Developing Teamwork Skills Across the Mechanical Engineering Curriculum

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An issue for academia, business and industry

Not all employees, especially those in the technical professions, enjoy working in groups. Some prefer to work alone, sharing their ideas and results in a low-key way. They sometimes have trouble seeing their work as part of a larger picture.

However, employers assume a certain skill set from entry-level employees, including communication skills such as being able to work effectively in teams. Exacerbating the issue, few companies offer sustained teamwork training but do conduct much of their work using employee teams.

Teamwork and the engineering profession

With engineered systems getting more complex, the activities needed to develop such systems are becoming akin to those in "contact team sports" where every player has to perform as part of a larger entity and in service of a common goal. One may view the process of creating a product as consisting of three major stages: system architecture; subsystem and component level design; and manufacturing and assembly. Functioning in the various product lifecycle stages requires an engineer to perform in complex team environments that are:

- multidisciplinary for example, mechanical engineers working with electrical engineers.
- multifunctional for example, an engineer in charge of a glass system in a passenger car door working with others in charge of safety, acoustics and others.
- multicultural for example, white collar engineers working with blue collar factory workers.
- multilevel for example, working in a team with entry-level designers as well as managers.
- multinational for example, an American engineer working in the U.S. arm of a Japanese company.
- multiorganizational for example, a design/release engineer at an original equipment manufacturer working with counterparts through the supply chain.

The team environments in which a typical engineer must function are not only complex but are also dynamic requiring members to cycle in and out as needed. This is a far cry from the team "cell" model where a group of engineers work together over an extended period of time during which team members are afforded the time to work through any interpersonal issues.

While it might not be possible for a higher education engineering program to train its graduates for the various team situations that will be encountered in engineering practice, it is imperative

that engineering graduates be imbued with the necessary knowledge and skills to shorten the learning curve.

It is incumbent on schools to produce future employees ready to be productive members of work teams. Schools face two additional challenges: 1. Finding time in an already-packed Engineering curriculum to add teamwork experiences. 2. Making sure that students know the value of teamwork and embrace its lessons despite personal preferences for working alone.

Current practice: Program outcomes, course syllabi and textbooks

Program outcomes: A quick sampling of Engineering program and course outcomes show that schools promise students expertise in teamwork upon graduation. Stanford University's Mechanical Engineering learning outcomes, follow the ABET learning outcomes, lists seven learning outcomes that graduating students are expected to demonstrate. Number 5 is listed as: "an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives." ^[1] Massachusetts Institute of Technology's BSME Course Objectives include "3. Communicate effectively as members of multidisciplinary teams." ^[2] One of Georgia Institute of Technology's Program Educational Objectives for its BSME is "Our graduates will be global collaborators, leading and participating in culturally diverse teams, fostering inclusive environments, and acting ethically to discover and apply new knowledge and engineering practices." ^[3]

How do students gain this knowledge and experience of teamwork? Many Engineering programs continue to offer Technical Writing as a stand-alone one-time course, usually in the student's second or third year. This is important because Technical Writing is typically where teamwork is introduced and/or practiced.

Course syllabi: It seems logical to assume that Engineering and Technical Writing course syllabi would support learning and using teamwork skills. A quick sampling of syllabi suggests that students do have teamwork experiences but little in the way of instructions on functioning successfully in a team. An Introduction to Technical Writing syllabus from the University of North Texas covers concepts taught over a 15-week semester. A goal for students is to "write collaboratively and work as a member of a team." ^[4] Teamwork is covered in one class and students then collaborate on a project that receives a team member evaluation at semester's end. A Technical Writing syllabus from Louisiana Technical University covers 10 weeks but does not list teamwork or collaboration among its topics. ^[5] Despite this, students do work on group projects for which they are graded. Based on this small sampling, it appears students are expected to know and use teamwork skills without much formal or sustained instruction.

