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Navigating the Mystery: An Approach for Integrating Experiential Learning in Ethics into an Engineering Leadership Program

Dr. James N. Magarian, Massachusetts Institute of Technology

James Magarian is a Sr. Lecturer with the Gordon-MIT Engineering Leadership (GEL) Program. He joined MIT and GEL after nearly a decade in industry as a mechanical engineer and engineering manager in aerospace/defense. His research focuses on engineering workforce formation and the education-careers transition.

John M. Feiler, Massachusetts Institute of Technology
Leo McGonagle, Massachusetts Institute of Technology

Leo McGonagle helped conceive and design the Gordon Engineering Leadership Program (GEL) and was named executive director as the program launched in 2008. He helped oversee the program's growth from MIT start-up with twenty students to a well-established School of Engineering program with over 150 students participating annually, recognized nationally and internationally as a model for effective engineering leadership education. Leo brought the concept for the innovative Engineering Leadership Lab (ELL) to GEL, having overseen similar experiential teamwork and leadership development courses elsewhere. He has instructed this highly rated course each year. Leo's passion is developing leaders. Before joining GEL, he served the nation in the U.S. Army Corps of Engineers, achieving the rank of Lieutenant Colonel. Among successive organizational leadership positions of increasing responsibility, Leo spent six-years on elite-school college campuses, overseeing leader development programs while coaching, advising, and mentoring emerging-leader students. As department chair of the Army Reserve Officers Training Corps (ROTC) Program at MIT, he was responsible for the leadership development and commissioning of students from MIT, Harvard, Tufts, Wellesley, Gordon, Salem State and Endicott College. He previously served in a leader and character development role at The United States Military Academy at West Point.

Leo led soldiers during the Persian Gulf conflict, in support of the Global War on Terrorism in Iraq, and during peace enforcement operations in Bosnia-Herzegovina. He was awarded three Bronze Star Medals for leadership and service during wartime operations. He earned his commission through ROTC and was a Distinguished Military Graduate, He is a graduate of the U.S. Army Ranger School and the U.S. Army Command and General Staff College. He earned a M.S. in leadership development and counseling from Long Island University and a B.A. in psychology from Boston University. He is a member of the American Society of Engineering Education (ASEE). Leo is an avid hiker, and when not at work can usually be found on a New Hampshire White Mountains high-peak.

Eileen Milligan, Massachusetts Institute of Technology
Alexander Rokosz, Massachusetts Institute of Technology
Elizabeth Schanne, Massachusetts Institute of Technology
Dr. Reza S. Rahaman, Massachusetts Institute of Technology

Dr. Rahaman returned to MIT in 2018 after a 29 year career in the Consumer Packaged Goods, Pharmaceuticals, and Agricultural Chemical Industries to lead the four School of Engineering Technical Leadership and Communication (TLC) Programs – the Gordon-MIT Program in Engineering Leadership (GEL), the Undergraduate Practice Opportunities Program (UPOP), the Graduate Engineering Leadership Program (GradEL), and the School of Engineering Communication Lab.

Immediately prior to MIT, Reza was the Vice-president of Research, Development, and Innovation for the Specialty Division of the Clorox Company. In that role he was accountable for developing innovation strategies for a diverse set of businesses and ensuring robust technology roadmaps and innovation pipelines to deliver growth and profit targets for 45% of the Clorox Company portfolio ($2.7bn in net customer sales). Among his businesses were Brita, Burt's Bees, Glad, Hidden Valley Ranch, Fresh Step, and Kingsford Charcoal.

In addition to his passion for developing leaders, Reza is passionate about workplace equality. He was the Executive Sponsor of the Clorox Pride Employee Resource group, and was a member of the Board of Directors of Out & Equal Workplace Advocates, the world's premier nonprofit promoting LGBT+ workplace equality from 2016-2021. He currently serves as a Board Ambassador. He and his husband James enjoy travel and hiking

Reza received his BSc.(Eng.) in Chemical Engineering from Imperial College London, and his MSCEP in Chemical Engineering Practice and Ph.D. in Chemical Engineering from MIT.

Prof. Olivier Ladislas de Weck, Massachusetts Institute of Technology

Olivier de Weck is the Apollo Program Professor of Astronautics and Engineering Systems at MIT. His research focuses on the technological evolution of complex systems over time, both on Earth and in Space . He is a Fellow of INCOSE and AIAA and served as Faculty Co-Director of the MIT Gordon Engineering Leadership Program.

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Abstract

This Practice Paper describes an approach for integrating ethics experiential learning into an Engineering Leadership (EL) program. We discuss motivations for EL programs' continued efforts at incorporating and enhancing ethics learning; for instance, to strengthen students' sense of connection between ethics and day-to-day engineering work, to grow their abilities to recognize decisions with ethical implications, and to build their awareness of how ethical lapses can transpire in team settings. We review experiential learning as a means of facilitating development in these areas through activities that immerse student teams into unfamiliar dilemmas requiring ethical reasoning. Further, we describe key challenges of operationalizing experiential learning in ethics, such as incorporating realism and unpredictability, prompting the critical thinking necessary for recognition of ethical dilemmas, and creating a learning context that does not feel contrived or exaggerated. We then present designs of a class session and an associated team-based experiential "engineering leadership lab" (ELL) recently developed at the Gordon-MIT Engineering Leadership Program (GEL). Focusing on the ELL, we discuss how this activity was structured to address aims and challenges; for instance, by embedding an ethical dilemma into a product development scenario requiring decision making under schedule and financial pressures in a realistic organizational environment. We share team-level performance observations from a recent instance of the activity; here, all 23 teams composing the program's first-year cohort participated. We observed that team performance varied across a range of outcome categories: those that submitted the activity's deliverables while failing to navigate its ethical dimensions, those that contributed deliverables reflecting a partial recognition or incomplete handling of ethical dimensions, and those that submitted deliverables reflecting thorough navigation of ethical dimensions. These performance observations were possible because the activity involved making resource choices linked to ethical implications, resulting in certain materials' use (or absence) evident in teams' physical deliverables. Students' post-activity reflections, submitted after they participated in an activity debrief, included indications of intended learning in a majority of cases (83% of submittals) based upon a rubric. Drawing from activity observations and reflections, we discuss how teams' ethical decision making appears to have been strained by various intended pressures intrinsic to the activity (e.g., time and resource constraints, a competitive context, and costs), yet, that many students' reflections contained ideas for mitigating such pressures through enhanced critical thinking and team collaboration. Though program-level evaluation of ethics learning is ongoing, we conclude by sharing lessons-learned from this module's development, identifying implementation considerations for other programs wishing to explore similar forms of ethics experiential learning.

Introduction

Undergraduate Engineering Leadership (EL) programs frequently describe ethics education as a key facet of their curricula (e.g., [1-5]), a movement aligned with contemporary engineering accreditation criteria emphasizing ethics [6] and with calls for curricula that reflect a prominent need for ethical reasoning in engineering practice (e.g., [7-9]). At the same time, recent studies suggest much work remains in establishing how to best deliver engineering ethics learning in programs [10-13]. Ongoing challenges include strengthening students' sense of a pragmatic connection between ethical reasoning skills and their use in day-to-day engineering work [10-12], sharpening students' recognition of when decisions carry ethical implications [10, 11], and helping students to see ethics from beyond a lens of individual conduct (i.e., toward group, organizational, and societal perspectives) [12,13], among others. This paper describes how an undergraduate EL program, the Gordon-MIT Engineering Leadership Program (GEL), has recently developed experiential learning content aiming to address challenges such as these. After briefly introducing GEL's inclusion of ethics-related learning components across its curriculum, we focus this Practice Paper on the design of a particular ethics learning activity dubbed "The Mystery Lab." We discuss motivations underlying the creation of The Mystery Lab, observations from a recent instance of the activity, and initial lessons-learned from its development and operation.

Integrating ethics education into EL programs

While it is now common to find ethics courses or units of instruction in EL programs, educators caution that ethics coverage still risks be handled by programs as "a box to tick" [8, p. 118]. What it takes to achieve deeper integration of ethics into the core of programs continues to receive scholarly attention, both in terms of learning goals to target, and in how programs or courses are best structured. For instance, traditional approaches involving discussion of professional ethics codes and their application to cases of past mistakes and failures, though fundamentally informative, can instill concepts at a high level of abstraction in professionally inexperienced students, making it difficult for them to employ these concepts in new or unclear situations [10, 14]. Scholars point out that strengthening students' understanding of how ethical reasoning can apply across various ambiguous and less dramatic contexts can be as important as developing an ethical reasoning capacity itself [12]. Further, incorporating learning in critical thinking [15], alongside learning in professional ethical orientations and frameworks, can help students strengthen their ability to recognize when ethical reasoning applies to a situation [9, 10]. Traditional engineering ethics instruction can also tend to emphasize individual behavior in emergency-type scenarios [12], while inadvertently downplaying emphasis of ethics as pertinent to day-to-day group and organizational processes and environments [10, 12]. The latter contexts, for instance, include engineering organizational cultures that risk perpetuating groupthink, biases, or inequitable conditions in engineering, which, in turn, can result in unjust outcomes in both engineered products/services and among the profession's workforce. Recognizing how broader social systems intersect with ethical considerations and are influenced by engineering leadership is identified as another key learning enhancement opportunity area [8, 16, 17].

Scholars of EL education have also highlighted how ethics content's positioning in the curriculum can be salient to student perceptions [7, 8]. For instance, are engineering ethics-related lessons or courses embedded in EL programs' required cores, or are they limited to optional or elective content? If ethics coverage is included in programs' cores, how is the learning operationalized to reinforce it as being integral to engineering leadership practice? Proposals for embedding ethics instruction more integrally within engineering coursework have included increasing the emphasis on human-centric approaches to design on engineering team projects [10, 17], mitigating or reducing the isolation of ethics instruction from other aspects of courses and projects [8, 13], and increasing the use of experiential learning approaches for ethics instruction [12, 17-20], among others. As this paper's central focus, we illustrate how an ethical reasoning challenge can be operationalized in an EL program using a team-based experiential learning approach.

