honors short course. Descriptive statistics and analysis are further supported by qualitative evaluation, which suggests that lower-stakes activities that provide team-building functions can, increase teamwork skills among undergraduate engineers. Implications for planning more team-building activities into engineering coursework are discussed. Effects for team-building are highlighted because it has been shown to foster collaboration, communication, and mutual trust among team members, leading to improved productivity, creativity, and innovation.

INTRODUCTION

Engineering has become inexorably linked to many facets of daily life in the twenty-first century. If society is to navigate a complex world successfully with overwhelming challenges such as globalization, economic competition, the energy and climate crises, and quantum leaps in information technology and its management, engineers must be integral to leadership in education, government, and industry (NAE, 2020). Appropriately preparing engineers for this task requires a holistic approach to developing professional competencies coupled with leadership development within preparatory programs for engineers.

Conflating leadership development - the shared process by which people work together to overcome challenges and meet goals - with the more managerial-focused endeavor of *leader* development can be exclusive and hinder innovative problem-solving (Garahan & Clegorne, 2020). Good leadership requires a holistic understanding of multifaceted problems, including technical, human, and conceptual elements (Mumford et al., 2000), and competencies to engage them all. Teamwork is among the most important competencies within engineering teams (Clegorne et al., 2021). However, how and when teamwork is taught as an element of shared leadership is critical. A student's developmental readiness and prioritization between task and process can determine how they value leadership as a tool for engaging in complex problems. Here we report the findings of a mixed-method case study during a five-week project which used visual thinking skills and art appreciation as a shared experience that scaffolded a team project for high-achieving engineers in a research-intensive university.

REVIEW OF LITERATURE

The Call for Leadership-Coupled Professional Skills

Engineers must grow more cooperatively and innovatively in teamwork to create complex, creative solutions to today's and tomorrow's challenges. The U.S. Bureau of Labor lists engineering as a high-demand need for the nation (Bureau of Labor Statistics, 2023). Organizations within the engineering field have also expressed a need for a workforce equipped with professional skillsets that match technical competencies (ASCE, 2021; NAE, 2020; ASEE, 2015). Though governmental and professional organizations have voiced the need for engineers with professional competence, developing the competencies within post-secondary preparatory programs has been less than ideal. Clegorne et al. (2021) further identified specific leadership-coupled competencies such as communication and teamwork.

There is a danger in misconstruing the need for more significant development of leadership-coupled competencies in engineering with a need for more positional leaders or managers. Indeed, the administrative arrangements of most organizations are, and will remain, relatively hierarchical, as is structurally necessary. Such hierarchical frameworks were evident during the development of the leadership-coupled competency framework (Clegorne et al., 2021). Simply mentioning the word “leadership” to CEOs and COOs in engineering firms conjured notions of positional authority and/or top-down management despite accreditation standards that suggest engineers have “an ability to function effectively on a team whose members together provide leadership**”** (ABET, 2023). Here we did not grapple with any call for “flatter” organizations or the disruption of current organizational structures (though such calls are essential to consider broadly). Instead, we focused this project’s scope on developing better team leadership, specifically through developing teamwork as a leadership-coupled competency.

Given the expressed calls for teamwork and problem-solving from the engineering industry and professional organizations, one might assume that significant curricular interventions would be employed. However, engineering programs typically have far fewer leadership-related objectives than other undergraduate degrees. U.S. post-secondary engineering programs averaged just 1.3 leadership competencies per program (for comparison, education programs averaged 13, and public service programs averaged 18.7) (Seemiller, 2016). Given these data, it is unsurprising that engineering students develop leadership competency at a slower rate than students in all other undergraduate majors (Stephens & Rosch, 2015). Beyond diminished leadership skills, Stephens and Rosch (2015) found that engineering majors predicted lower co-curricular involvement and fewer mentoring experiences in college. These predictors are alarming because co-curricular involvement and mentoring relationships have been identified as two of the most critical high-impact practices for leadership development in post-secondary settings (Priest & Clegorne, 2015).

Distributed Leadership and Teaming in Engineering Practice

Any organizational structure that uses shared ideation and accountability for bringing about or managing change is now commonly referred to as having distributed leadership (Harris et al., 2007). Spillane et al. (2004) have produced the most developed theoretical work on distributed leadership, defining it as a socially distributed activity that “stretch(es) over the activities of a number of individuals and...is completed by numerous leaders” (p. 20). Practically speaking, aspiring engineers’ appeals for stronger leadership skills are centered on this workplace ecosystem (Hacker, 2017). Western’s (2013) distributed leadership, particularly his notion of eco leadership, is consistent with the industry’s objective for young engineers to contribute in various team roles within the workplace and to modern society (NEA, 2020).

The American Society of Civil Engineers (ASCE) echoes the calls from industry and professional organizations for engineers with better leadership and teamwork competency. The ASCE regularly publishes its Body of Knowledge (BOK) which it defines as “the necessary knowledge, skills, and attitudes required of an individual entering the practice of civil engineering at the professional level”

(Civil Engineering, 2019). A recent content analysis of the current BOK showed that the publication frequently espouses the eco-leadership paradigm. However, the precise language employed to define leader training often undermines distributed leadership principles in favor of a larger organizational ecosystem that privileges technical skills above human skills (Garahan, Clegorne, & Simmons, 2020). Regardless of the authors' intentions, the BOK does not promote the human skills associated with teamwork because the vocabulary used to communicate eco ideas still has roots in the 20th-century hierarchical administrative approaches.

Kotter demonstrates the peril of combining management and leadership (Kotter, 1999). He suggests that management mainly concerns processes and materials, whereas leadership primarily concerns people and connections. In such a paradigm, leadership is more distributed, and management is inherently hierarchical. Solely focusing on leader development is challenging because one assumes that the focused training of this elite class of team members will inspire greater benefits throughout the organization. In such a paradigm, leaders aspire to be ideal amalgams of technical expertise and inspirational charisma as described in the early 20th-century notions of the "Great Man" and "Trait Theories of leadership" (Northouse, 2016; Western, 2013). Both perspectives rely on the idea that leaders are born rather than developed.