Textbooks: A quick survey of technical writing textbooks suggests that Technical Writing instructors cover teamwork as a separate skill, taught in a class session or two and sometimes supported by a group project. Experience also suggests that few Engineering instructors devote significant time to discussion of teamwork. In 1997, Burnett's *Technical Communication*, 4th ed.'s chapter on teamwork provided helpful checklists but a single collaborative activity and assignments that were stand-alone vs integrated into course activities. ^[6] In 2010, Tebeaux and

Dragga's *The Essentials of Technical Communication*, 3rd ed. offered a chapter on collaborative writing but solo activities in which students evaluated documents on websites. ^[7] By 2017, Lannon and Gurak's *Technical Communication*, 14th ed. included a more robust chapter on teamwork with team projects at the end. ^[8]

In short, universities promise to graduate students proficient in teamwork, syllabi indicate little formal tuition in teamwork, and textbooks treat teamwork with a single chapter with some team-related exercises. Students pay attention to what is emphasized: Teamwork instruction needs to be robust, repeated, and experienced over the course of the student's college career.

Another approach – Embedded technical writing

In 2016, the Mechanical Engineering curriculum at University of Detroit Mercy moved from the traditional one-semester Technical Writing class offered through the English Department to an Embedded Technical Writing approach. Among other "soft" or "people" skills, teamwork is discussed and practiced from day one through graduation. Over a series of five technical writing classes from first through third year, students grow in their understanding of the value teams can bring to problem solving, project management and relationship development. Hands-on practice and reflections help them internalize a teamwork approach to work.

ENGR 1020 – Basic Engineering Graphics and Computer Aided Design – In their first semester of college life, students on Day One see how business and industry value the "people" (soft) skills they will bring to the workplace (Figure 1). "Soft skills include interpersonal (people) skills, communication skills, listening skills, time management, problem-solving, leadership, and empathy, among others. They are among the top skills employers seek in the candidates they hire because soft skills are important for just about every job." ^[9]

Why Technical Communication Skills: Vital to Employers, Employees & Students

- Journal of Engineering Education: 64% of a typical engineer's day is spent in writing, oral presentations or meetings [1]
- IEEE: Engineering professionals spend 44% of their time writing, alone or in a team [2]
- Society for Manufacturing Engineers: "lack of communication skills among the top 'competency gaps' in engineers' education" [1]
- ABET now requires engineering programs to demonstrate student proficiency in writing and presenting [1]
- Survey respondents: Technical abilities are a given; communication and leadership skills differentiate [1]

Figure 1. First-year students learn the practical value of the communication skills taught in their engineering classes. This is an excerpt from "Why We Need Technical Writing in Engineering Classes."

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Students also build on knowledge they already possess about peer review as they work in teams to review classmates' audience analyses and two sets of instructions for multitools they design.

ENGR 1080 – Fundamentals of Engineering Design - ENGR 1080 is the foundation course for teamwork because the entire semester revolves around learning about teamwork, developing skills in working in teams, and providing feedback to classmates on their team performance.

On Day One of class, instructors assign students to a team of 4-5 people. They will work with these students for the remainder of the semester on a variety of activities. Their first job is to generate Team Lists in response to prompts they are given (Figure 2). The idea is to pull from their existing knowledge to start a semester-long discussion.

Each team has 3-5 members. When random selection is desired, index cards of different colors can be distributed. The prompts are listed below. All start with the same lead-in: "List, then rank order...

- 1. 5 Characteristics of Effective Team Leaders.
- 2. 5 Helpful Behaviors that Team Members Can Exhibit to Help their Group Succeed.
- 3. 5 Ground Rules to Establish in the First Team Meeting.
- 4. 5 Ways to Encourage Under-Participating Group Members.
- 5. 5 Ways to Deal with Conflict in Teams.
- 6. 5 Pros of Using Teams in the Workplace.
- 7. 5 Cons of Using Teams in the Workplace.
- 8. 5 Tools that Help Teams in the Workplace."

ENGR 1080	Teamwork & Collaboration: Brainstorming	Winter 2022
Team 1 – Effecti	ve Team Leaders	
Step 1 – Each team	member should start by making an individual list. Your 7	Task: Brainstorm
5 characteristics of	effective team leaders. Then rank order those qualities	in terms of
importance to the s	success of the team. Characteristic #1 would be the most	t important.
Task: Develop 1 ma success of the team	r list is complete, work with your teammates to combine ster list of 5 items, and rank order the new list in terms o n. Characteristic #1 would be the most important. When on the white board and include a title.	of importance to the
Step 3 – As a team,	briefly present your list. Follow this format:	
1. Intro	duce yourselves by name.	
2. Read	l the task you were given.	
3. Expl	ain your list.	
4. Desc	ribe your team's decision-making process.	
Due: 1/10/2022. 3	p.m.	

