Application Summary

Competition Details

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Application Information

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Application Details

**Proposal Title:** Cornerstone Design
Nomination of Dr. Dima Nazzal, Director of Professional Practice and Senior Academic Professional, H. Milton Stewart School of Industrial and Systems Engineering, for CTL Curriculum Innovation Award
February 28, 2021

1 DESCRIPTION OF THE INNOVATION: CORNERSTONE DESIGN

1.1 Problem Statement
Capstone Senior Design
The Root Causes
The Solution

1.2 The Objective of the Innovation

1.3 The Learning Outcomes of the Intended Audience

2 APPROACH TAKEN

2.1 Approach Summary

2.2 Detailed Description of the Approach

2.3 How This Approach Promotes Design Thinking

3 INNOVATION EVALUATION

4 DESCRIPTION OF THE POTENTIAL FOR OTHERS TO ADOPT OR ADAPT THE INNOVATION

Adaptability within ISyE
Adoptability by Industrial Engineering departments outside Georgia Tech
General Adoptability
Recommended Resources

REFERENCES

Letters of Support
1. Edwin Romeijn, Ph.D., H. Milton and Carolyn J. Stewart School Chair and Professor, ISyE
2. Chen Zhou, Ph.D., Associate Chair for Undergraduate Studies and Associate Professor, ISyE
3. Emma Baubly, B.S. Industrial Engineering, Spring 2020 BSIE Graduate, Master of Health Systems Student at Georgia Tech
4. Laura Hancher, B.S. Industrial Engineering, Fall 2020 BSIE Graduate, Bain Consulting
5. Garrett Witt, B.S. Industrial Engineering, Fall 2020 BSIE Graduate
1 Description of the innovation: Cornerstone Design

1.1 Problem Statement

Starting in Summer 2018, I led the development of Cornerstone Design, a new course for undergraduate industrial engineering students. Before I present the motivation for Cornerstone Design, let me describe the course/program that highlighted the need for this innovation.

Capstone Senior Design

All Industrial Engineering (IE) undergraduate seniors culminate their undergraduate educational experiences with a capstone course called Senior Design (SD). In SD, students complete an intensive team-based engineering design project working with an actual industry client. SD involved hundreds of organizations; large and small; for-profit, governmental, and non-profits; manufacturing, logistics, healthcare, airline, retail, hospitality, and energy. Student teams work on specific design projects to generate, evaluate, and communicate solutions to their clients.

Since 2013, I have advised numerous SD teams and so have many of my colleagues. Approximately, 360 students/year complete SD working with 40 different industry clients. Through our work with SD students, the faculty realized that while our students excel in analysis and modeling, they struggle with several key design skills:

- Ability to place the problem in the larger context of the system
- Ability to handle uncertainty and incompleteness in information, and ambiguous objectives
- Ability to identify the root cause of the problem and uncover opportunities for achieving a client’s goal; (the teams are usually biased by the client’s perception)
- Ability to consider the human behavior impact on the success of a design solution
- Ability to plan for the fact that design is an iterative process that involves multiple alternatives evaluated along multiple criteria
- Ability to communicate the problem, and its design solution concisely and effectively
- Ability to navigate working and making decisions as a team

These are all critical design skills for any engineer. By the end of SD, and with the help of the faculty advisors and the faculty evaluators, most teams successfully navigate these challenges and deliver exceptional work products to their clients. However, addressing all these challenges during SD is a reactive approach. Some faculty cynically used the analogy of “throwing them into the water to learn how to swim”. Surviving the water is not what we seek to teach them, rather it is how to skillfully navigate the turbulence. We recognized that preparing our students for the design process should happen earlier in our program, as opposed to when they are dealing with an actual industry collaborator as they are also navigating the job market.

The Root Causes

Our curriculum is a series of technical courses that teach students either relevant methods such as optimization, simulation, regression analysis, machine learning, and stochastic models, or relevant domain knowledge such as quality control, supply chain logistics, production systems, demand planning, and facility logistics. All these courses are organized to build the knowledge acquisition with gradual increase of complexity in the analysis or modeling of each topic. Textbook problems or sometimes a
class projects includes a well-defined problem that usually involves identifying the known and unknown variables, deriving the mathematical relationship among them, and applying the formula to obtain a solution. Design, however, is very different; I like the way Dym et al (2005) describe it in their seminal paper on engineering design education [1] as “an iterative loop of divergent-convergent thinking”. This one characterization packs most of the complexity and frustration with design projects for our students.