In contrast, leadership development promotes a shared process highly contingent on context and perspective (Heifitz et al., 2009; Jepson, 2009; Skipper & Bell, 2006; Western, 2013). It follows that creating a leadership culture throughout the engineering workforce (i.e., Robledo, Peterson, & Mumford, 2012) instead of a cadre of leaders could lead to improved teamwork and resilience in addressing complicated technical problems. For most firms, management and positional authority will always be necessary to ensure the systematic operation of the organization. On the other hand, teams of people rather than technical systems carry out the mission-driven work of companies, and the human network feeds on leadership. Organizations need effective management and leadership.

Understanding the varied possible effects of the BOK's discourse requires comprehending the distinction between management training (sometimes tied to leader development in the BOK) and leadership development that is entangled with good teaming. The focus of leadership education should shift from the leader to the systems, surroundings, and, most importantly, other team members. This creates room for practitioners and educators to stress team connectedness and the idea that being a leader might often entail being a follower and vice versa.

CONCEPTUAL FRAMEWORK

Conceptually, this work relies on Marton's (1981) Critical Realism and, to some extent, Alexander's (2007) Philosophical Pragmatism, as it engages both reality and individuals' conceptions of that reality in equal parts. In other words, the internal relationship between the phenomenon and the experiencer is critical. Our case study surrounded a five-week special course for honors engineering students wherein two primary theoretical applications were employed. First, Abigail Housen's (2002) theory of aesthetic development and accompanying Visual Thinking Strategies (VTS) were used to plan activities for the participants, creating a shared experience and offering a non-pejorative and ambiguous environment to engage complex ideas. Second, Driskel et al.'s. (2010) Collective Orientation (CO) scale also served as a limited quantitative component of this mixed-method case study to measure the change in CO. Observations from the quantitative part of the case were then used to frame participants' teamwork experiences during the study qualitatively.

Aesthetic Development and Visual Thinking Strategies

Housen (2002) demonstrated that given an experience with subjective stimulus, in her case, art, there were predictable stages of an individual's distinct interpretation. In subsequent work, she established that viewers' ways of evaluating images predictably change when exposed to a carefully curated series of VTS materials and artworks. Also, increased aesthetic cognition was followed by increased critical and creative thinking. Philip Yenwine (1997) suggests that individuals expanded abilities that were not generally connected with art during VTS sessions. Housen's findings also remain consistent across the boundaries of race and gender (Housen, 2002). The assertion that VTS is a generally applicable pedagogy for expanding creative and critical thinking provided an attractive model for coaxing out dialogue and expression among team members.

Collective Orientation

Driskell et al. (2010) explained that successful team members value collaboration over independence and favor cooperation over individual controls. The two underlying characteristics of Collective Orientation are affiliation (the preference for teamwork over individual work) and dominance (self-interest, dominance, and control vs. other-interest and cooperation). These two general factors within the Collective Orientation model are corroborated by evidence from other studies. *Getting along* (achieving social acceptance) and *getting ahead* (achieving status and power) are two fundamental themes driving social interaction, according to Hogan (1983). Wiggins and Trapnell (1997) refer to these two broad constructs as dominance/agency and nurturance/communion, whereas McClelland (1961) called these two factors the need for affiliation and the need for power. Driskell et al. (2010) quantitatively linked notions of affiliation, communication, and getting along with more successful teams. The Collective Orientation construct was linked to team productivity across various team tasks. It has been demonstrated that Collective Orientation is linked with efficient team performance in decision-making, negotiation, and execution activities.

PURPOSE OF THE STUDY

This study aimed to determine if VTS activities might increase Collective Orientation among engineering students and how educators can plan practical experiences accordingly. We sought to uncover answers to RQ1 using a pretest/posttest methodology with scores on a Collective Orientation instrument (Driskell et al., 2010). Several qualitative sources provided data that was coded using phenomenographical techniques (e.g., Aflague & Ferszt, 2010; Marton, 1986) to explore potential answers to RQ2.

RESEARCH QUESTIONS

Given the reported growth individuals may experience through participation in VTS activities, we wondered if exploring the subjectivity and ability of art together might lead engineering team members to develop human and interpersonal skills towards expanded Collective Orientation. Were this the case, it would have implications for planning educational experiences within post-secondary engineering curricula. To this end, a mixed-method case study was designed to answer two questions:

Research Question 1 (RQ1): What effect will a five-week course employing Visual Thinking Strategies and an engineering group project have on students' measured Collective Orientation scores?

Research Question 2 (RQ2): What can be learned about planning experiences to develop Collective Orientation from students' varied experiences in the course?

METHODOLOGY

We were provided an opportunity to explore how VTS activities might affect Collective Orientation in a five-week exploratory honors course at a research-intensive southeastern university. This short honors course allowed students to explore topics outside their typical program of study with very little risk to their grade point average, time, or primary program. While participation was required to complete the credentials to graduate with honors at the university, students were given various choices to meet these requirements. Thus, the participants in this study were deeply motivated, high-achieving individuals, a trait common to many engineering students (ASCE, 2021).

Research Design

This study employed a sequential explanatory mixed method design that involved sequentially collecting and analyzing quantitative and qualitative data (Teddlie & Tashakkori, 2009). The design began with collecting and analyzing quantitative data using a Collective Orientation instrument to provide a broad understanding of how the VTS experience changes student teaming dispositions. This quantitative exploration was followed by collecting and analyzing qualitative data captured through semi-structured interviews and analysis of student video logs and assignment examples. The qualitative analysis provided a more detailed and nuanced understanding of the topic. This design was beneficial because there was a need to understand the meaning and context behind the numerical data, especially given the localized case (Creswell & Plano Clark, 2018).