Motivation for curricular innovation – The promise of experiential learning in ethics

A growing set of examples in engineering education literature describe new experiential learning approaches for ethics instruction in engineering [12, 17-20]. Motivating this trend, scholars discuss how traditional approaches to ethics instruction have largely focused on retrospection and historic review, often at the expense of other learning modes, such as experimentation and personal experience [18, 19]. Those latter modes can be important toward building an ability in students to handle “unfamiliar tensions” [18], a capacity essential for joining new work environments and in dealing with new products or unproven technologies [17, 18]. Further, while retrospective approaches can help students learn important generalized concepts in ethics, critics have pointed to students’ difficulties in building perceptiveness of how these concepts can apply to them personally in realistic early-career engineering situations [12, 17, 19]. Existing approaches, in other words, risk inadvertently building within students a false sense of distance between themselves and ethical reasoning contexts due to the high-profile scenarios often used to categorize ethical failings [12, 19]. In light of these considerations, we reason that an approach of integrating unexpectedness and early-career realism into scenarios requiring critical thinking for recognition of ethical dilemmas may be a promising means of constructing experiential learning modules in engineering ethics.

Researchers have explored several lesson or activity design approaches for ethics experiential learning. Spierre et al. [18] and Voss [19], for instance, describe leveraging students’ participation in games or game-like scenarios. Kim et al. [12] and Ochs et al. [20] propose utilizing students’ experiences in real workplace environments, such as internships. And Golecki and Bradley [17] describe leveraging the context of a capstone design course. Despite their variety, these approaches share a common foundation: leveraging students’ personal experiences as a setting for ethical reasoning, such as through requiring students to evaluate their own decisions or courses of action (i.e., where the stakes and tradeoffs are real to the learner). As one author describes it, these approaches “[allow] students to draw on their own experiences…to create a focal point and meaning around abstract ethical concepts” [19, p. 1390].

While the literature on experiential learning in engineering ethics has grown substantially in recent years, extensions of this strategy into the realm of engineering leadership education is comparatively rarer in published research. Our development of The Mystery Lab, therefore, leverages an opportunity to explore how the strengths of an experiential approach to ethics instruction can be applied not just to personal decision making, but to the collective behaviors of teams and to the decisions of team leaders through a team-based experiential learning activity.

Background

GEL program structure

Established in 2007, GEL is an undergraduate certificate program for juniors and seniors at Massachusetts Institute of Technology. The program can be taken as a one- or two-year course of study, with the latter track composed of additional peer leadership opportunities and coursework leading to an "advanced" designation on students’ engineering leadership certificates. GEL rests on a curriculum referred to as *Capabilities of Effective Engineering Leaders* [2], which was developed at the program’s launch through a yearlong series of design workshops conducted with faculty in engineering and in leadership, accomplished practitioners from industry, and leadership educators from the military [21]. The program's first year core structure is described in detail by [21], and can be summarized as consisting of three pillars: 1) an Engineering Leadership Lab (ELL) where students meet weekly in small teams to face leadership challenges keyed to the *Capabilities* [2], 2) a seminar-style Engineering Leadership class (EL), synchronized to the lab, where students study the academic background underlying the leadership capabilities prior to the related ELL and discuss and reflect on the lessons learned following a given lab, and 3) one from a number of elective courses that fulfill a Design and Innovation Leadership Requirement, which focuses on the engineering design process and the roles of leadership and teamwork therein. The program's second-year students serve as "team coaches" for the ELL teams (which are composed of first-year students). The second-year students also take turns serving as facilitators of the ELL activities, responsibilities for which they receive separate guidance and coaching from the program's teaching staff during additional for-credit time when first-year students are not present. A given unit of instruction for first-year students in GEL therefore consists of a seminar-style class centered on a topic from the *Capabilities* [2], with associated reading and pre-work assignments, followed by a team activity-based ELL facilitated by second-year students. First-year students who serve as their team's leader for a given week's ELL (a rotating assignment) are required to submit a structured reflection assignment on the ELL.

Experiential learning context in GEL

The primary context for experiential learning in GEL is the weekly two-hour ELL. Operating this lab as three separate sections enables the program's first-year cohort of up to 150 students to be distributed into approximately 24 six-student teams, with up to eight teams per lab section. Course staff establish these student teams in Week 1 of the semester by diversifying team membership by academic home departments, campus living group affiliations, and demographics (information that is provided when students apply for admission to GEL). These student teams formed in Week 1 remain together for the duration of the semester. GEL program cohorts, meanwhile, have tended to be demographically diverse in their representation of historically underrepresented groups in engineering. For instance, in the most recent three program cohorts preceding this paper (through Fall 2023), women have composed 54% - 60%, Black or African American students have composed 14% - 19%, and Hispanic or Latinx students have composed 10% - 24% of their cohorts. Recently reported (Fall 2023) representations of these groups in the undergraduate population at MIT are 49%, 9%, and 15%, respectively [22]. Academic department representation in GEL has followed a typical top-five ordering, which has tended to track the relative ordering of department enrollments in MIT's School of Engineering. In the most recent three cohorts, the departments most represented have been Electrical Engineering/Computer Science (32% - 40%), Mechanical Engineering (20% - 25%), Aerospace Engineering (7% - 15%), Chemical Engineering (4% - 6%), and Biological Engineering (1% - 3%).

Though students have prior exposure to a given leadership capability from one or more preceding EL seminars, ELL provides the opportunity for hands-on practice and feedback for the given capability. Each ELL usual begins with five minutes of introduction or framing of a problem or scenario, delivered by a second-year program student. Then, one member of the first-year student team, designated as the team leader for the week, steps forward to receive an instruction packet that outlines the specific objectives, deliverables, constraints, etc., for the scenario. It is this first-year student leader's responsibility to disseminate this information to their team and to organize and lead the team's activity toward achievement of the scenario's objectives. After the activity period (usually 55-70 minutes), teams' results are typically revealed to the full class, followed by approximately five minutes, each, of both team-level and classroom-wide debrief discussions. Throughout the ELL, approximately three to five invited guest observers who are, themselves, practicing engineering leaders from industry or research environments, watch the activity. These guests, referred to as "engineers in the room," are then invited to spend a few minutes sharing observations and advice, helping to contextualize the learning by connecting it to their world of practice. Finally, as the ELL period ends, each team's second-year student team coach conversationally delivers feedback to the first-year team leader (scaffolded by a feedback form shown in Appendix A); that first-year team leader then has five days to submit a personal reflection on their ELL experience and feedback (via a reflection prompt shown in Appendix B).

Each ELL activity is self-contained (i.e., not part of an ongoing, semester-long challenge or project), with each primarily focused on one or two *Capabilities* [2]. The decision to situate the ELL learning activities into this short-duration format represents a trade-off in educational design that is balanced, in part, by other facets of GEL. For instance, GEL students participate elsewhere in a multi-week team project, where success rests on a range of capabilities, as part of their coursework for the program's Design and Innovation Leadership Requirement. Further, students select a long-duration engineering project for a leadership post-mortem analysis as the basis for an essay assignment in the EL seminar course. Yet, in ELL, keeping the activities restricted in time and scope allows greater emphasis to be placed on a narrower range of capabilities, which, in turn, allows for timely and focused feedback that is commensurately scoped. GEL is therefore composed of both deep practice opportunities in particular capabilities and of experiences emphasizing the integration of a wide range of capabilities.

Embedding ethics education into GEL – The class-lab pair

Ethics learning is facilitated in several areas of GEL's curriculum. First-year program students initially encounter it in their first semester through The Mystery Lab and its associated seminar class session. Yet, while The Mystery Lab serves as a principal introduction to ethical reasoning, most ELL activities rest upon multiple capabilities; achieving successful outcomes in several other downstream ELLs, for instance, also involves ethical reasoning. Notable examples include "Advocating" (a scenario with truth-in-advertising implications), "Negotiating and Compromising" (a scenario that introduces tensions between local incentives and organizational- and societal-level harms/benefits), and "Inquiring and Dialoguing" (a scenario with social justice implications related to recognizing and mitigating harassment and discrimination). Beyond these first-year ELL experiences, second-year students are tasked with providing first-year students with feedback on ethical reasoning as part of their recurring duties as ELL Team Coaches (see: Appendix A). GEL students, meanwhile, are prompted to practice ethical reasoning through stakeholder awareness or human-centered design modules within their Design and Innovation Leadership Requirement coursework. Finally, the second-year program students are required to complete a semester-long Engineering Leadership Elective course, several options for which are ethics courses (e.g., *Ethics for Engineers, Ethics of Technology, Experiential Ethics*). We focus this paper on first-year students' introductory learning in The Mystery Lab, yet we note the other learning experiences, above, to illustrate how ethics coverage in GEL occurs throughout the program.

The Mystery Lab and its preceding Engineering Leadership seminar class session are designed as a class-lab pair. This paired scheme is used throughout Year 1 in GEL; however, at the point early in the program schedule when The Mystery Lab occurs, students are not yet accustomed to it. The Mystery Lab is run as the third ELL of the year (from among 24 ELLs in total), and those ELLs preceding it are only loosely coupled with the Engineering Leadership class. Topics covered in the earlier sessions, for instance, include team forming, team contracts, and leadership styles. The associated early ELLs include a basic teamwork challenge centered on resourcefulness and a Teamwork and Leadership Reaction Course [23] composed of a series of 20-minute micro-activities where students take turns leading and providing feedback to each other. The Mystery Lab is therefore the first full ELL in the program that embodies the class-lab pedagogical model. The

Mystery Lab's positioning in this regard is notable because its unannounced, unexpected main topic is both intentional and uncharacteristic of the remainder of program (where ELL topics and learning objectives are otherwise fully transparent and discussed in advance).