Figure 2. This team activity has two parts. First, students generate their own list in response to the prompt. Second, they meet with others on their team to generate a single team list. Then they present their combined list to their classmates.

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ENGR 1080	Teamwork & Collaboration: Brainstorming	1/19/2023		
Team 1 – Effective Team Leac	lers			
1. Effective Communication listens as well as talks)	(shares a clear goal for the team, is clear about tasks	and deadlines,		
2. Respect (listens to others'	ideas and incorporates them)			
3. Allow for Critiques (asks f	or and uses feedback)			
4. Patience (waits for respor	nses, knows that different people work at different spe	eds)		
5. Keep Group on Task and	Efficient (checks in with team members to make sure	work is getting done)		
Note: Difference between a visionary and a leader. Visionary gets the big picture. Leader manages the tasks that are done to realize the vision. Can be a leader without being a visionary. Not all visionaries are easy to work for. Ex., Steve Jobs – visionary and communicator but not a nice person.				

Figure 3. Although blanked out here, team members' names are listed to recognize their contributions. This is the first of seven lists generated by teams in the Winter 2023 class. Notes are based on class discussions as the lists are presented.

Once students have discussed their existing knowledge and attitudes about teamwork, they begin to explore other sources of information, starting with readings from *The Handbook of Technical Writing*. ^[10] In class they watch and then discuss an excerpt from "Remember the Titans," a 2000 film in which a "high school football team is forced to integrate, bringing together players from different racial backgrounds. Coach Boone, played by Denzel Washington, takes charge and helps the team overcome their differences and work together. Amidst challenges and resistance, the players learn to respect and support each other. Through hard work and determination, they become a united team, overcoming prejudice and achieving success on the field." The film shows in a visceral way how teammates can hinder – or help – each other. ^[11] The takeaway lesson from the movie is that teambuilding takes time, patience and wisdom as it progresses through the four phases: forming, storming, norming and performing. The students can also consult a variety of articles posted on the course's Blackboard site (Figure 4).

uild Content v Assessments v Tools v Partner Content v			
h	Teamwork in the Workplace: Overview 🔘		
	Attached Tiles: 🚯 Teamwork_1000_Fail 2019,ppt 🔘 (3.176 MB)		
	The Four Stages of Teams: Forming, Storming, Norming, and Performing ©		
	Attached Flies: 🗋 Forming-Steaming_Steps in Team Formation.pdf 🕲 (702.277 KB)		
3	Leadership and Thinking Hats: Leaders We Deserve 💿		
	Edward De Bono invented Six Thinking Hats a a system for managing team dynamics. Its popularity derives from its apparent simplicity as a means of identifying the thinking process, and the perceived benefits of structuring and sequencing them for more effective outcomes. See a briaf overview at:		
	http://www.deltonograue.com/siz_thirking_helts.shp		
3	How to Have a Difficult Conversation 🗇		
	Attached Files: 🗋 Worried about a Difficult Conversation (1) pof 🔘 (222.308 KB)		
-	Five Steps from Engineering to Leadership: Article 🛇		
	Attached Files: 🗋 Five Steps from Engineer to Leadership of 😳 (2.036 MB)		
-	How to Work in Global Teams 🗇		
	Attached Ries: 🚹 How to Work in Global Teams pol 🚳 (186.494 KB)		
_			
	Your Thoughts on Teamwork: Student Brainstorming 🗇		
3	Teamwork Lists - Winter 2021 🔘		
	Attached Files: 🔯 ENGR 1080 Tearnwork Lists, W21 vtf 🕲 (162:003 KB)		
1	Teamwork Lists & Discussion Points_W22 ©		
=1	Attached Files: 👔 Team Lists_W22.pdf 🕲 (390.008 KB)		
	Teamwork Lists & Discussion Points_W23 ③		
	Attached Piec: D EVGR 1010 Teamwork List, V23,pdf @ (154,162 KB)		

Figure 4. Students can create their own path to learning. For instance, a student hesitant about confronting a teammate might read "How to Have a Difficult Conversation," written by a professional hostage negotiator.