Research Participants

Participants self-selected into this study by signing up for the honors course offering and signing informed consent. It was made clear to all students that participation was not required and would not affect their grades. All 22 members of the class chose to participate. Table 1 provides each participant's brief profile and a pseudonym assigned to maintain their anonymity.

A variety of engineering majors were represented, along with one participant who was not an engineer (indicated by asterisks in the table). Participants were relatively balanced between male and female genders, with one student identifying as non-binary. The researchers acknowledge that unbalanced representation should always be interrogated in social science and recognized as problematic. In this case, underrepresentation was found within the racial makeup of the class. White students were overrepresented, as they are in most engineering majors (NSF, 2021). The course also consisted of students who identified as Black, Asian/Pacific Islander, Middle Eastern/North African, and Hispanic. Considering the small size of the case and overarching demographics within the engineering fields, however, this case was relatively diverse. Given the compact size of the course, there was insufficient statistical power for inferential statistics. However, descriptive statistics and qualitative data provided evidence to draw some initial conclusions.

Table 1 Overview of Participants

Pseudonym	Year of Study	Gender	Race	Engineering Major
Alissa	4th Year	Female	White	Industrial and Systems
Zumena	2nd Year	Female	Middle Eastern/North African	Civil
Eli	2nd Year	Male	Black	Public Relations*
Michelle	4th Year	Female	White	Computer Eng.
Darren	4th Year	Male	White	Civil
Henry	4th Year	Male	White	Computer
Shaun	3rd Year	Male	White	Mechanical
Jessica	4th Year	Female	White	Civil
Melissa	4th Year	Female	Hispanic Non-White	Computer
Hailey	3rd Year	Female	White	Environmental
Devin	4th Year	Male	White	Mechanical
Nia	4th Year	Female	Black	Environmental
Bella	4th Year	Female	Hispanic Non-White	Civil
Thomas	3rd Year	Male	White	Mechanical
Ilsa	4th Year	Female	Hispanic Non-White	Civil
Jamie	4th Year	Female	Hispanic Non-White	Civil
Nola	2nd Year	Female	White	Mechanical/Tech
Arman	2nd Year	Male	Middle Eastern/North African	Mechanical
Maggie	4th Year	Female	White	Civil
William	2nd Year	Male	Asian/Pacific Islander	Computer
Terry	3rd Year	Non-Binary	White	Mechanical
Nicholas	4th Year	Male	White	Industrial and Systems

* Indicates non-engineering major

Research Instruments

We used two instruments to collect data for the case. The first was the Collective Orientation Questionnaire (Driskell et al., 2010). The instrument included 15 five-point Likert-type items that, when averaged, produced an overall score indicative of Collective Orientation (1 = lowest Collective Orientation and 5 = highest) for each participant. We administered the Collective Orientation Questionnaire once at the outset of the course and again after all course activities were completed in a pretest/posttest design. A semi-structured qualitative interview protocol was also used to facilitate focus group interviews with each project group after the experience. Further data was gleaned through observations of class meetings and a review of recorded student video logs, presentations, and class discussions.

Data Collection

Over five weeks, students met each Friday and worked on their projects in between. The initial class meeting was designed to orient the students to the project, provide some background on VTS, and group the students into their project teams. Students selected a campus issue that affected their daily life, such as campus beautification, parking reform, etc., for which they would design and propose solutions at the end of the course. Students also completed the pretest of the Collective Orientation instrument at the outset of day one.

On the second and fourth class meetings, the students met at an on-campus art museum where docents trained in Visual Thinking Strategies guided them through several art exhibits and facilitated a discussion using the tenets of VTS. During a five-minute walk back to the classroom after visiting the art museum, students captured their impressions and reflections from the museum using a video log on their phones. They then participated in group and class discussions once arriving at the classroom.

The third and fifth class days were reserved for group work, class discussion, and presentation of the group projects (on the final day). Once the class was over, each group debriefed with a 40 to 60-minute focus group interview with a researcher about the process. All individual reflections, class discussions, projects, and debriefs were recorded and transcribed.

Data Analysis

After the quantitative Collective Orientation data was collected, we summed and averaged the scores for each participant on both the pretest and posttest instruments. The dependent variable related to RQ1 was *change in Collective Orientation*, hereafter *CO change*. Data hereafter are expressed as the raw change on the five-point scale and the percent change relative to a participant's pretest score. Individual CO change scores were grouped using different independent variables to determine if the data had links of interest. Simultaneously, qualitative data gleaned from recordings of reflections, class meetings, group presentations, and focus groups were analyzed. Verbatim transcripts were coded using qualitative analysis software wherein we identified significant text, statements, and phrases, identified meaning, and assigned codes to the statements. We employed Marton's method of phenomenographical analysis (Marton, 1986; Marton & Booth, 1997), which others have further operationalized (Aflague and Ferszt, 2010). This method involves several steps, as noted in Table 2. Given that the objectives of interest in this study were the second-order perceptions of a phenomenon as opposed to the phenomenon itself, phenomenography was an appropriate methodology for this qualitative study. Phenomenography assumes the existence of a single phenomenon or "reality," in this case, the VTS experience in the honors class.

Table 2: Phenomenographic Analysis (Adapted from Aflague & Ferszt, 2010)

Familiarization	Transcriptions were reviewed several times while listening/viewing the recordings.
Condensation	Significant statements were assigned codes that were short but representative of the statement.
Comparison	Significant dialogue is compared to discern similarities or differences.
Grouping	Similar responses are clustered.
Articulating	There is an attempt to draw out the essence of experience noted in statement groups (code clusters). Grouping and articulating may repeat several times.
Labeling	Themes of essential experience are given appropriate titles.
Contrasting	Essential experiences are compared to ascertain a range of experiences within the exploration.