The Engineering Leadership class session that precedes The Mystery Lab is structured similarly to how this class operates throughout the year. Namely, there is assigned pre-reading, instructor-led discussion, and short-format in-class groupwork. We briefly review this session's design here because it is integral with the design of The Mystery Lab. Students attend this class session earlier in the same week (i.e., on Monday or Tuesday) as the lab (i.e., on Friday). Assigned pre-readings for the class span three topic areas: a compilation introducing ethical reasoning frameworks (i.e., consequence, duty, virtue, and justice) (see, e.g., [24-26]), a critical thinking framework for engineers [15], and an excerpt discussing how ethical dilemmas can often arise as "ill-structured problems" in engineering [24, p. 135 - 137]. After a brief instructor-led review of the ethical frameworks (with emphasis that the frameworks set is a non-comprehensive introduction), students are prompted to discuss how they would navigate a situation where the acceptable courses of action implied by the different frameworks conflict. Here the class is introduced to the concept of pluralism in ethical reasoning [24], where frameworks are used together to help identify a "best" course of action even if alignment with all frameworks is imperfect (e.g., illustrating why one might choose not to cheat even where positive consequences appear to outweigh negative ones, yet where duty, virtue, and justice frameworks would be violated). The class then discusses how ethical dilemmas in engineering rarely arrive as clear, binary choices (i.e., they are more often ill-structured [24]), often arrive without warning, and often require critical thinking skills to recognize them (e.g., to notice conflicts of interest, or unfounded or biased assumptions giving false confidence). In small breakout discussion groups, students then discuss with peers how they would use concepts from class to resolve an engineering situation involving the discovery of very low probability errant sensor readings in an autonomous vehicle's navigation system – a dilemma taking place within a business context where delays could imperil the small company involved. The groupwork prompt leads to a class-wide debrief in which student groups compare their proposed courses of action. The class concludes with an instructor-led discussion on how expanding teams' reasoning beyond optimizing for short-term incentives, such as in situations similar to the groupwork prompt, can lead teams to more substantial consideration of duty and justice dimensions intrinsic to engineering practice, including those that relate to public safety, diversity and equity, and sustainability (see, e.g., [16, 17]). The end of a typical Engineering Leadership class session would also usually include a preview of the forthcoming Friday ELL, with guidance on how the frameworks from class might be effectively employed there; such a preview is intentionally skipped for this particular week.

Learning objectives established for the full cycle of learning of the class-lab pair (i.e., the EL class session on Ethical Action and Integrity, The Mystery Lab ELL, and the brief wrap-up discussion at the start of the following week's class) are as follows. Terms in parenthesis indicate the primary venue of learning for each.

By the end of this unit of instruction, students will be able to…

- *Analyze* a given ethical dilemma using multiple ethical decision-making frameworks (class)
- *Describe* how critical thinking processes can aid in evaluating competing demands to determine appropriate courses of action (class)
- *Recognize* an ethical dilemma (lab)
- *Consider* appropriateness of resource use as part of ethical decision-making (lab)
- *Navigate* ethical decision-making in "gray area" situations tied to external pressure (lab)
- *Practice* using an ethical decision-making model in the context of a build project (lab)

The Mystery Lab's activity, described in the section that follows, presents student teams with a decision-making challenge involving the use of scarce public resources during an engineering start-up's formative stages. Given that *recognition* is a key learning objective, the mechanism of unexpectedness (i.e., not labeling the activity as an ethics challenge) is central to intended learning. The use of critical thinking in a teamwork setting is designed to be an antecedent to effective recognition of the ethical dilemma, as might manifest during the activity through team members' inquiries such as: "might this deal be too good to be true?," "what are we missing?," "are we making reasonable assumptions about what we're entitled to here?" Further, The Mystery Lab is designed to establish a close sense of proximity between the undergraduate students who undertake it and the risks of ethical lapse it carries: the activity is ostensibly about a group of employees who choose to spin a start-up company out of a government-funded research lab, yet it closely parallels the types of shared resource dilemmas university students might face in their day-to-day lives. This latter point is emphasized through another revelation at the lab's conclusion: the resource availability constraints and guidelines employed in the activity are actually those from an MIT policy that currently applies to them as students.

Experiential learning activity: Design of "The Mystery Lab"

At the onset of the activity period, ELL student team leaders receive instructions for the day's challenge (Appendix C), which categorize the activity as a decision making and resourcefulness challenge. The instructions inform students that they are a team of research fellows at a Federally Funded Research and Development Center (FFRDC). They then learn that one of their Center's projects, development of a "groundbreaking multi-purpose 9-legged helper robot," has been cancelled by the government. Despite the cancellation, the team believes this product has significant potential in commercial markets, so they decide to spin-out a startup company to continue the project on their own. The students' fellowships at the FFRDC will be ending soon and they begin transitioning their work to this new private venture. In the meantime, they learn, given the nature of the project's termination, that they are allowed to use the intellectual property from the robot project for their own pursuits. Yet, they also learn that their FFRDC employer maintains an "Acceptable Use Policy" governing whether and how the government lab's internal resources can be used by employees outside the bounds of the Center's own projects.

The students discover that their nascent robotics startup is taking off very quickly. They find themselves with four competing demands for early-stage robot hardware all due at the same time: A) one to show at a research conference, B) another to present at a trade show, C) a third robot for their first paying client, a hospital, and D) a fourth robot for an unknown additional paying client. The startup has only limited cash on hand from its two early clients' order deposits; yet, the team faces substantial needs for physical materials and software licenses to complete the four pieces of hardware. The student teams are provided with information about parts and software accessible to them, both commercially and within their FFRDC employer (Table 1). Their robots require "programmable control cards," "machined frame members," and "software licenses," all of which can be acquired by different means and at differing costs. The robots themselves must be built to comply with a specific physical configuration (Figure 1) and must be delivered to the front of the classroom by the end of the activity period. In total, when the activity concludes at the 55-minute mark, the student teams must deliver the physical hardware and their profit/loss calculation, and must be ready to explain how they've best positioned their company for success thus far.

Beyond the activity's backstory and team deliverables, several aspects of the activity's logistics are intentional facets of its educational design. For instance, the various material resources (both FFRDC's resources and commercially-available resources) are positioned at "material stores" physically separated by a distance of over 75-meters at opposite ends of a long corridor near the classroom. This distance adds a time demand and a need for forethought. The material stores, themselves, have small built-in time delays in their operation (see: Appendix D) that result in student queuing. The design of the "9-legged helper robot" is technically trivial (it is composed of small foam blocks, toothpicks, and stickers), yet it is laborious to assemble, with a specific pattern of toothpicks required at internal connection points (Figure 1); moreover, there are four of them to build. All of these time demands are meant to instill pressure upon the teams to make decisions about resource acquisitions quickly; they are meant to mimic real-life pressures that can cloud ethical decision-making. Further, the company's dire financial situation (i.e., limited cash on-hand to fulfill near-term obligations, while nonetheless being accountable for a profit/loss calculation) is similarly meant to strain decision-making. However, student teams learn during the activity that a substantial loan is available to them from a prospective investor to cover near-term expenses (see: Appendix D). Thus, financial solvency is not an issue that limits completion of the milestones due within the activity period. Lastly, through a statement in the opening paragraph of the students' instructions (Appendix C), the existence of the FFRDC's "Acceptable Use Policy" regarding employees' use of Center resources is made clear to students. However, as explained in a footnote, the full text of this policy is available "by request." This detail is meant to instill realism: formal guidance is often available in larger organizations, but some level of inquiry and proactiveness may be necessary to obtain it.

Table 1. Resources available to build robots during The Mystery Lab activity

	Internal Lab Resources (L)				Commercially Available Resources (C)			
Component	**Abbreviation**	**Visual Representation**	**Cost**		**Abbreviation**	**Visual Representation**	**Cost**	
Frame member, stock	L-M	Yellow toothpick	$0	ea.	-	-	-	
Frame member, fabricated	L-F	Blue-green toothpick	$25	ea.	C-F	Red toothpick	$50	ea.
Blank control card	L-C	White foam block	$0	ea.	C-C	Purple foam block	$100	ea.
Software license	L-SW	Green sticker	$0	unlimited	C-SW	Blue sticker	$6,000	unlimited

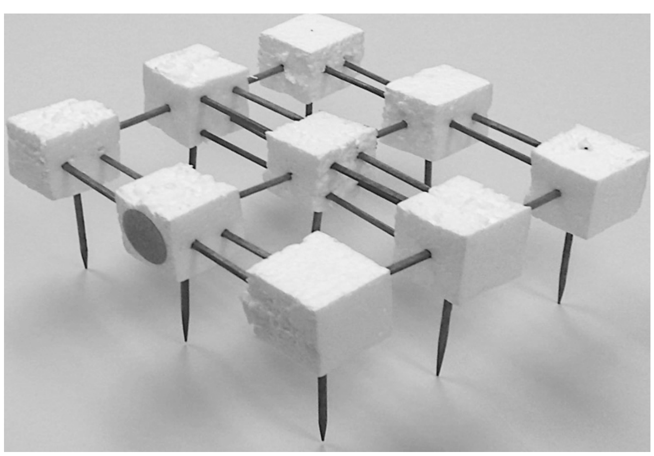

Figure 1. The Mystery Lab's hardware deliverable: "9-legged helper robot" (composed of toothpicks, foam blocks, round stickers)

The activity is designed to facilitate students' recognition, through critical thinking and application of ethical reasoning, that any use of the taxpayer-funded resources from the FFRDC's internal inventory is unethical in their for-profit, private startup company. This realization may take place during the activity time or during the team- or class-wide debrief discussions at the end of the activity. The fact that a "research conference" and a "hospital" are two of the use cases for their start-up's robots is an intended distraction meant to stir internal team debate: though those venues may be associated with public causes, the venues themselves are not the operative consideration here; rather, it is that the FFRDC's internal resources are intended for the work of the public research lab on other projects. Consuming such resources here is unethical, at least in part, because it pulls them away from their intended purposes to give considerable advantage to a private company at an unwitting public's expense.