The Solution

Cornerstone Design, an early design course focusing on “framing the problem” without solving it. The course lays out the foundation for design thinking using a project-based learning approach, interactive sessions with instructors, and a goldmine of past capstone SD projects that ISyE has kept for years organized in a database, which includes all the relevant data files, original team notes, deliverables, and code.

1.2 The Objective of the Innovation

Cornerstone Design aims to address the design skill gaps outlined above by offering a learning environment that utilizes multiple past SD projects each semester complemented with lessons on key engineering design and industrial engineering principles. The ultimate goal is - through multiple diverse projects - students develop the skill to structure the way they approach complex undefined problems that are fraught with data gaps, uncertainty and ambiguity in objectives, and conflicting priorities. Students will also work in teams with a rotating leadership role so that each student is exposed to the challenges and rewards of being a project leader. Students learn how to effectively and succinctly communicate the motivation for solving a problem and the scientific evidence supporting their design solution hypothesis.

1.3 The Learning Outcomes of the Intended Audience

Design involves the complex and iterative process of asking questions, learning, making a decision, evaluating, going back to asking more questions, and so forth. All this conducted in a system context, while working within a team of varying skills and priorities. The complexity of addressing unstructured open-ended problems makes teaching design difficult. As an academic and practitioner – I worked for a global engineering design company as director of R&D – I knew that equipping students with long-lasting design thinking skills will be a huge challenge. Therefore, I was very deliberate about the process of developing the cornerstone design course. I sat down with many faculty colleagues who are involved in SD to brainstorm ideas for how to best address the design challenges we see. Joel Sokol, Craig Tovey, Pinar Keskinocak, Chen Zhou, Shabbir Ahmed, George Nemhauser, Leon McGinnis, and Steve Hackman all contributed perspectives that were invaluable for the design of the Cornerstone Design course. Here are its four primary learning outcomes:

- Outcome 1: Students should learn the elements of the design process, terminologies and semantics, and - very importantly - the connections between the design problem elements: Need and Motivation, Symptoms vs. Underlying Causes of a Problem, Problem Solutions vs. System Opportunities, Design Alternatives, Design Requirements and Constraints, and Success Evaluation Metrics.

- Outcome 2: Students should be able to apply the design process framework and learned structure to actual industry problems by transforming a vague “situation” given by a client. This includes students being able to a) Engage in inquiry and information gathering, b) Engage in exploratory and explanatory analysis of the gathered information, and c) Identify the root causes of problems or
recognize opportunities that can be leveraged, d) Propose initial approaches to exploit the opportunities, and e) Make a plan to execute on the proposed initiatives.

- **Outcome 3:** Students are able to **communicate their analysis of a problem or opportunity and their proposed design solutions in oral and written form concisely and effectively.** This includes students being able to a) Establish the connections between the need of the client and the proposed solutions while also identifying the metrics that demonstrate that connection, b) Identify key messages from their inquiry that are worthy to highlight and support their messages.

- **Outcome 4:** Students learn **how to work within a team and learn what it means to lead and manage a team project.** This includes student being able to a) Have explicit discussions as a team to outline their goal (as a team), align expectations, and assign roles, b) Manage conflicts productively, c) Manage a project plan and hold each other accountable, while being supportive of individuals on the team.

## 2 Approach Taken

### 2.1 Approach Summary

Cornerstone Design involves a suite of features integrated to achieve its learning outcomes: Four distinct projects in the semester with different objectives:

- **Field Data Project:** Assigned on the second week of the semester, it is a project that involves collecting and analyzing data to answer one fundamental business question involving the tradeoff between efficiency and service.

- **Prescriptive/Guided Project Proposal:** Assigned the 5th week of the semester after exposure to engineering design terminologies and a series of dissections of proposal samples from past SD projects. This project allows the teams to - gradually and with direction from instructor - frame the problem through a structured approach to describing the system and analyzing its performance data.

- **Structured Project Proposal:** The second project is assigned on the 8th week of the semester. Also based on a past SD project. During this project the team gets less prescriptive guidance on what to do, but the instructor maintains some structure by giving mini deadlines leading up to the final submission of a proposal and its presentation.

- **Independent Project Proposal:** In the 11th week of the semester, each team chooses one of two “situations” based on past SD projects to analyze and develop a design solution proposal. The data and information are provided as soon as a choice is made, and less guidance is provided.