Ultimately, the final product of this analysis is the development of what Marton (1986) refers to as the outcome space. The outcome space represents the relationship between participant responses and the essences within. This representation is how we can examine the whole picture of the collective human experience of given phenomena in the face of variation across participant expressions of those phenomena (Åkerlind, 2005). This process, using multiple observations of multiple groups and individuals over time and across numerous interviews, settings, and instances, lends trustworthiness and credibility to the findings.

FINDINGS

Descriptive statistics from the case provided evidence toward answering the question about the effect a five-week course employing Visual Thinking Strategies and an engineering group project have on students' measured Collective Orientation scores (RQ1). Collective Orientation - the dependent variable in this portion of the analysis - improved across the participants by an average of 6.67%, and there were some interesting differences in group means. When considering quantitative data, we must consider the small size of the case. It is possible that, over the five weeks of the case study, participants experienced other social interactions outside the case that might have impacted the Collective Orientation. Still, measurable increases in Collective Orientation within this relatively short period warrant further examination. Qualitative inquiry assisted in helping unpack the experiences of the participants and how they attributed their development to the course activities and answer the question regarding what can be learned about planning experiences to develop Collective Orientation (RQ2). While each experience was unique, the experience itself was positively discussed by all participants. The notion that a shared experience within the context of a lower-stakes project emerged among the most powerful themes. Below, we share more specific descriptive statistic comparisons and qualitative examination of the research data.

Quantitative Data

In general, the participants in the case group improved Collective Orientation by 6.67%. Table 3 shares the pretest, posttest, and difference for each individual and each score's mean and standard deviation. Individual differences were apparent in the data. Descriptive statistics were examined across independent variables such as race, gender, project team, and college major. Each of these areas of analysis is discussed below.

Table 3 Participant Scores and Descriptive Case Statistics

Pseudonym	Pretest	Posttest	Change (%)	
Zumena	2.47	2.6	0.13	(5.41%)
Jessica	3.13	3.2	0.07	(2.13%)
Hailey	3.20	3.67	0.47	(14.69%)
Nia	3.20	3.73	0.53	(16.56%)
Ilsa	3.27	3.4	0.13	(4.08%)
Nola	3.40	3	-0.40	(-11.76%)
Shaun	3.07	3.53	0.46	(15.11%)
Devin	3.20	3.8	0.60	(18.75%)
William	3.60	3.47	-0.13	(-3.61%)
Terry	3.73	4.47	0.74	(19.73%)
Nicholas	3.93	3.2	-0.73	(-18.64%)
Alissa	2.27	2.53	0.26	(11.62%)
Eli	2.60	3.13	0.53	(20.38%)
Darren	2.87	3.33	0.46	(16.16%)
Henry	3.07	3.4	0.33	(10.87%)
Thomas	3.27	4.13	0.86	(26.43%)
Arman	3.47	3.47	0.00	(0.10%)
Michelle	2.80	3.4	0.60	(21.43%)
Melissa	3.20	3.87	0.67	(20.94%)
Bella	3.27	3	-0.27	(-8.16%)
Jamie	3.40	3.07	-0.33	(-9.71%)
Maggie	3.47	3.13	-0.34	(-9.71%)
Mean	3.18	3.39	0.21	(6.67%)
StDev	0.40	0.45	0.43	

Race and Gender

Race and gender identity information was collected from participants at the outset of the case. Here, we report the group pretest and posttest means and average CO change as scale intervals and percentages relative to the pretest score. Every subgroup sorted by race or gender showed an increase in CO save for one. There was a single participant who identified as an Asian male that showed a decrease in CO (-3.61%). Given the lack of sample size, it is impossible to say if this trend would carry over to others sharing the same identity. Averages across all other race and gender groupings showed positive change. While a larger, more equally distributed sample might have allowed for an inferential comparison of group means and variations, it was beyond the scope of this case and intervention. Here it suffices to share that an average positive CO change was recorded across nearly all included races and genders. Tables 4 and 5 provide details of the descriptive statistics broken down by race and gender.

Table 4 Race and Collective Orientation Change

Race	*n*	Pretest		Posttest		Change (%)
		Mean	StDev	Mean	StDev	
Asian	1	3.60	0	3.47	0	-0.13 (-3.61%)
Black	2	2.90	0.42	3.43	0.42	0.53 (18.28%)
Hispanic	4	3.28	0.08	3.34	0.40	0.05 (1.57%)
White	13	3.18	0.42	3.45	0.50	0.26 (8.19%)
Middle Eastern/Northern African	2	2.97	0.71	3.04	0.62	0.07 (2.30%)

Table 5 Gender and Collective Orientation Change

Race	*n*	Pretest		Posttest		Change (%)
		Mean	StDev	Mean	StDev	
Female	12	3.09	0.38	3.22	0.42	0.13 (4.14%)
Male	9	3.23	0.40	3.50	0.31	0.27 (8.23%)
Non-Binary	1	3.73	0	4.47	0	0.74 (19.73%)

Project Teams and Participant Majors

A team design project was the primary activity in the honors course that framed the case. Participants divided themselves into teams of five or six and were asked to choose an issue on campus that affected their daily lives. Their task was to develop a strategy to improve the issue as a team and present a proposal to the class at the end of the five-week cycle. The products of this work are less important here than the process by which they were developed and their impact on the learners. The teams named themselves, but here we will use deidentified team names to protect the participant's anonymity. Table 6 presents relevant pretest and posttest descriptive statistics and team means.