Observations from "The Mystery Lab"

Student teams in action

In a recent instance of The Mystery Lab described here, the participating GEL cohort consisted of 23 student teams across the three ELL sections. All of these student teams participated in the activity, as indicated by all teams' delivery of robots to the front of the classroom at the activity's conclusion and all teams reporting their profit/loss calculation. Figures 2 - 3 show teams in action; for instance, assembling robots and acquiring robot components. Figure 4 shows an example line-up of one ELL section's completed robots on the designated delivery table.

Figure 2. Student teams preparing robots

Figure 3. A student purchasing robot components

Figure 4: Delivered robots at the activity's conclusion

Team deliverables

Table 2 summarizes the resource composition of each of the 23 teams' delivered robots, showing the breakdown of materials used from the internal lab resources and those sourced from an external commercial source (with the latter highlighted in bold for ease of comparison). The table also indicates whether each team requested a copy of the Acceptable Use Policy at some point during the activity. A small majority of teams (13 of 23 teams, 57%), requested a copy of the policy. Finally, Table 2 shows teams' reported expenses and their net profit (with net losses highlighted in bold). 61% of teams operated profitably during the activity period, while a substantial minority chose to operate at net losses (an outcome enabled by the availability of the loan).

From Table 2, it is clear that a wide variety of solutions to the activity's prompt was pursued and delivered among the teams. One team, Team 20, elected to use entirely commercially-sourced resources across all four of their robots. Eight other teams (Teams 2, 3, 10, 13, 15, 17, 19 and 23) chose to use substantial proportions of commercial materials such that they incurred financial losses in delivering their four robots. Many teams, 14 in total, however, chose to use predominately internal materials from the government lab to build their robots, resulting in positive net profits for the activity period. Across all teams, the robots for the paying customers (Robots C and D) were more likely to be constructed from commercial materials, while those for the research conference and trade show (Robots A and B, respectively) were more likely to be constructed from internal lab materials.

Table 2. Summary of team deliverables and expenses reported during The Mystery Lab activity

	Composition of Teams' Delivered Robots													
	Robot A (Research Conference)			Robot B (Trade Show)			Robot C (Hospital Client)			Robot D (Unknown Client)				
Team No.	Control Card	Frame Member	Software License	Control Card	Frame Member	Software License	Control Card	Frame Member	Software License	Control Card	Frame Member	Software License	Team Expenses	Team Net Profit
1	L-C	L-F	L-SW	L-C	L-F	L-SW	L-C	L-F	L-SW	L-C	L-F	L-SW	$2,900	$7,100
2*	**C-C**	L-F	L-SW	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	$14,675	**-$4,675**
3*	L-C	L-M	**C-SW**	L-C	L-M	**C-SW**	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	$10,700	**-$700**
4	L-C	L-M	L-SW	L-C	L-M	L-SW	L-C	L-M	L-SW	L-C	L-M	L-SW	$0	$10,000
5	L-C	L-M	**C-SW**	L-C	L-M	**C-SW**	L-C	L-M	**C-SW**	L-C	L-M	**C-SW**	$6,000	$4,000
6	L-C	L-M	L-SW	L-C	L-M	L-SW	L-C	L-F	L-SW	L-C	L-M	L-SW	$725	$9,275
7	L-C	L-M	L-SW	L-C	L-M	L-SW	**C-C**	**C-F**	L-SW	L-C	L-M	L-SW	$2,350	$7,650
8*	L-C	L-M	L-SW	L-C	L-M	L-SW	L-C	L-M	L-SW	L-C	L-M	L-SW	$0	$10,000
9*	L-C	L-M	L-SW	L-C	L-F	L-SW	**C-C**	**C-F**	L-SW	L-C	L-M	L-SW	$3,075	$6,925
10*	L-C	L-M	L-SW	L-C	L-M	L-SW	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	$10,700	**-$700**
11	L-C	L-M	L-SW	L-C	L-M	L-SW	L-C	L-M	L-SW	L-C	L-M	L-SW	$0	$10,000
12*	**	**	**	L-C	L-F	L-SW	L-C	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	$4,525	$5,475
13*	L-C	L-M	L-SW	L-C	L-M	L-SW	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	$10,700	**-$700**
14	**	**	**	L-C	L-M	L-SW	**C-C**	**C-F**	L-SW	L-C	L-M	L-SW	$2,350	$7,650
15*	L-C	L-M	L-SW	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	$13,050	**-$3,050**
16	L-C	L-M	L-SW	L-C	**C-F**	L-SW	**C-C**	**C-F**	L-SW	**C-C**	**C-F**	L-SW	$6,150	$3,850
17*	L-C	L-M	L-SW	L-C	L-F	L-SW	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	$11,425	**-$1,425**
18*	L-C	L-M	**C-SW**	L-C	L-M	**C-SW**	**C-C**	L-M	**C-SW**	L-C	L-M	**C-SW**	$6,900	$3,100
19	L-C	L-F	L-SW	**C-C**	**C-F**	L-SW	L-C	**C-F**	L-SW	L-C	**C-F**	L-SW	$11,975	**-$1,975**
20*	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	**C-C**	**C-F**	**C-SW**	$15,400	**-$5,400**
21	L-C	L-M	L-SW	L-C	L-M	L-SW	L-C	L-M	L-SW	L-C	L-M	L-SW	$0	$10,000
22*	**	**	**	L-C	L-M	L-SW	**C-C**	L-F	L-SW	**	**	**	$1,625	$8,375
23*	L-C	L-M	L-SW	**C-C**	**C-F**	**C-SW**	L-C	L-M	L-SW	**C-C**	**C-F**	**C-SW**	$10,700	**-$700**

Notes: * Indicates that the team requested a copy of the Acceptable Use Policy at some point during the activity
** Indicates that the particular robot was not delivered by the team
Robot components acquired from the commercial source are denoted in **bold**
Negative net profit (loss) values are denoted in **bold**

Activity debrief and reflections

After the close of the activity period, team results were shared with the entire classroom (i.e., separately at each of the three ELL sections). Robots were displayed at the front of the room for all to see, and profit/loss calculations were posted on the chalkboard. A non-student role player representing the investor then announced whether they would be choosing to further invest in any of the teams, revealing, at this point, a criticism of teams' choices to take materials from the government lab. Pointing to the availability of their loan, as well as to legal and ethical considerations, they explained they were expecting teams to source all materials commercially and that they would only further invest in teams that had undertaken full commercial sourcing (in this case, only Team 20 received notice of further investment). The second-year student facilitating the activity then revealed that the capability of *Upholding Ethical Action, Integrity, and Courage* [2] was in fact the ELL's main focus. First-year student teams were next asked to hold a 5-minute team-level debrief at individual team tables, at which point the second-year Team Coaches at each table asked their team to discuss what they felt they did well and what they could improve upon regarding carrying out the preceding activity. Following the team-level debrief, the class section convened a class-wide debrief where teams were invited to share insights from their team discussions, and instructors and guests offered comments. As the final component of the ELL, those first-year students from each team who served in the capacity of team leader received feedback on their performance from their Team Coach (in the format of Appendix A, which references capability definitions from [2]) and were asked to submit a reflection on the activity and their feedback within five days (in the format of Appendix B).

As part of the conclusion to the class-wide debrief, the second-year student ELL facilitator revealed that the Acceptable Use Policy from The Mystery Lab was in fact an excerpt from MIT's Acceptable Use Policy, with the institution name changed. The policy excerpt, therefore, illustrated how one large non-profit institution handles its widely-accessible internal resources in a context where many community members are engaged in personal side-projects and pursuits; while "incidental" use for personal purposes is allowed in some cases, resources are indeed substantially restricted in their acceptable uses. Instructors explained to students the educational reasoning behind the choice to embed MIT's policy into the activity: to emphasize to students that the ethical dilemmas exist in closer proximity to them than they may realize. Also at the end of the class-wide debrief, the Engineer in the Room guests, who had been observing teams throughout The Mystery Lab, were invited to discuss connections between the activity and their experiences in practice. For instance, one guest shared a story from their professional experience where a colleague took the uncomfortable step of inquiring why safety tests run by another colleague seemed to be completed unusually quickly, an action that led to the discovery of fraudulent behavior that compromised product safety. The guest shared with students that "asking the extra question" is often uncomfortable, but expressed hope that the ELL's practice opportunity will strengthen their confidence for handling these challenges in the workplace.

All 23 first-year student team leaders submitted their reflections on The Mystery Lab. For ELL class credit, these reflections are graded simply for completeness and timeliness; yet, for descriptive purposes here, two instructors (both coauthors of this paper), independently reviewed them for indications of intended learning using a predetermined rubric. Most reflections (19 of 23, 83%) demonstrated some degree of student development in their capacity for recognition of ethical dilemmas. The rubric consisted of two criteria, both of which needed to be satisfied for a reflection to be counted in this percentage: 1) an acknowledgement somewhere within the reflection that the activity represented an ethical or moral dilemma, and 2) a discussion of how recognition of an ethical dilemma was integral to performing effectively in the activity, either in terms of reflecting on how their team could have done better with recognition, or why they did well with it. Examples of how students discussed the need for enhanced recognition in situations similar to the activity included the following:

- "Rather than immediately jumping to the deliverables of a problem statement, I should grapple with and understand all the background – something that led me to overlook the ethics of this lab."
- "Although I did not know that there was an ethical dilemma at the time…I should have slowed down to make sure that I understood what the task was and helped lead my team down the correct path."
- "I knew there was something missing...but I silently assumed that I'm missing it due to the pressure of performing on the spot...Because I didn't have a good grasp of the problem myself, I wasn't able to guide my team...to think about the ethics problem."
- "I would say that we just did not pay enough attention to details. Our main thought process was that we needed to make something and we needed to profit. This was our driving factor, and we bulldozed ahead to complete this mission."
- "We forgot crucial details about what we were actually doing - we only assigned commercial materials to models that we were planning on selling, forgetting that all of our activities are commercial…we took the policies laid out too literally: Rather than understanding it as an ethical document."