Dispersed throughout the semester are lessons on **principles** that are relevant to the engineering design process such as principles and stages of “information gathering” and principles of variability in the types of systems common in industrial engineering problem solving. The first part of the course has more guided lessons and interactions between instructor and students. The latter part of the course is primarily team work sessions, in which the instructor and the teaching assistants rotate among the teams to provide advice as needed.

### 2.2 Detailed Description of the Approach

Figure 1 below shows the path of progress through the course utilizing the different learning components from lesson delivery of design principles and showcasing to dissect past design projects, to the four projects the teams work on during the course.
Figure 1: Cornerstone Design course progression. There are five distinct learning mechanisms including lesson delivery dispersed throughout the timeline with heavier content in the first half of the course. Four projects: Field Data project, Prescriptive proposal development, Structured proposal development, and Independent proposal development.

I will now describe the unique features in the course visualized in Figure 2, and what makes them beneficial to supporting the learning outcomes.

Figure 2: Cornerstone Design Course Key Features
• **Utilizing past SD projects** allows for actual situations including messy and incomplete data sets, client conversations, dilemmas and obstacles. It also allows for seniors or graduate students who participated in the utilized SD project to speak to the class (after the Cornerstone Design students have gone through the experience) and provide their perspective. Most prominently, the three proposal development projects that the teams get immersed in to develop their own proposals by framing the client’s problem are based on actual past SD projects. However, past projects are integrated and dispersed throughout the course. In the first week, they’re introduced often by a graduating senior who completed the project, and occasionally by the instructor if having a student on the team is infeasible. Throughout the semester, past projects are used as examples when we dissect a problem statement or critique a proposal in class. 50 capstone SD projects are completed in ISyE every year. All the data files and deliverables are stored in a database. **Cornerstone Design** is the first organized effort to tap into this enormous resource, which ISyE has gone into great effort over the years for keeping organized, and yet never used. Figure 3 shows screenshots of the SD Projects Database from which Cornerstone Design project-based learning content is developed.

![Screenhots from SD Projects Database](image)

Figure 3: Screenshots from the SD Projects Database. (A) shows organization by semester, (B) Fall 2020 Projects organized by Client/Team, (C) Showing the organization of the folders and the level of record keeping for a sample project with The Fox Theatre.

• **Instructor and TAs play multiple roles in active work sessions:** When we reach the stage in the course at which the teams are developing project proposals to frame the design problem for the past senior design client, the instructor and TA put on the “client” hat as the teams are gathering information about the system and the need for a design solution. Once the team collects the information they need from the client, the instructional staff puts on the “faculty advisor” hat; now the team is analyzing information and identifying opportunities and they need occasional coaching and feedback on their analysis. All this takes place during class times that are designated active work sessions. Some classes involve lectures and problem-solving, and half the classes involved active work sessions for the teams, while the instructor and TA rotate among the teams to ask or answer questions. A few pictures from a pre-pandemic and post pandemic iterations of the course are in Figure 4.
Figure 4: In class Sessions. (A) shows multiple teams huddling together and working on problems or projects. (B) Shows the instructor coaching a team, (C) and (D) show a team presenting their project proposal in-person during Spring 2019 and Fall 2020, respectively.

- **Team composition remains the same throughout the four projects.** This allows students in a team to bond, learn each other’s strengths and challenges, and build trust gradually through working together. It also allows the leadership role of the team to rotate from one student to another. This gives training to every student in the course on what it takes to manage and lead a team.

- **Field Data project.** This initial data project serves two purposes: It is the first project in the semester given as soon as registration ends and the teams are formed, and therefore it’s a warm-up project helping students to become familiar with their teammates. The goal is for students to answer a fundamental business question: What data do you need to collect for a “service system” such as a cashier for a grocery store or a coffee shop in order to determine the relationship between service (measured by customer waiting time) and number of servers? Many teams are tempted to go to the grocery store or coffeeshop of their choice (e.g., Trader Joe’s or The Dancing Goats) and start collecting data. These teams quickly find out that they need more trips because they did not form a data collection plan. Successful teams get more value out of the time they invested in these visits because they spend more time planning the collection of information. This is one of the important lessons in real-world projects. Many teams get frustrated about all the “wasted” time as a result of chaotic observations and insufficient data collections. On the other hand, teams that introspect on the goal of the project, research customer behavior, and make a plan for when, how, and what data to collect, show higher performance than their counterparts and with lower stress levels.
Turning Lemons into Lemonade COVID-19 made in-person data collection unsafe and unpredictable, which presented a great opportunity for innovation. June 2020 came with the headlines about the scandalous voting lines in the US primary elections in Georgia [2]. I decided to reshape the Fall 2020 Field Data Project of Cornerstone Design. The fundamental aim of the project remained unchanged: Determine the required data, then collect and analyze that data, to quantify the relationship between number of servers for a system and the service level offered to customers, as measured by waiting time. I collaborated with a data reporter from Georgia Public Broadcasting (GBP), hired two research assistants, and we designed a new data project based on the voter turnout and waiting times in the Georgia Primaries. The GBP reporter supplied data sources for voter turnout and number of voting machines and poll pads he obtained from the State based on their allocation to each polling location. My research assistant and I designed a python-based simulation tool that the students can use to generate random but valid datasets and model a polling location in Georgia. This replicated the experience of collecting information. Teams were asked to compare the resources given to multiple locations by the state, and the voter turnout at those locations, with the resulting wait times. The teams also came up with recommendations to reshuffle the resource allocations.