After preliminary team presentations about teamwork and then generational communication (including team peer reviews), the class focus shifts to the engineering design process. Students work together in their teams to identify a consumer product, do a market study to determine the need, design the product and how it will function, and make cost estimates. The end goal is to build a presentation, topic by topic, which would persuade an investor to fund a start-up company. See Appendix A for a list of topics and activities in ENGR 1080.

As students work in their assigned teams, they quickly identify the strengths of their teammates and refine their own communication and presentation skills. Using a real-life project over a period of weeks helps students internalize teamwork ideas in a way that one class lecture or unrelated team activities cannot do.

The teamwork aspect of ENGR 1080 is very important and is weighed at 10% of the course grade. Part of that grade is determined by a peer evaluation survey that students have created in a

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guided class discussion. The survey is scored on a 1-5 Likert scale with 1 indicating strong disapproval and 5 indicating strong approval on the following statements regarding a team member: contributed sufficient time and effort; properly communicated regarding attendance matters; communicated ideas and perspective in meetings; delivered work in a timely manner; delivered quality written work.

ENGR 1021 – Intermediate Graphics and Computer Aided Design - Students continue to peer review projects that include an assembly team assignment and producing/presenting graphics posters based on raw data. Their assembly design project is done in groups of three and includes a reflection on team contributions.

ENGR 3720 – Mechanics of Materials Lab – Students work alone, with a partner, and in teams to produce reports that describe the material tests conducted. With team reports, students switch roles so they all have experience in drafting (and reviewing) report sections. They also have a chance to comment on their colleague's input and workload.

ENGR 4920 – Computer Aided Engineering – Thermal Cup Challenge is a partner project to produce a cup with a lid usable by a consumer whose mobility is limited to the use of just one hand. The partners then produce a poster and a presentation designed to persuade an investor to invest in their start-up project. The timeline is tight and poster skills are new, so these teams feel extra pressure to produce and sell a product. They have a chance to reflect on their own and their partner's performance at the end of the semester.

Approach in other Engineering courses

Teamwork is embedded in a number of engineering courses outside those of the Embedded Technical Writing program.

ENGR 3110 – This course introduces students to the intricacies of intercultural teamwork by discussing the following four dimensions of cultural practices:

- 1. Communicating: This focus is on low-context versus high-context communications and how that could affect the workings of a team that comprises members who need and emphasize much detail in how they communicate (low-context) as well as ones who rely on tacit forms of communications (high context). Such an awareness could help mitigate problems arising from differences in communication styles.
- 2. Evaluating: This focus is on direct negative versus indirect negative feedback and how this might affect how team members assess and evaluate each other's work. For example, a person accustomed to receiving indirect negative feedback (characterized by soft and nuanced criticism) might find it difficult to accept feedback from another team member accustomed to using direct language.
- 3. Disagreeing: This focus is on the fact that some people are confrontational in how they deal with disagreements while others shun confrontation. An understanding of these differences might help a non-confrontational person realize that disagreements are not personal while

also helping a confrontational person realize the need to "tone down" their approach in service of better team dynamics.

4. Scheduling: This focus is on the differences in how people from different cultural backgrounds view the concept of time and punctuality. Team members who are accustomed to linear time (for whom schedules and timely work is paramount) might find it difficult to accept that others who operate on flexible time (for whom tight scheduling might not be viewed as important or even possible). Such an awareness is very important for the proper working of a team. ^[12]

MENG 4930/4950 – These two courses are designated to provide a capstone design experience. To accentuate the importance of teamwork, engineering students are paired with nursing students to develop assistive devices for a specific client with a physical disability. The teamwork skills and mindset developed in the Program are brought into a much sharper focus when students must navigate working in such diverse teams and with a real-life end user.

It should be noted that this approach to teaching teamwork and developing teamwork lends itself to other classes. For instance, Business Writing at University of Detroit Mercy uses the Team Lists and Team Reflection activities as does the Professional Communication class at Oakland Community College. See Appendix B for a sample student reflection on teamwork.

Conclusions and next steps

A sustained approach to teaching teamwork supports learning of this key concept in several ways by:

- 1. Emphasizing the importance of teamwork skills for current and future success.
- 2. Helping students develop communication skills around explaining ideas, setting goals, confronting colleagues, solving problems, and communicating with management.
- 3. Setting realistic expectations of their own and others' performance and experience giving and receiving productive feedback.
- 4. Engendering confidence in students that they have the necessary tools to succeed in team projects at school and in the workplace.