Further, several students raised key points about teamwork or their team's social context as they discussed what it would take to recognize and act upon the activity's ethical dilemma, for example:

- "I felt something was off throughout most of the lab, but because certain members of my team had interpreted the instructions a certain way and were quite confident about it, I didn't really raise my concerns until the end of the lab when it was too late."
- "Once we finished the project some of my teammates said 'I'm confused about what the challenge is,' 'Is there a difference,' 'Free stuff is that good or bad,' and 'We should have someone read the fine print.' As a leader I was happy and proud of what I thought was that we finished the project in ample time. I did not dismiss what my teammates said, but I also did not act upon what they said. These oversights cost us in the long run."
- "I implemented a very action-oriented decision making structure for this challenge...this meant I didn't leave much room for taking a deep dive on the instructions. Going forward...it may be a good option to delegate a team member to specifically look for details..."

Discussion

Insights on student learning

At first glance, the set of student team deliverables from the activity component of The Mystery Lab (Table 2) is striking in its variety (e.g., materials that ranged from fully government-sourced to fully commercially-sourced; profits that varied from -248% to +174% from the mean). Yet, given the intended experiential learning mode, it is important to emphasize the purpose of the activity component within the overall educational unit: it is not for student teams to obtain a specific right answer in one try; rather, it is to create a personal experience "focal point" [19, p. 1390] for students to draw upon as they build more concrete meaning of the unit's ethics concepts. The ELL format, furthermore, helps to situate these personal experiences in a comparative frame of peer examples and available alternatives through the class-wide sharing of all teams' outcomes. This comparative frame plays a key role in supporting discussion during post-activity debriefs and as well as students' engagement in reflection. Compared to teams' physical deliverables, students' post-activity reflection submittals paint a much more consistent picture of intended development from the overall educational unit. Here, only 17% (4 of 23 reflection submittals) neglected to discuss intended learning in the area of recognizing an ethical dilemma through applied critical thinking; all others were able to cite pertinent areas of their activity performance to refine toward enhancing their ability to detect a similar ethical dilemma in the future. We caution, however, that students' reflective sense of how to perform more effectively, while a component of intended learning [18], is not, on its own, an assurance of improved future performance. In this light, we also discuss planned assessment of longer-term ethics-related development among program students in *Challenges, limitations, and future work.*

An illustrative example of students leveraging the post-activity comparative frame to enhance their learning relates to sensemaking about profit in the activity. As shown by Table 2, it became clear to students soon after the activity that profitability was approached quite differently by different teams. This sense of difference appeared to prompt questions during team- and class-level debriefs about the role of profit in the scenario, as well as to prompt scrutiny of assumptions surrounding profit. Instructors observed student teammates (i.e., on teams that elected to take a positive profit) asking each other why they originally sensed they needed to report being profitable during such an early stage of their hypothetical start-up company. These discussions unearthed unfounded (and initially unspoken) assumptions that teams realized they had been harboring regarding a perceived need to become profitable within such a short timeline as a goal of the scenario. Acknowledgement of these unspoken assumptions also appeared in reflection submittals (e.g., "I was so primed to think only about 'maximizing profit'" and "our original thought process was…that we needed to profit"). There was, of course, no such requirement in the activity prompt about being positively profitable, a point that was reinforced by the investor role-player at the conclusion of the activity. Moreover, the debrief and reflection components appeared to provide an opportunity, albeit retrospectively, for students to practice identifying and testing poorly-founded assumptions, a key component of the unit's critical thinking framework [15].

Also an encouraging sign among students' reflection submittals were the discussions of the role of teamwork and team social context toward (or straining) ethical decision making in the activity. Here, some students appeared to develop a sense of pitfalls and opportunities tied to ethical action in team settings. As one expressed: "because certain [team] members...were quite confident...I didn't really raise my concerns until the end..." Another, citing their own perceived overconfidence as a leader, shared: "I was happy and proud of what I thought was [success]... I did not dismiss what my teammates said, but I also did not act upon what they said. These oversights cost us..." In both such cases, the reflection submittals suggest students' heightened sense of the importance of effective listening and of accounting for diverse perspectives when it comes to navigation of ethics dilemmas in team settings – skills, however highly valued in a broad sense, that students may not have connected directly to team-level ethical performance until now.

Risks, opportunities, and extensions of experiential learning in engineering ethics

Despite their potential to help situate ethics learning into practice-representative contexts, activity- or simulation-based experiential learning modules can involve curtailing or condensing otherwise realistic experiences. A real-world ethical dilemma akin to a company's decision-making process about material sourcing, for instance, may be unlikely to take place within 55-minutes. We can identify elements of nuance that are at risk of being lost by condensing experiences. For example, a mechanism within The Mystery Lab intended to reinforce the presence of an ethical dilemma is the role that the Acceptable Use Policy plays in emphasizing choice implications. Ethics and adherence to rules or laws, however, are not identical concepts [24]. The presence of the policy, and its implicit authenticity in coming from the students' university's policy, provide an efficient means of conveying the gravity of the situation and of reinforcing students' connectedness to it; yet, we cannot be sure that students are correctly interpreting the intended role of the policy during the activity period. It is important here that students do not infer a simple equivalency between ethical reasoning and "following the fine print." Examples of risks to learning, such as this, highlight the opportunity offered by the class-lab pairing. This scheme provides a venue, via the class component, for longer-form instructor-moderated discussion about concepts (and conceptual distinctions, in this case) as a means of supplementing the fast-paced experiential learning component. For this reason, in the EL class sessions that follow each ELL session, time is reserved at the start of class to continue developing, discussing, or reinforcing concepts tied to the activity.

The class-lab pairing scheme also enables instructors to extend the learning achieved within a given ELL beyond a particular week's educational unit. Given that the ELL activities are self-contained, they risk being isolated; it is the seminar class component, therefore, that serves as the "glue" that connects learning experiences, both to elsewhere in the class and to future sessions of the lab. This ability to facilitate connections allows separate experiential learning instances to be additive, which is particularly salient for ethics-related learning where The Mystery Lab serves as merely a conceptual introduction. This introductory unit is strongly connected to (and extended by means of) many other units in the program. As select illustrative examples of how these connections are forged within GEL's first-year curriculum: the critical thinking framework from the introductory ethics unit is employed in a future unit on understanding customer and societal needs, benefits, and harms; the concept of ill-structured problems from this unit is revisited in a unit on systems thinking; and the ethical frameworks, particularly duty and justice, are referenced in a lab activity on inquiring and dialoguing, where students learn, through conversations with non-student role players, about colleagues facing unjust workplace conditions (of discrimination and harassment) and contemplate how to be supportive allies. More broadly, themes about ethics' integral role in building just and equitable team and organizational environments in engineering [8, 16] and of engineers' responsibilities for safety and public wellbeing [27] are built upon throughout the program through this additive set of experiences and discussions. The introductory ethics unit and its Mystery Lab component are therefore strategically positioned early in this sequence so that learning achieved there can provide a springboard to future concepts rooted in the foundation it lays.

Challenges, limitations, and future work

The distributed nature of ethics learning in GEL poses challenges for assessing its overall impact on student development. Evidence of learning presented in this Practice Paper is highly localized (in time) relative to one learning experience, yet research suggests that development of ethical reasoning in engineering undergraduates may be best evaluated longitudinally [11, 20]. We therefore present The Mystery Lab (and its associated class lesson) as a promising building block of ethics learning, rather than as a holistic solution. Our understanding of The Mystery Lab's overall impact integral to its host EL program would be strengthened by further assessment. This assessment work is presently in-process at GEL as part of a program-level longitudinal assessment plan [28] that includes self-efficacy measures related to ethical reasoning; we plan to report on this effort in future work (see [9] for further details of a similar program-level self-efficacy-based assessment approach employed elsewhere). Moreover, the longitudinal assessment in-process in GEL will examine full program cohorts, whereas the evidence of learning discussed in this Practice Paper draws from an approximately random sample of reflection assignments contributed by those students appointed to the team leader role during The Mystery Lab activity.

Meanwhile, local to the activity itself, observations suggest an opportunity to augment or refine the questions set in the team debrief prompt in the ELL Instructors' Document (Appendix D). Since some students reported (via ELL reflections) that team members' inputs relevant to team decision making were not always taken into account during the activity, a debrief question assessing the inclusive environment in the team would be helpful to call peers' attention to these lapses. A current debrief question asks about achieving "agreement" and "resolving differences" within the team, but can be improved by first asking about the extent that diverse inputs are being heard and considered by the team.

Lastly, we call attention to The Mystery Lab's unique positioning in the GEL curriculum, highlighting the possibility that its learning efficacy could be sensitive to such. For instance, we were seemingly able to sustain students' unexpectedness of the activity's ethical dimensions based on when and how the activity was positioned in its host program's sequence (as described earlier in *Embedding ethics education...*). It is unclear how effective The Mystery Lab would be, on the other hand, if it were part of a semester-long class on ethics where every learning component is expected to be about ethics, or if it were announced as an ethics activity. Positioning should therefore be kept in mind by programs considering a similar ethics experiential learning activity. Future work that examines a learning activity similar to that of The Mystery Lab in different curricular positionings could supplement the findings shared here.

Conclusions

The Mystery Lab was designed to challenge students with navigating an unheralded ethical dilemma intertwined with day-to-day, team-based engineering work. Viewed in isolation, observations from The Mystery Lab's activity component suggest that many student teams struggled to identify and reason through the embedded dilemma, resulting in submittal of deliverables that ostensibly violated pertinent ethical standards. Yet, broader observations of learning from beyond the activity component, specifically, those from the reflection component of the unit, indicated development in intended areas in the majority of cases. Our observations from operating The Mystery Lab therefore suggest there is promise in employing experiential learning toward developing EL students' ethical reasoning skills; yet, that care should be paid to designing the learning segments that immediately precede and follow an experiential component, including conceptual learning, discussion, and reflection components. While GEL's implementation of The Mystery Lab relies on a certain set of program structures described here (i.e., class-lab pairing, positioning within a year-long sequence, and the presence of other longer-form coursework components), we hope that sharing its design may assist other EL programs with examining the viability of similar experiential learning modules tailored to their programs. Given both the relevance and challenges of facilitating learning in ethics for EL students, a library of examples of such modules would strengthen the EL education community's ability to impact this area of learning across program types and configurations.