While each team yielded positive gains on average, team Gamma showed the greatest increase in CO with an average CO change of 0.41 or 14.01% relative to their pretest score. The "Alpha" and "Beta" teams showed substantial gains of 5% and 5.34%, respectively, and the "Delta" team averaged a smaller increase of 2.09%. Of note here is that the three teams with the highest improvement scores also have relatively few members who decreased their individual CO (no more than two members of any team). Conversely, Team Delta had three members who had meaningful negative CO changes (Jamie, Bella, and Melissa with -8.33, -6.67, and -8.33, respectively). These team members accounted for over half of team Delta's membership.

Table 6 Team membership and Collective Orientation Change

Project Team	Participants	Pretest Mean	Pretest StDev	Posttest Mean	Posttest StDev	Change (%)	
Alpha	Zumena, Jessica, Hailey, Nia, Ilsa, Nola	3.11	0.33	3.27	0.43	0.16	(5.00%)
Beta	Shaun, Devin, William, Terry, Nicholas	3.51	0.36	3.69	0.48	0.19	(5.34%)
Gamma	Alissa, Eli, Darren, Henry, Thomas, Arman	2.92	0.44	3.33	0.52	0.41	(14.01%)
Delta	Michelle, Melissa, Bella, Jamie, Maggie	3.23	0.26	3.29	0.36	0.07	(2.09%)

It was also noted that positive CO change increased as teams became more disciplinarily diverse. Team Delta was the least interdisciplinary, with only civil and computer engineers. All three civil engineers (Jamie, Bella, and Melissa) showed decreases in CO – as noted above - while both computer engineers showed large increases (Michelle with 15% and Maggie with 16.67%). The relationship of CO change and major is further discussed below but appeared to intersect with other teams in this case. For instance, team Alpha and team Beta (the teams with moderate average CO increases) represented at least three different engineering disciplines. Further, team Gamma, the team with a very high CO change, boasted five different disciplines, including one public relations member who was not in the engineering or technology fields. Disaggregating CO change data by major (Table 7) helped further unpack this connection.

Table 7 Participant Major and Collective Orientation Change

Major	*n*	Pretest Mean	Pretest StDev	Posttest Mean	Posttest StDev	Change (%)	
Civil Engineering	7	3.12	0.35	3.10	0.26	-0.02	(-0.62%)
Computer Engineering/Sci	4	3.17	0.33	3.54	0.23	0.37	(11.63%)
Environmental Engineering	2	3.20	0	3.70	0.04	0.50	(15.63%)
Industrial & Systems Engineering	2	3.10	1.18	2.87	0.47	-0.23	(-7.58%)
Mechanical Engineering	6	3.36	0.23	3.73	0.52	0.38	(11.26%)
Public Relations	1	2.60	0	3.13	0	0.53	(20.38%)

We will note, again, that the small size of this case does not yield the statistical power to conclusively demonstrate a relationship between diverse teams and their ability to affect individual Collective Orientation. However, the team means within this case suggest the relationship to interdisciplinarity should be considered. Some notable differences were observed when the data were disaggregated according to major. Computer, environmental, and mechanical engineering participants averaged substantial gains in CO change relative to their pretest scores (11.63%, 15.63%, and 11.26%, respectively). The public relations student saw even greater improvement, with a CO change of 20.38%. The civil and industrial, and systems engineers in the case, however, showed reductions in CO change. Civil engineers averaged a CO change of -0.62% and industrial and systems engineers averaged a reduction of -7.58%. The trend with civil engineers in the case intersected with group membership as every member within Delta with a reduced CO change score was a civil engineer.

Quantitative Summary

One further note that can be shared has to do with the pretest score and subsequent change in CO. Participant pretest scores were arranged from lowest to highest, and the sample was divided into three balanced strata (7 participants in the low group, 8 in the middle group, and seven in the high group). When we stratified the sample based on pretest scores (Table 8) it became apparent that those with lower initial CO benefitted the most from the case study activities.

Table 8 Pretest Strata and Collective Orientation Change

Group by Pretest	***n***	**Pretest**		**Posttest**		**Change (%)**	
		Mean	**StDev**	**Mean**	**StDev**		
Lower Pretest	7	2.73	0.30	3.13	0.41	0.40	(14.56%)
Moderate Pretest	8	3.22	0.05	3.60	0.37	0.38	(11.92%)
Higher Pretest	7	3.57	0.20	3.40	0.51	-0.17	(-4.76%)

Participants scoring in the middle of the sample also benefited substantially. However, among those with the highest test scores, only one individual increased their CO score, another remained the same, and the remaining five had meaningful losses in Collective Orientation.

Ultimately, we can only address the extant data in this case to address RQ1. Within this small exploratory case, the activities generally increased Collective Orientation among most participants (72.7%). Some individual aspects, particularly college major and the interdisciplinarity of the project team itself, seemed to influence participant CO change more than others. Additionally, the case activities appeared to substantially improve the scores of those with lower and moderate pretest CO (only one of fifteen participants across these groups showed a negative change). However, case activities appeared less successful with high pretest scorers (only one of 7 participants in this group showed a positive change). While the latter may result from compression at the top of the CO instrument's scale, we posit it is unlikely, as even the highest pretest score (3.93) still had plenty of capacity to grow within the scale. Given the smaller size of the study and related lack of statistical power, we will share the findings with the case's qualitative data below.

Qualitative Themes

Theme 1: Subjectivity as a Shared Experience

As might be expected, individual experiences with the art museum and VTS reflections varied widely from participant to participant. Personal reflections of the art exhibits were descriptive of the art and whether they, as an individual, liked it or not. Some participants immediately saw connections between the museum visits and the course objectives. The most interesting responses, however, were discussed with regards to how the experience helped participants to hear different opinions on a given issue. William explained, “When it comes to art, you have to think very abstractly, and you have to think about other people’s views and their perspective.” Arman was struck by the “different perspectives that people could have on the same piece of art” and went on to share:

> “I really did not like the museum...but what I really enjoyed about it is how everybody’s else’s thoughts are completely different. They can be completely random, completely unique, but you can kind of see where they’re coming out from. And it’s really unique how people come up with these ideas because like, it’s definitely from like, past experiences and everything.”