One goal of this paper was to offer examples of how teamwork can be presented, along with skill building, practice, and reflection. Another goal was to give Engineering instructors ideas and resources that can be imported into their own classes. A final goal was to provide institutions with an approach that more closely aligns the school's goals with teamwork skills of their graduates.

Next steps could include a review of Engineering courses that have students working in teams. Student experiences could be enhanced by including formal and sustained tuition in teamwork concepts and reflections on the part teamwork plays in their lives.

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Appendix A: Syllabus – ENGR 1080, Fundamentals of Engineering Design, Winter 2023 (excerpt)

Topics	Date	Assignment	Assignment Due Date
Lecture: Introduction of course and syllabus, team building, and team assignments	Jan. 9 M		
Lab (sec 01): Assign Semester Teams and Teamwork presentations			
Lecture: Opportunity recognition and value proposition	Jan. 11 W	Assignment 1: Technology discovery –	Jan. 18
Lab (sec 02): Assign Semester Teams and Teamwork presentations		Internet of Things	
NO CLASS - Dr. Martin Luther King, Jr. Day	Jan. 16 M		
Lecture: Teamwork presentations. No Lab	Jan. 18 W		

(continued on next page)

Topics	Date	Assignment	Assignment Due Date
Lecture: Audience analysis and formal tone, thesis Statements and rhetorical strategies Lab (sec 01): Assigned readings and begin work on Communicating across the Generations presentations	Jan. 23 M	Assignment 2: Communicating Across the Generations presentations	Jan. 30
Lecture: Ideation / Concept generation and 30- second pitch Lab (sec 02): Assigned readings and begin work on Communicating across the Generations presentations	Jan. 25 W	Assignment 3: Opportunity recognition and individual value proposition	Feb. 6
Lecture: Opportunity recognition and value proposition (makeup)/ Finish work on Generations presentations Lab (sec 01): Presentation#2: Communicating across the Generations	Jan. 30 M		
Lecture: Understanding intellectual property Lab (sec 02): Presentation#2: Communicating across the Generations	Feb. 1 W		
Lecture: Formal reports vs. presentations Lab (sec 01): Presentation #3: Individual value propositions cont'd.	Feb. 6 M		
Lecture: Presentation #3: Individual value propositions cont'd. Lab (sec 02): Presentation #3: Individual value propositions cont'd.	Feb. 8 W		
Lecture: Customer discovery Lab (sec 01): Choose a team value proposition to work on together the rest of the semester	Feb. 13 M	Assignment 4: Team value proposition and Customer discovery	Mar. 20
Lecture: Research: Customer interviews and active listening Lab (sec 02): Choose a team value proposition to work on together the rest of the semester	Feb. 15 W		

Topics	Date	Assignment	Assignment Due Date
Lecture: Pro-forma financials (understanding return on investment [ROI])	Feb. 20 M		
Lab (sec 01): Work on Customer Discovery			
Lecture: Pro-forma financials cont'd. / Mid-term self-assessment (optional, extra-credit)	Feb. 22 W	Assignment 5: Pro-forma financials	Apr. 3
Lab (sec 02): Work on customer discovery		Extra-Credit	Friday, 2/24
Lecture: Workplace Presentations Lab (sec 01): Work on customer discovery /	Feb. 27 M		Apr. 3
Lab (acc of). Work on customer discovery?			
Lecture: Technology Plan Lab (sec 02): Work on customer discovery	Mar. 1 W	Assignment 6: Technology plan	Mid-Term grades available
Lab (sec 02). Work on customer discovery			available
NO CLASS – Spring Break	Mar. 6- 11		
Lecture: Workplace Presentations cont'd. Peer Reviews: Customer Discovery	Mar. 13 M	Rough Draft Customer	
Lab (sec 01): Work on Pro-forma financials, technology plan (sketch, flowchart, roadmap)		Discovery - Due	
Lecture: Peer Review: Technology Plan	Mar. 15 W	Rough Draft Technology	
Lab (sec 02): Work on Pro-forma financials, technology plan (sketch, flowchart, roadmap)		Plan - Optional	
Lecture: Presentation #4: Team value proposition & customer discovery	Mar. 20 M		
Lab (sec 01): Presentation #4: Team value proposition & customer discovery			
Lecture: Formal Reports & Report Template	Mar. 22 W	Assignment: Final Report –	Apr. 10
Lab (sec 02): Presentation #4: Team value proposition & customer discovery		Rough Draft	
Lecture: Persuasion	Mar. 27 M	Rough Draft -	
Lab (sec 01): Work on Pro-forma Financials and Technology presentation / Peer Review - Pro-forma Financials - optional		Pro-forma Financials - Optional	