Based on the students’ feedback, this was a remarkably beneficial and engaging project. Both to see the complexity and tradeoffs in designing election systems, and to analyze a system that was of great interest to our civicly engaged students. Most teams took this further and conducted extra research by calling election boards and asking for layout drawings and interviewing them about their COVID-19 precautions and preparations for the November elections. The code for the tool is on Github [4] to make it available to students and any other educators or researchers. Figure 6 shows the interface of the election data generator and simulator tool, and sample outputs.

Figure 5: Voting Line during Georgia’s Primaries in June 2020 [3]

Figure 6: Screenshots of the Voting Polling Location Simulation Tool. (A) user interface to set parameters, (B) Raw data output file sample, (C) Optional Graphs to plot performance
• **Engaging in Inquiry by Formalizing Data Requests**: Data transfer from industry client to SD teams is usually fraught with confusion, miscommunications, and delays. That’s not unusual, but some structure and etiquette to the process can help mitigate some of these issues. Therefore, I added a module on information gathering. Also, in their projects, the teams practice a more professional data request process with templates and justifications. This is valuable because it involves a) Deliberate thinking about the problem they are trying to frame, and b) Writing a set of questions they would like to answer about the system they’re supposedly designing or improving. The data request should be specific but also justifies the request for each dataset. This protocol is important for two reasons: 1) It allows the students to think clearly about what data they need and learn not to ask for everything, and overwhelm their client needlessly, as I observed in SD, and 2) By understanding the justification for a specific data, the provider of the data can provide substitutes if requested data is not available, or the team have to be creative. Deadlines for data requests that are weeks ahead of the proposal deadline are intended to help students learn to plan their projects.

• **Scaffolding**

The first three weeks are focused on making students excited about the prospect of solving a real-world problem and learning about *vocabulary* and *structure* by dissecting past project proposals and problem statements, while simultaneously learning the key elements in a problem/opportunity statement and the structure of an engineering design proposal. The *dissection* and later *critique* of past proposals help students by exposing them to a variety of examples to understand how to make a clear, data-driven case for an engineering design project. The first project proposal they develop is guided and prescribes discrete steps and questions they should think about as they are framing the problem or analyzing the data to identify opportunities. The second project proposal is less prescriptive but offers some structure by enforcing deadlines for data requests, informal progress reports and milestones. The final project is more self-directed, but the instructor is available as needed to answer questions or provide advice.

• **Supplemented Instruction of Principles**. I oversaw hundreds of SD projects and actual industry projects from my experience as SD coordinator, practitioner, and researcher. As a result, I integrate into Cornerstone Design what I perceive as recurring and key fundamentals that should aid industrial and systems engineers with approaching a vast proportion of the problems that they are likely to encounter in SD or in their early problem-solving jobs. Topics like how to conceptually describe a “discrete event flow system”, “impact of variability in flow lines”, “pitfalls of estimating the monetary value” are all integrated throughout the course both to introduce these topics in the context of the assigned projects, but also to offer a variety of formats for how we spend class time.
2.3 How This Approach Promotes Design Thinking

There are three key elements of this structure that I believe promote design thinking. First, it requires students to **work through the uncertainty, messiness, and vagueness** of an actual design project. It introduces students early in their educational path of becoming engineers to how a set of principles can give them direction to build on their solution hypotheses. Second, a team works together through four self-contained projects, which requires students to engage in **productive arguments** (not at first), set their egos aside to focus on the goal, understand their strengths and areas of discomfort, negotiate roles, and most importantly learn to listen to each other. Third, the **repeated work** on delivering a proposal not only exposes them to the variety of problems in our discipline but also makes them repeatedly practice the process of framing the problem, communicating it, and selling their approach. Design thinking comes with expertise. Every project is unique but repeated exposure forces one to start following a structure on how to approach vague problems efficiently and effectively.