Alissa agreed saying, “It shows how we would all work together as teams in our future careers...you kind of have to figure out how to work together within that to come up with the best possible product that you can offer.” Terry summed up the points that his peers were making by saying:

> “You can just stop personalizing your own ideas...anyone not liking this idea isn’t a reflection of their thoughts on me, you know, kind of starts to fade away as we just start to argue about something kind of arbitrary. Like in the museum, you know, deciding one person thinks this, [another] person thinks this...it’s entirely subjective and there is no, like, qualitative answer that is anymore correct than another. Then the boundaries kind of go away and we stop personalizing.”

This theme was one shared across participants. While, as illustrated above, the personal connections were varied, the core theme was evident. In short, the VTS experiences at the museum provided a shared understanding of subjectivity that carried over into group work and meaning-making as a team.

Theme 2: Participant Thoughts on Group Work

Participants’ views on group work could be sorted along a spectrum within the case. At one end, we found participants who were repulsed by group work. In the middle of the spectrum were those amenable and those excited about it on the other side. Those who identified with the first group shared sentiments with participants like Alissa who captured the feeling in two words, “Oh, no!” Zumena expanded the feeling sharing:

> "I usually resent [group work] and I’m immediately like, Oh my God, no, I don’t really want to do group work as much....trying to form a group of people who maybe you don’t really know as much because you [don’t know] their work ethic is you don’t know if they’re gonna help with the group at all.”

Shaun attributed the distaste for group work to a lack of experience, saying, “I think just in general, just a lot of those upper-level classes don’t have that many presentations with group members. So you’re not always comfortable with working with other people or not.” Taking up a position in the middle of the spectrum Michelle simply stated, “like the idea. Usually...I work better just working alone, but my first reaction was it’ll be a good chance to kind of help with [teamwork skills].” In a quote more representative of the side of the spectrum that was excited about group work Nola said, “it’s really cool to just see different people’s perspectives and work to put them all together and create one thing.”

Far more participants than not were dubious of group work, but most also were open to the potential for skill development. The primary source for the openness was a recognition that teamwork was a desired skill within the profession. Devin highlighted this recognition:

> “I attended a talk recently with some engineers from Lockheed Martin, and one of their big focuses was also the professional skills was just making sure that we knew how to properly communicate and work effectively with other people and not just have those other skills of the technical knowledge.”

Despite the discomfort with group work, participants collectively shared that the group project experience was better in the honors course than in past experiences. Zumena concluded her statement above by sharing “But this time it was this time it went really well because everyone had their own ideas, and everyone helped.” Zumena’s statement was representative of most participants, and the sentiment was, “This time was better because everyone pulled their weight”. Given the overwhelming response that the group projects were better received by participants in conjunction with then generally raised CO scores, interview questions sought to further uncover why participants felt the experience was different this time.

Theme 3: Shared Language and Lower Stakes Were the Difference This Time

The theme echoed across every focus group, and all individuals was the VTS experience as a point of departure and its function in the group expectations of the course’s product. The VTS activities at the museum provided a shared experience and explicit example of subjectivity when observing the same scene, whether it was a piece of art or a campus issue. This was discussed earlier in the first theme, but it bears need for repeating because it was such a thread through participant responses. Participants regularly discussed the foundation the experience set for their work. There was no evidence that VTS, specifically, was the operative experience. Rather, VTS served as a shared experience highlighting individual subjectivity.

Rooted in the participants’ shared experiences, the final project in the class was a group PowerPoint presentation on their proposal. The participants agreed that the lower stakes nature of the project and less involved product allowed them more time and freedom to engage with one another. This was compared to the project experiences typically found in their engineering classes, where the products were so extensive, and timelines were so short that they did not have time to come together as a team. Henry captured the point of departure for the theme, sharing, “Well, again, like there wasn’t as much pressure here because it wasn’t like we were trying to make some real, formal, long essay.” Devin summed up the challenges with typical capacity issues in class projects, saying, “You have one person step up very quickly, and then everyone else needs to fall in line and have a part to do and actually do that in that short period of time.” Terry agreed and contrasted the typical experience with the case’s project: “It didn’t feel like that time crunch was on us...we really got the chance to sit and think about it and decide, talk, and communicate.” Zumena drove the point home when she shared, “Having the light workload definitely helped with like throwing out like there was a bigger or larger portion of living out ideas so we could ...find a topic...because we had like a bunch of different ideas at first. If it was maybe a heavier workload or [faster timeline], we may not have found the idea that we did, and it may not have been as completely thought out”. In short, the quotes above found enthusiastic agreement with all group members in the focus groups and highlighted an emphasis on lower-stakes projects for increasing practical teamwork.

The illustrative comments shared so far in this theme have come from the membership of teams Alpha, Beta, and Gamma. Team Delta's responses to the same interview questions (general questions about how they felt about the project) yielded a different perspective. While the other teams seemed to engage more collaboratively throughout the experience, Delta set aside some time in the beginning to collaboratively plan the project before dividing tasks and operating more independently towards a shared goal. Bella shared:

> "Of the five days, we used three of them solely for collaborating... there was no real rubric to it so it was supposed to be a simulated to the real world as possible...that sometimes came with...lack of communication. And I know that I, as a person...need a lot of structure."

Michelle picked up from there, adding:

> "I agree. Because...you didn't really have a set guideline like you usually do for a lot of projects. [In the honors class] you are kind of able to kind of explore what you wanted to do and how you wanted to do it with this project. But I thought that was nice - the freedom that we had."