Topics	Date	Assignment	Assignment Due Date
Lecture: Persuasion	Mar. 29 W		
Lab (sec 02): Work on Pro-forma Financials and Technology presentation			
Lecture: Presentation #5: Pro-forma financials and Technology plan	Apr. 3 M		
Lab (sec 01): Resolve technology issues, etc.			
Lecture: Presentation #5: Pro-forma financials and Technology plan cont'd.	Apr. 5 W		
Lab (sec 02): Resolve technology issues, etc.			
Lecture: Venture creation within and outside of corporations	Apr. 10 M	Assignment 7: Venture plan	Apr. 19
Lab (sec 01): Work on venture creation			
Lecture: Teamwork evaluations / Venture creation cont'd.	Apr. 12 W	Assignment: Final Pres. – Rough Draft	Apr. 19
Lab (sec 02): Work on venture creation		_	
Lecture: Preparations for final presentations	Apr. 17 M		
Lab (sec 01): Course feedback / Q&A on reports, presentations, etc.			
Lecture: Team presentations - dry run	Apr. 19 W		
Lab (sec 02): Course feedback / Q&A on			
reports, presentations, etc.			
Lecture: Final Presentations – Group 1	Apr. 24		
Final Exam: Final Presentations – Group 2	Apr. 28	Final Report / Final	Apr. 28
FINAL EXAM		Presentation	
Friday, Apr. 29		w/ Notes Pages	
11:00 a.m. – 12:50 p.m., E230		 uploaded to Blackboard 	
		Remember:	
		Your .Ppt Notes	
		pages are	
		Appendix A in	
		your Final	
Cullabus is subject to shance. Any sha		Report	

Syllabus is subject to change. Any changes will be announced in class. Final Grades due by Monday, May 1, 2023, 11 a.m.

Appendix B: In-Class Assignment 3 – Teamwork: My Reflections

ENL 3080-02

Business Writing / McCall

Winter 2023

In-Class #5: Teamwork: My Reflections

You've had the chance to generate your own list of teamwork ideas and read lists compiled by your teammates. Then you worked with your teammates to create a group list. Plus, you've read the text and Blackboard articles* for further information about teams in the workplace.

In this assignment, you will again work as an individual to reflect on your experiences with teamwork. Start with research:

- Visit Blackboard and the Workplace Teams: Resources folder again.
- Pull down and read 3-4 lists generated by previous classes. See where their ideas overlapped with yours and where their ideas were new and different.
- Review the articles on Blackboard and the sections in your text
- If you like, do your own research on teams and their role in the workplace

To fully understand and integrate new information, we need to reflect on what we've learned. Write a brief memo to your instructor addressing these ideas:

- List 3 new ideas you've learned about teamwork and the impact those ideas will have on you
 going forward as a person, as a student, and as an employee.
- Describe the value that teams can bring to the workplace. You can start with an opinion but pull from at least two of your sources to back up your claims. <u>Cite these sources in text</u> (Source) and give an MLA citation(s) at the end of the memo.
- 3. Use this title in the Re: line: Teamwork Reflections: Joe Smith (use your own name).

*Blackboard Articles on Teamwork

- "Working in Global Teams"
- "Forming-Storming: Steps in Team Formation"
- "Five Steps from Engineer to Leadership"
- "Worried about a Difficult Conversation? Here's Advice From a Hostage Negotiator"

Tone: Use business language, write in complete sentences, capitalize proper nouns and so on. Be sure to edit and proofread before submitting.

Assignment Submission: Hard copy in class on due date.

Due Date - 3/31/2023 4/3/2023

Points - Up to 50 points. You will not receive full credit unless you cite sources.