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Appendix A: Engineering Leadership Lab team leader assessment feedback form

Team Leader Assessment Report

Part I - Record of Observations and Feedback

a. SUMMARY OF OBSERVATION: Summarize the most significant observed leadership behaviors/Capabilities.
Use sufficient detail to support overall assessment and summary ratings in Part II.

b. FEEDBACK: Comment on at least one "MAINTAIN" and one "IMPROVE" Capability as identified in Part II.

Satisfactory:

Needs Improvement:

ELL Name	Assessment Date	Assessor's Name	Initials	OVERALL ASSESSMENT
				E S N
Rated Student's Name	Student's Signature and Acknowledgement (see below)			Reflection Required: Y / N Due date:

Part II - Summary Ratings

TI Taking Initiative	1 2 3 4 5	**ID** Inquiring and Dialoguing	1 2 3 4 5
MD Making Decisions in the Face of Uncertainty	1 2 3 4 5	**SC** Developing and Deploying Structured Communications	1 2 3 4 5
UR Upholding Responsibility, Urgency, and Will to Deliver	1 2 3 4 5	**MC** Negotiating, Compromising, and Managing Conflict	1 2 3 4 5
ER Exercising Resourcefulness, Flexibility and Change	1 2 3 4 5	**AI** Advocating and Influencing	1 2 3 4 5
EA Committing to Ethical Action, Integrity, and Courage	1 2 3 4 5	**DC** Building Diverse Connections and Communicating across Cultures	1 2 3 4 5
FT Fostering Trust, Loyalty, and Team-Building	1 2 3 4 5	**IC** Interacting Constructively; Providing and Receiving Feedback	1 2 3 4 5
______	1 2 3 4 5	______	1 2 3 4 5

Appendix B: Engineering Leadership Lab team leader reflection template

ENGINEERING LEADERSHIP LAB - LEADERSHIP REFLECTION AND SELF-ASSESSMENT

STUDENT: ______________________________ ELL NAME:_______________ DATE:_________

ASSESSED BY:_____________________________

STUDENT REFLECTION

ACTIVITY AND PERFORMANCE SUMMARY:

WHAT I DID WELL: (List two or more capabilities in which you excelled and explain)

WHAT I NEED TO IMPROVE ON: (List two or more capabilities which you can improve upon and explain)

COMMENTS ON THE PERFORMANCE FEEDBACK AND COACHING RECEIVED:

Appendix C: The Mystery Lab student instructions

STUDENT PACKET

Engineering Leadership Lab: "The Mystery Lab"

Overview:

You are a team of fellows at TikTec National Laboratory, a Federally Funded Research and Development Center (FFRDC), which heavily emphasizes innovation in order to develop practical solutions for some of our nation's most critical challenges. Due to limited resources, the scope of all the ideas generated in the lab exceeds the lab's resources for maturing these concepts – so, the lab must prioritize which ideas it funds, versus which it lets go. Part of what attracts reputable research fellows to TikTec is the fact that they might walk away with some great IP to develop on their own post-fellowship – TikTec understands and embraces this reality, and thus maintains a "Acceptable Use Policy"[1] about how its internal resources may/may not be permissible for fellows to use for their own personal pursuits.

TikTec Lab recently decided not to maintain control over the IP for MachBOT, a groundbreaking multi-purpose 9-legged helper robot. As far as TikTec is concerned, the MachBOT project is cancelled. However, believing that MachBOT has huge market potential, your team founded a small start-up company (Global Engineers Ltd.) to further develop and sell MachBOT commercially. Your fellowships will soon be ending. Your team must juggle the fact that there are now multiple demands for MachBOT hardware that are all due around the same time period. Also, you've still got your "day jobs" as fellows at TikTec Lab until a few months after the initial critical MachBOT deliveries are due. Your small company team's critical commitments are:

- **[Deliverable A]** – Build 1 MachBOT to show at an academic research conference
- **[Deliverable B]** – Build 1 MachBOT for a technology expo / trade show to attract potential clients
- **[Deliverable C]** – Build 1 MachBOT for the first real paying customer – a local hospital
- **[Deliverable D]** – Build 1 MachBOT for the second real paying customer

At any given time within TikTec Lab, there are concurrent teams working on taxpayer-funded research projects, as well as other competing teams working on their own personal projects. **Each student team must compete for resources along with everyone else at TikTec.** Your goal is to best position your company for success.

	$	Notes
Total Revenue to Date	$10,000.00	Received from the 2 paying customers based on a $5,000.00 unit price (price was derived from an early business development estimate)
Costs to Date	N/A	No costs accrued; all material/lab/tool resources used thus were from TikTec Lab, via trying to comply with the acceptable use policy.

Deliverables:

- **Acquire material for, build and deliver the MachBOTs** (labeled A, B, C or D) by the end of the activity.

After the 55-minute activity concludes, teams must report:

- **Profit earned***
- **Confirm MachBOT deliveries that have been completed** (i.e. A, B, C, and/or D)
- Explain how you've **best positioned your company for success,** given the constraints

**Note: Profit = [Total revenue to date] – [Totals cost incurred to build units, incl. unused parts (team labor is free)]*

Ground Rules:

- With the exception of parts color (which is not specified), MachBOTs must match the photo provided.
- Your team may meet, plan and strategize within the classroom, but **your MachBOT material cannot enter the classroom until the 55-minute period has ended** – you are competing against other teams and you should not reveal your progress to them.
- Trading/bartering/buying/selling parts between competing teams is not allowed. Mergers/partnerships between competing teams is not allowed.

Resources to Build MachBOTs:

A MachBOT uses only two unique parts: machined frame members and programmable control cards. The control card is blank (unprogrammed) when it's procured; it must be programmed for it to become usable.

[1] TikTec Lab's "Acceptable Use Policy" is available for reference at teams' request

Appendix C: The Mystery Lab student instructions [Continued]

STUDENT PACKET

Engineering Leadership Lab: "The Mystery Lab"

Material is available from the following sources (you may not use material from any other sources):

- TikTec Lab material is located: ______
- External material is located: _______

	TikTec Lab Resources				Resources External to TikTec Lab		
Part:	**Machined Frame Member**	**Machined Frame Member**	**Blank Control Card**	**Software License - Control Card Programmer**	**Machined Frame Member**	**Blank Control Card**	**Software License - Control Card Programmer**
Color Code	Yellow	Blue-Green	White	Green Sticker	Red	Purple	Blue Sticker
Stock Type	**TikTec Labs Stock Inventory** (Material bought by the lab and shared across lab projects)	**TikTec Labs Machine Shop Services** (You buy the raw material, TikTec Lab staff machines it for you when they have time)	**TikTec Labs Stock Inventory** (Material bought by the lab and shared across lab projects)	**TikTec Software Lab** (Non-profit use software license from Gordonica, Inc.)	**Commercial Machine Shop** (you pay for all material and fabrication costs)	**Commercial Electronics Vendor**	**Gordonica, Inc.** (Commercial software vendor)
Availability	Stocked in abundance	Available at the rate at which it can be produced; production is ongoing	Stocked in abundance	N/A (always available)	Available at the rate at which it can be produced; production is ongoing	Stocked in abundance	N/A (always available)
Other Notes	TikTec maintains a large bulk stock, but periodically a large internal project may consume all of it. It will then be replaced fairly promptly.	The machine shop will consistently release another batch of parts every five minutes	Always available	Your team has access to a non-profit/unlimited use license owned by TikTec Lab. You can program a control card in negligible time for free using this license. Control cards programmed with this license get a green sticker.	The machine shop will consistently release another batch of parts every five (5) minutes	Always available	For a one-time cost of $6,000, you can obtain a commercial license to program all of your control cards. Control cards programmed with this license get a blue sticker **You must obtain a paper certificate if you purchase this license**
Cost	Free to TikTec Lab employees	$25 each	Free to TikTec Lab employees	Free to TikTec Lab employees	$50 each	$100 each	$6,000 one-time cost for unlimited-use license