Despite the emphasis on early communication, team Delta ended up dividing tasks in favor of personal accountability rather than teamwork. Bella explained, "I think splitting the work into different tasks and like specific goals for everyone individually helped because it created like accountability, and it also made the end goal clear. And like the bigger picture, by separating it into smaller parts." Team processes from that point were described more in terms of feedback and evaluation on individual efforts and pulling together the presentation.

Team Delta's approach, as compared to that of the other teams, is notable because Delta was the team that had the lowest CO change relative to their pretest scores (see Table 6 above). While Alpha, Beta, and Gamma described collaborative processes, contrasting this approach to the division of labor strategy used in their previous engineering team projects, Delta applied their earlier methods in this course instead. Looking back to the quantitative data, the comparison is interesting. Some members of team Delta increased their CO decidedly while others showed substantial losses. We suspect Delta's choice to employ more individualistic strategies is a potential contributor to some members' negative individual change scores and lower average change scores when compared to other teams.

DISCUSSION

The findings above discuss the quantitative and qualitative evidence from this 22-participant mixed-method case study. Ultimately, the quantitative data suggest a general improvement in CO within the case and has highlighted some identity-based and experiential differences in CO change. The qualitative analysis has provided contextual evidence that shared experiences, explicit attention to individual subjectivity in groups, and low-stakes introductory team tasks were appreciated within group projects. Both the quantitative and qualitative data support the notion that educational experiences can be planned to facilitate better teaming in post-secondary educational experiences.

We conducted this case study because we were interested in the applicability of VTS in educational experiences designed to improve leadership-coupled competencies, particularly those associated with teamwork. The exploratory findings of this case suggest that engineers are no different than others when it comes to team-building. However, participant responses illustrate that we often do not plan educational time to develop teams before thrusting them into production tasks.

The result was apparent in the participants' distrust of group work and the rationale they provided to support their concerns. We posit that participant statements about the shared VTS experience, gaining comfort with subjectivity, and positive experience with the lower stakes projects are tantamount to a team-building exercise. It is unsurprising, then, that most (72.7%) of the participants increased their Collective Orientation.

Team-building is widely accepted in the workforce as an essential element of group performance and productivity. Team-building has been shown to increase trust, communication, team effectiveness, and job satisfaction (Little & Luebbe, 2016; Capurro & Britain, 2017; Steffens et al., 2018), and has also been demonstrated to improve the individual outlook on several psychological factors such as optimism, hope, resilience, and self-efficacy (Park & Lee, 2019). Overall, these studies suggest that team-building can positively affect trust, communication, job satisfaction, team effectiveness, and employee well-being. This is further supported by Stumpf and Edwards' (2021) meta-analysis that synthesized the findings of 67 studies on the impact of team-building interventions on team outcomes. Though the meta-analysis found that team-building interventions significantly positively affected team cohesion, communication, and task performance, these effects were more potent when interventions were targeted at specific team processes and contextualized to the team's goals and needs.

IMPLICATIONS FOR EDUCATIONAL PLANNING

Following the discussion above, it is important to note that the effectiveness of team-building interventions can vary depending on the context, task, and individuals involved. This case study provides some limited evidence that one particular pedagogy – Visual Thinking Strategies – and a low-stakes team project supported the development of teamworking skills among a small case of undergraduate engineers. We suggest that finding opportunities to employ low-stakes team-building strategies – those with a minimal impact on students' grades - early in engineering programs and coursework requiring new teams is essential.

Across all participants, group work was a challenging subject. While different individuals were more or less comfortable performing in groups, the participants all shared that high-stakes projects with significant impacts on their course grades were deterrents to team-building. VTS activities appeared useful in helping students recognize subjectivity within problem-solving tasks and catalyzed conversation and team-building. However, we suspect that various other team-building strategies might be equally effective, provided that students are given the freedom and time to explore teaming without the threat of permanently damaging their grades or career aspirations. Taking time to plan the scope and sequence of these interventions carefully is something post-secondary engineering programs should consider.

Providing space to develop collective or team orientation and specific relationships with a given team requires dedicated time and space within college coursework. Engineering curricula are traditionally saturated with the technical skills that the field demands. One might argue that finding the space for proper team-building is impossible given the long list of technical skills required to produce a competent engineer. We posit that more effective teams are more efficient.

The exercise in this study was completed in five 90-minute sessions across approximately one month. Faculty and curriculum designers in post-secondary engineering should consider the overall time savings in the curriculum if human skills are given even the most rudimentary attention in a safe space. Planning such experiences before important group projects will likely have powerful implications. Effective teams spend less time arguing and more time collaborating to produce results.

Corporations in the United States connected to industries that hire engineering graduates understand this (Steffens et al., 2018) and devote time and funds to develop - or remediate - human skills that emerging engineers lack (National Academy of Engineering, 2020). Perhaps higher education institutions should plan for foundations of human skills development with leadership coupled with competency preparation towards teamwork. If industries primarily concerned with production recognize how effective teams save time, so should engineering programs.

CONCLUSION

A quote attributed to Abraham Lincoln reads: "Give me six hours to chop down a tree, and I will spend the first four sharpening the axe." While the tasks at hand for early career engineers are primarily technical, most of the problems they will face require complex and diverse teams to address. Preparing for the work is about more than having the right technical skills. We must plan time to "sharpen the axe" – in this case, develop the human skills – that allow competent technical personnel to flourish, both inside the classroom and beyond.

As team-building approaches are applied in various engineering courses, this line of inquiry would be supported better with further research. Different team-building methods and shared experiences might be explored across different contexts to determine the most effective approaches. Additionally, larger cases with greater samples may provide more generalizable findings. Taking time to explore and plan these experiences within post-secondary engineering curricula may support the development of professional skills that have remained elusive in the curriculum.

REFERENCES

ABET (2023). *Criteria for accrediting engineering programs, 2022-2023*. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2022-2023/

Aflague, J. M., & Ferszt, G. G. (2010). Suicide assessment by psychiatric nurses: A phenomenographic study. *Issues in Mental Health Nursing, 31*(4), 248-256.