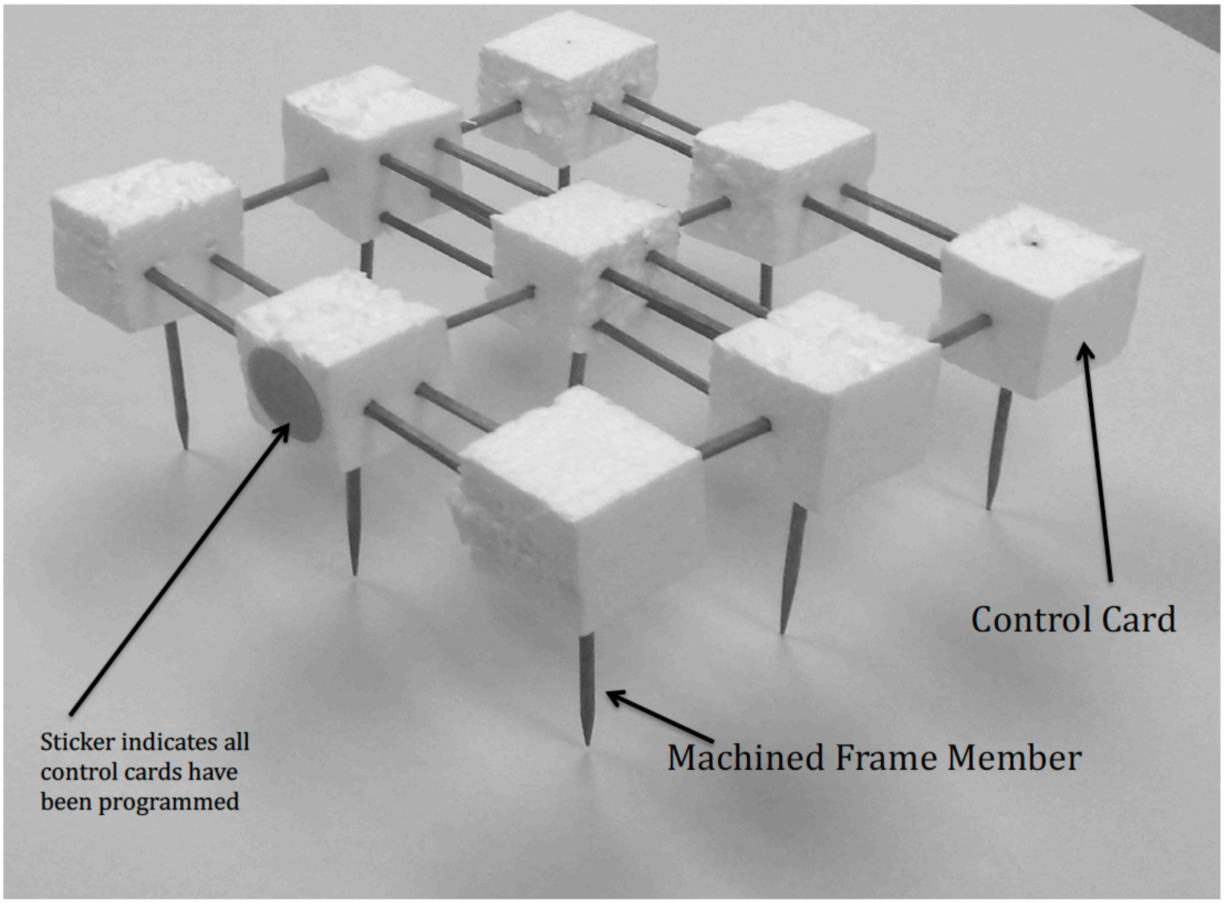
- **To ensure manufacturing integrity and quality control, once material has been procured from a store, it cannot be returned or exchanged in any way.**

Appendix C: The Mystery Lab student instructions [Continued]

STUDENT PACKET

Engineering Leadership Lab: "The Mystery Lab"

MachBOT Design:



Appendix D: The Mystery Lab instructors' documentation

INSTRUCTION PACKET

Engineering Leadership Lab: "The Mystery Lab"

Overview: Students have tight manufacturing deadlines, different options for resources to use (of varied appropriateness) and multiple concurrent product deliveries. They have to decide which resources they should use in order to "deliver" and how much profit to try to accrue, based on the scenario at hand. Initial framing of the lab is minimal; it's initially framed to be about decision-making and resourcefulness. The lab's ethics focus is revealed and discussed during debrief.

Capabilities [of Effective Engineering Leaders]:

***Committing to Ethical Action, Integrity, and Courage (EA)*–** Adherence to ethical standards and principles. Demonstrating the courage to act ethically and with integrity. Committing to practice is accordance with norms of professional responsibility and one's responsibility to society.

***Exercising Resourcefulness, Flexibility, and Resilience (ER)* –** Ability and willingness to approach problems, tasks, and situations making ingenious use of the resources of the situation and group, and to manage the use of time. A willingness to accept and respond to change, embrace various views, be adaptable, and maintain and take alternative courses of action when necessary.

***Making Decisions in the Face of Uncertainty* (MD)–** Ability and willingness to make decisions based on the information at hand, factoring in risks, uncertainty, and potentially conflicting objectives

Learning Objectives: By the end of the class, students will be able to:
1. Recognize an ethical dilemma.
2. Consider appropriateness of resource use as part of ethical-decision making.
3. Navigate ethical decision-making in "gray area" situations coupled with external pressure.
4. Practice using an ethical decision-making model in a build project context.

Timeline:

Time	Activity	Notes
1 min	Activity Framing and Introduction	Lab Leader – Introduction of the lab brief framing of the activity as "an additional opportunity to practice MD, ER, and other Capabilities" as students will compete against other teams to launch their start-up.
7 min	Instructions Provided to Teams	Lab Leader takes Team Leaders outside of the classroom, provides them with copies of the instructions, and a brief opportunity (~1-min) to ask questions. FIRST-YEAR STUDENT Team Leaders are directed to return to this location in 30-min.
55 min	Activity: "Getting it off the Ground"	Students will have 55 minutes to plan, obtain material, and build the deliverable "MachBOTs". Teams are intentionally aske to leave the classroom and find a location nearby, but out of sight of other teams.
	Investor / VC meeting with Team Leaders	About 30-minutes into the activity, Team Leaders will return to the original meeting location to engage with a potential investor (VC). VC will present each team with a loan/investment proposal offer for up to $10,000.
5 min	Results, "Winner" declaration	**Teams must return to the classroom.** Teams will deliver their completed MachBOTs to their designated area, then calculate the team's cost-per-unit and potential profit (if any). Results are posted and compared. VC announces partnership (if/as applicable)
5 min	Activity "reveal"	Lab Leader "reveals" the actual Capabilities and Learning Objectives

Appendix D: The Mystery Lab instructors' documentation [Continued]

INSTRUCTION PACKET

Engineering Leadership Lab: "The Mystery Lab"

10 min	Team Debrief	Team Coaches facilitate team debrief
5-7 min	Class-wide debrief	Lab leader facilitates class-wide debrief centered on key-concepts / frameworks presented in EL.
5 min	Comments from "Engineers in the Room"	Engineers from industry provide comments and observations about the lab and/or anecdote regarding the importance of Ethical Action / decision making in engineering industry.
2 min	Administrivia	Instructors will make administrative comments
5 min	Assessment	Team Coaches will meet with Team Leaders and conduct a formal performance / assessment review.

Assessment: By the end of the lab, each Team Leader will have an Assessment Card and overall assessment rating (E/S/N) completed by their Team Coach.

General Instructor Notes: This will be listed as "The Mystery Lab" in the course syllabus.
On the board, write the topic "Resourcefulness in Entrepreneurship."

Also write the following points:
1. Your team must deliver robots by the end of the activity period.
2. You're competing against other teams to break into the market.

Reveal and share the complete learning objectives with students during the post-activity debrief.

The acceptable use policy will be available at the TikTec stockroom (store) upon student request (so students don't immediately realize the main point is ethical decision-making). All teams will have access to varied means of obtaining materials. They'll be color-coded to show whether they're TikTec or Commercial parts and a clear/concise table will be provided listing costs. At the end of the activity, students will tally up their expected profits for the units they've built based on which parts they used.

The expectation is that each team delivers a different answer for "profit" (some of which may/should be negative – i.e. a loss/loan). It's also expected that the different teams will succeed at delivering different numbers of MachBOTs – the dilemma will be that the required (4) cannot be built profitably (ethically) using only commercial parts. Teams/Team Leaders will have to decide whether to build 4 (unethically) using only TikTec parts or at a negative profit (i.e. a loss/loan), or to build only a subset of the 4 MachBOTs within ethical bounds and at some profit margin.

At the end of the activity, teams calculate and report their results which will be posted for comparison. During team debriefs, the team coach will ask first-year students how/if they applied the Ethical Decision-Making Framework and discuss each deliverable and why the team used a particular set of parts.

Scoring: Note that each team's results should be denoted on the chalkboard beside their team number (see Photo 1)

Framing: After the welcome, Team Leaders should receive instructions (outside of the classroom) and immediately began reading the instructions. It was a deliberate choice to not provide any guidance or context regarding ethical decision-making.

Debrief:
Introduce learning objectives. In addition to applying the decision-making framework and discussing various scenarios, the Team Coach can encourage the team to respond regarding the following:

Photo 1: Scoreboard from one ELL section

Appendix D: The Mystery Lab instructors' documentation [Continued]

INSTRUCTION PACKET

Engineering Leadership Lab: "The Mystery Lab"

- What do you sense this lab was about?
- How did you make decisions during the lab? Did you use the ethical decision making Frameworks or some other process?
- What do you think is the "the right approach" to this lab? (Is going negative by taking a loan the only strategy?)
- Within the constraints of the exercise, does the team feel that they best positioned their company for success?

After team debrief, the class will all discuss together (class debrief). Recommended prompts:

- (Look around the room and comment on unique/interesting examples of material choices.) Ask what differences students noticed across the teams?
- Describe your strategy, was your choice right? Now that you've seen results from other teams, do you still think you made the right choice? Why might there be differences between teams?
- How did you set your company up for success? Let's talk about the decision to be profitable.
- What is ethical behavior for each scenario?
- Talk about your experience in your team. Did everyone agree? Did anyone feel bad? How did you resolve your differences?
- Ethical decision-making process – did applying a particular lens lead to an outcome you didn't expect? Did any particular lens stand out as critical?

Equipment List

- Plastic containers for each type of part
- 6 sheets of 1" x 12" x 28" foam (Smooth Foam brand, purchased at Michaels) – See Photo 2
- 1 can of spray paint (craft/acrylic) that's appropriate to use on foam
- At least 3 colors of toothpicks (or standard toothpicks dyed with RIT fabric dye) – see the resource/materials list (2,000 of each color)
- Round stickers in any 2 colors (250 of each color) (recommended Avery 5461 Round ¾" Diameter Labels)

Photo 2: Uncut foam material

Student Handouts:

- Acceptable Use Policy available to teams upon request from TikTec store.
- Each team receives one copy of the instructions
- Ethical decision-making process (for the debrief only, see separate file) (1 per Team Coach)
- Calibration cards (1 per Team Coach)
- Assessment Cards (1 per Team Coach)
- Spot Report Forms (available)

Working with "Engineers in the Room":

This is a sensitive topic that can inspire a wide range of anecdotes. It is recommended that the Lab Leader and the instructional staff meet with any visitors and discuss what kind of contribution would be most beneficial.