Åkerlind, G. (2005). Learning about phenomenography: Interviewing, data analysis and the qualitative research paradigm. In *Doing developmental phenomenography* (pp. 63-74). Melbourne: RMIT University Press.

American Society of Civil Engineers (2021). *Report card for America's infrastructure*. https://infrastructurereportcard.org/

American Society for Engineering Education (2015) Transforming undergraduate education in engineering. http://tuee.asee.org/phase-i/

Bureau of Labor Statistics. (2023). *Occupational outlook handbook: Archetecture and Engineering.*

Capurro, G. C., & Brittain, D. R. (2017). The impact of team-building on communication and \job satisfaction among nursing staff. *Journal of Nursing Education and Practice, 7*(2), 77-85.

Civil Engineering Body of Knowledge 3 Task Committee. (2019, April). *Civil engineering body of knowledge: Preparing the future civil engineer.* American Society of Civil Engineers.

Clegorne, N. A., Simmons, D. R., & McCall, C. (2021). Leadership competencies for post-secondary engineering experiences: A delphi study of industry perspectives. *Journal of Leadership Education, 20*(1).

Creswell, J. W., & Plano Clark, V. L. (2018). Designing and conducting mixed methods research (3rd ed.). Sage Publications.

Driskell, J. E., Salas, E., & Hughes, S. (2010). Collective Orientation and team performance: Development of an individual differences measure. *Human Factors, 52*(2), 316-328.

Garahan, K. L., Clegorne, N. A., & Simmons, D. R. (2020). Understanding leadership through an ecological lens: A rhetorical cluster analysis of the civil engineering body of knowledge. *The International journal of engineering education, 36*(1), 130-141.

Hacker, S. (2017). *Pleasure, power and technology: Some tales of gender, engineering, and the cooperative workplace*. New York, NY: Routledge.

Harris, A., Leithwood, K., Day, C., Sammons, P., & Hopkins, D. (2007). Distributed leadership and organizational change: Reviewing the evidence. J*ournal of Educational Change, 8*(4), 337-347.

Heifetz, R. A., Grashow, A., & Linsky, M. (2009). *The practice of adaptive leadership: Tools and tactics for changing your organization and the world.* Harvard Business Press.

Hogan, R. (1986). Hogan Personality Inventory. Minneapolis, MN: National Computer Systems

Housen, A. C. (2002). Aesthetic thought, critical thinking and transfer. *Arts and Learning Research, 18*(1), 2001-2002.

Jepson, D. (2009). Studying leadership at cross-country level: A critical analysis. *Leadership, 5*(1), 61-80.

Kotter, J. P. (1999). *What leaders really do*. Boston: MA: Harvard Business Press.

Little, L. M., & Luebbe, P. E. (2016). The effects of team-building on trust and team effectiveness. *Journal of Leadership, Accountability and Ethics, 13*(4), 71-79.

Marton, F. (1986). Phenomenography—a research approach to investigating different understandings of reality. *Journal of thought*, 28-49.

McClelland, D. C. (1961). *The achieving society*. New York: Van Nostrand Reinhold.

Mumford, M. D., Zaccaro, S. J., Connelly, M. S., & Marks, M. A. (2000). Leadership skills: Conclusions and future directions. The Leadership Quarterly, 11(1), 155-170.

National Academy of Engineering (2020). *Grand challenges for engineering*. http://www.engineeringchallenges.org/challenges.aspx

National Science Foundation (2021). *Science and engineering degrees, by race/ethnicity of recipients: 2008-18.* https://ncsesdata.nsf.gov/sere/2018/

Park, S., & Lee, H. (2019). The effects of team-building on positive psychological capital and work engagement. *International Journal of Hospitality & Tourism Administration, 20*(2), 174-190.

Priest, K. L., & Clegorne, N. A. (2015). Connecting to experience: High-impact practices for leadership development. *New Directions for Student Leadership, 2015*(145), 71-83.

Robledo, I. C., Peterson, D. R., & Mumford, M. D. (2012). Leadership of scientists and engineers: A three-vector model. *Journal of Organizational Behavior, 33*(1), 140-147.

Seemiller, C. (2016). Leadership competency development: A higher education responsibility. *New Directions for Higher Education, 2016*(174), 93-104.

Skipper, C. O., & Bell, L. C. (2006). Influences impacting leadership development. *Journal of Management in Engineering, 22*(2), 68-74.

Spillane, J. P., Halverson, R., & Diamond, J. B. (2004). Towards a theory of leadership practice: A distributed perspective. *Journal of Curriculum Studies, 36*(1), 3-34.

Steffens, N. K., Graen, A. F., & Schuh, S. C. (2018). Team-building and its influence on team effectiveness: an examination of conceptual and empirical developments. *Journal of Occupational and Organizational Psychology, 91*(2), 273-293.

Stephens, C. M., & Rosch, D. M. (2015). Building leaders: A national examination of the leadership capacities within engineering undergraduate students. *International Journal of Engineering Education, 31*(4), 986- 997.

Teddlie, C., & Tashakkori, A. (2009). *Foundations of mixed method research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Sage Publications.

Wiggins, J. R., & Trapnell, P. D. (1997). Personality structure: The return of the big five. In R. Hogan, J. Johnson, & S. Briggs (Eds.), *Handbook of personality psychology* (pp. 737-765). San Diego, CA: Academic Press.

Western, S. (2013). *Leadership: A critical text*. Los Angeles, CA: Sage

Yenawine, P. (1997). Thoughts on visual literacy. In: Flood J, Heath SB, Lapp D, eds. *Handbook of research on teaching literacy through the communicative visual arts*. New York, NY: MacMillan Library Reference (pp. 845–860).