Appendix D: The Mystery Lab instructors' documentation [Continued]

INSTRUCTION PACKET

Engineering Leadership Lab: "The Mystery Lab"

Guidance for Staff Running Material Stores (8-Team Lab Section):

- Staff (TAs) will set up and operate two "material stores" in a corridor some distance away from the classroom
  - One store represents the TikTec Lab Stock (located _______)
  - The second store (Initech) represents the Commercially Available Parts (located ______)

- **Queue Management** – material availability is offered on a first-come-first-serve basis (based on the order in which students arrive at the store). Students cannot "camp out" in front of the queue for the entire lab period; they may stay at the front of the line until the next batch of parts are released and may have their pick of those parts, but then must relinquish their spot in line. Variation in material availability is an intentional aspect of this activity.

TIKTEC LAB STOCK MATERIAL STORE (8-Team Lab Section):

	TikTec Control Card (White Foam)	TikTec SW License (Green Sticker)	TikTec Stock Machined Frame Member (Yellow Toothpicks)	TikTec Custom Machined Frame Member (Blue-Green Toothpicks)
Total stock quantity:	225	Unlimited	750	655
Availability:	All are always available	All are always available	Entire stock is available except during two black-out periods:	55 are initially available. There should be no more than 55 toothpicks in the bin at any point. Additional toothpicks (to bring the total back to 55) are added every 5 minutes.
			t= 0-15 mins: all available	
			t= 15-20 mins: none available	
			t= 20-35 mins: all available	
			t= 35-40 mins: none available	
			t= 40-60 mins: all available	

COMMERCIAL MATERIAL STORE (8-Team Lab Section):

	Commercial Control Card (Purple Foam)	Commercial SW License (Blue Sticker)	Commercial Machined Frame Member (Red Toothpicks)
Total stock quantity:	225	Unlimited	750
Availability:	All are always available	All are always available	For the first 5 minutes, no toothpicks are available. At 5 minutes, 70 are added. There should be no more than 70 toothpicks in the bin at any point. Additional toothpicks (to bring the total back to70) are added every 5 minutes.
		NOTE: if a student requests a commercial software license, hand them a paper certificate (one per team) in addition to the stickers	

Appendix D: The Mystery Lab instructors' documentation [Continued]

INSTRUCTION PACKET

Engineering Leadership Lab: "The Mystery Lab"

TikTec National Laboratory – Acceptable Use Policy [EXCERPT]

6.3 Privacy and Confidentiality of TikTec Records

All members of the TikTec National Laboratory community are responsible for ensuring that their handling of information about individuals is consistent with the TikTec policy on privacy of personal information (see Section 11.2 Use of Personal Information). In addition, other records (that is, records that do not contain personal information) must be handled with due regard for privacy and confidentiality concerns.

6.4 Information Preservation and Security

6.4.1 Preservation of Information

TikTec has an obligation to provide accurate, reliable information to authorized recipients and to preserve vital records (see Section 13.3 Archival Policy). TikTec is increasingly dependent on the accuracy, availability, and accessibility of information stored electronically and on the computing and networking resources that store, process, and transmit this information. Records created and maintained in electronic form are included in the definition of archival materials. In addition, upon direction from the Office of the General Counsel, records must sometimes be preserved for prescribed periods of time for litigation or other legal purposes.

6.4.2 Security of Information

Individuals who manage or use IT resources required by TikTec to carry out its mission must take reasonable steps to protect them from unauthorized modification, disclosure, and destruction. Data and software are to be protected, regardless of the form, medium, or storage location of the information. The level of protection shall be commensurate with the risk of exposure and with the value of the information and of the IT resources.

Some information has additional legal protection, like certain medical information, education records, certain financial records, and specific categories of personal information covered in the Written Information Security Program. As described in the Written Information Security Program, teams that regularly use specified categories of personal information should have written procedures on protecting that data, and should also implement specific procedures concerning how that data is destroyed when no longer needed.

6.5 Responsible Use of Resources

6.5.1 Approved Use of Resources

All members of TikTec are obligated to use its resources in accordance with applicable laws, with Laboratory policies (including its policy against harassment, and its standards of honesty and personal conduct), and in ways that are responsible, ethical, and professional. Users of TikTec's network must also comply with the Network Rules of Use.

The use of TikTec's resources is restricted to Laboratory business and incidental personal use. Incidental personal use may not interfere with TikTec work, nor may it result in additional direct cost to TikTec. TikTec's computers and other resources must be used in a manner consistent with TikTec's status as a non-profit organization, and so, for example, cannot be used for the benefit of personal businesses or other organizations unless permitted by TikTec policy (for example, permitted under Section 7.1 Outside Professional Activities) or otherwise authorized. Unauthorized access to and use of TikTec's resources violates this policy.

6.5.2 Interference with Resources

Members of the TikTec community should not take unauthorized actions to interfere with, disrupt, or alter the integrity of TikTec's resources. Efforts to restrict or deny access by legitimate users of the Laboratory's resources are unacceptable. Individuals should not use TikTec facilities to interfere with or alter the integrity of any resources, irrespective of their location.

Destruction, alteration, or disclosure without authorization of data, programs, or other content that belongs to others but that is accessed through TikTec's IT resources is also prohibited. TikTec may block an individual or group's access to its resources in order to protect its resources and the information contained in them.

6.6 Privacy of Electronic Communications, Electronic Files, and Other Files

As noted, members of the TikTec community should exercise caution to protect information (and particularly personal information) from unauthorized disclosure. Particular caution should be used with electronic communications, because of the ease with which such communications can be distributed and due to concerns about unauthorized access. Unauthorized interception of email and other electronic communications is prohibited by TikTec policy and may also violate state and federal law.

Policy text drawn from posted MIT policies at: https://policies.mit.edu/policies-procedures

Appendix D: The Mystery Lab instructors' documentation [Continued]

INSTRUCTION PACKET

Engineering Leadership Lab: "The Mystery Lab"

For legitimate business reasons, representatives of the Laboratory may need to access electronic or other records (including paper files) without the consent of the individuals having custody of them; examples of these business reasons include access required by law, where the individual is unavailable due to illness, in the course of an investigation, or in cases of alleged misconduct. Teams may determine additional reasons for access, for example, due to sponsor requirements. Any member of the TikTec community who accesses information from records maintained by another individual without the individual's consent must seek prior approval from the applicable Senior Officer or his or her designee for such access and related disclosure; the Senior Officer or designee may consult the Office of the General Counsel.

6.7 Third-Party Products and Services

6.7.1 Restrictions on Use of Certain IT Resources from Outside Sources

Special restrictions are often placed on the use of IT resources — such as hardware, software, databases, and documentation — acquired from outside sources. Use of such IT resources may be further restricted by patent law, as a trade secret, or by contract in the form of a license or other agreement. Members of the TikTec community are required to abide by the restrictions imposed by law or by contract on IT Resources acquired for use at the Laboratory. Any individual who arranges for authorized distribution of information technology products and services from outside sources must advise the people having access to the products and services of all the associated usage restrictions.

6.7.2 Copyright

Unless it has been placed in the public domain, most third-party software is protected by copyright law and may be subject to restrictions on use, copying, and distribution. More information on copyright can be found at Section 10.3 Reproduction of Copyrighted Materials.

7.1 Outside Professional Activities

The Laboratory believes that its programs and projects can flourish only when sustained by continuous, active participation of its investigators and fellows in research, enriched in many cases by interaction with industry, business, other government entities, and other activities and institutions of our society.

This interaction, including outside consulting service to and research for other government entities and industry, is of greatest value when it contributes significantly to the public welfare, offers an opportunity for professional challenge and growth, or otherwise enhances the effectiveness of an investigator's or fellow's service to TikTec.

The potential magnitude of such outside professional activity is such that orderly procedures must be followed to ensure the evolution of policy to avoid ethical and legal conflicts of interest and to ensure that such activities do not conflict with the proper discharge of Laboratory responsibilities.

Essential to the effectiveness of such procedures are

a. complete disclosure of outside professional activities and
b. the availability of the best advice and consultation that can be obtained

Standards and Criteria: Personal responsibility, integrity, and high ethical standards are the principal factors in avoiding conflicts of interest, and the Laboratory expects that all members will conduct their outside activities in a manner that reflects credit on themselves, their profession, and the Laboratory without need for specific criteria or rules of conduct. The principal safeguards against abuse are the standards required by professional colleagues and the rigorous process by which the Laboratory evaluates and selects individuals for appointment and promotion.

Some situations, however, involve unique knowledge and understanding or are sufficiently complex that judgments may differ on whether there is a conflict of interest. Individuals of the highest integrity may, therefore, unknowingly place themselves in situations where conflicts exist. It is in such areas of doubt that guidelines or criteria may be useful and necessary. As the Committee on Outside Professional Activities participates in the discussion and resolution of situations of this type, the resulting practice and precedent will constitute and continue to evolve into guidelines both for the overall judgment of the committee and for the individual judgments exercised by team heads. Such guidelines are from time to time communicated to members in an appropriate manner

Association of TikTec National Laboratory's image or name with commercial interests in the public eye may lead to a conflict of interest. In the course of consulting or research, a member may provide a professional evaluation of products or services, based on evidence. However, publicly advertised endorsement of commercial products or services is not, in general, consonant with the independence and objectivity expected of members. In the conduct of their outside professional activities, members should be careful to avoid identifying the Laboratory with opinions or conclusions in public or private reports or in other ways.

Investigators and fellow should avoid association with activities of outside firms and, at the same time, activities within TikTec that are competing directly for government or private funds. Similarly, access of outsiders to facilities and staff, must be controlled by the responsible investigators and fellows in order to avoid undue pressure on those facilities or persons or the implication that an outside organization has a special relationship to TikTec when it does not.

Policy text drawn from posted MIT policies at: https://policies.mit.edu/policies-procedures