3. Innovation Evaluation

The innovation was created to address the preparation of ISyE students for their Capstone SD projects. Therefore, the quantitative assessment is based on evaluating how well the students who took Cornerstone Design perform in SD, some students took these courses months apart, and some took them years apart. I have offered Cornerstone Design in Fall 2018, Spring 2019, Fall 2019, Spring 2020, Fall 2020, and this semester it is offered by another instructor. I will report data for the students who completed both SD (ISYE 4106), and Cornerstone Design (started as ISYE 3803 Special Topics but it has been approved for a permanent number and this Spring it is offered as ISYE 3106).

**Measure 1: CIOS scores for course and instructor effectiveness.** All questions were given on a 5-point Likert scale. Surveys were run by Georgia Tech Office of Effectiveness, and results were not provided to instructors until after the final grades deadline. Figure 7 shows the CIOS results aggregated across all five offerings of Cornerstone: Fall 2018, Spring 2019, Fall 2019, Spring 2020, and Fall 2020 and they represent the interpolated medians as downloaded from gatech.smartevals.com. Figure 8 shows CIOS score for overall course effectiveness and overall instructor effectiveness over the four measured semesters I offered it (Georgia Tech did not run CIOS during Spring 2020 due to the pandemic.)
Figure 7: CIOS scores for "Course" and "Instructor" across all five semesters I taught the course. Sample Size = 74, Response Rate = 62%

Figure 8: Cornerstone Design Course and Instructor Effectiveness over Time
In addition to these strong CIOS scores, there are many positive comments about Cornerstone Design. Here are some typical ones in response to the question on the course’s best aspects:

“We had to use our analytical skills in a more abstract way than in other courses. This is one of the most useful classes I have taken. I do feel more prepared for Senior Design, and even for the jobs I’ll apply to. I have already talked about different projects (both the skills I used and my teamwork experience) in interviews and company workshops.”

“This course has been one of the most helpful courses for me in ISyE as it ties in our concepts to real world projects and examples.”

“I really liked the collaborative aspect of the group projects and the professor’s willingness to help. I also liked how supportive Dr. Nazzal was. It was also really cool how we got to do different types of projects (when I went to the senior capstone exhibition, almost all of the projects were related to something we’d done in class!).”

“It is very helpful going into senior design to not only have an understanding of how to successfully tackle our projects but also work on the soft skills. I enjoy presentations and practicing that because they took so long, but they were helpful in building my technical writing skills.”

“It is a class that you are likely not prepared to take but you take it for this reason. It is super helpful for being in senior design and there are direct applications that are guaranteed down the line. Lots of work but with high reward.”

One of my favorite unsolicited feedback on Cornerstone Design came from an exchange student from the National University of Singapore (NUS). He took the course in Spring 2019 with other exchange students (I was thrilled to have NUS students work with GT students on projects). The student wrote me an email in December 2020; almost 2 years after taking Cornerstone. He wrote:

“Recently, while reminiscing with my friends on our time at Gatech, I realized that amid the chaos that is the year 2020 I have forgotten that I owe you a long overdue thank you. First I would like to thank you for teaching the class that equipped me with the skillsets needed for my design project. I signed up your class hoping that I would be able to prepare myself for the year-long project to come when we return to Singapore. In the end, thanks to your clear instructions, well-structured topics, and the 4 well-thought-out class projects, I was able to learn skills that prepared me well to handle a real-world project and much more. I had the opportunity to work with the Singapore General Hospital (not quite Funny-Bone Clinic, but it was equally challenging :D), and I am happy to report that our project exceeded the expectations of our client. They even told me that they are planning to start a new official team that continues the works we have done! Second I want to thank you for making me remember why I chose IE as the discipline to pursuit. I discovered IE quite early on (in middle school) and had decided that this is what I would like to study for my undergrad. However, after joining my department of choice, my experience with IE has been plagued by doubts. With the increasing popularity of software engineering, machine learning, and other buzz words in the industry, many of my peers are working towards becoming developers in tech companies or joining the finance industry. I started seriously doubting my decision to study IE and explored other career options such as management consulting and software engineering. My search for a potential career path that aligns my interest in IE in Singapore was not fruitful, and I became very lost until I attended your class. Your class was able to so succinctly describe why I was so interested in IE when I
discovered it as a 17-year-old; I saw in IE the challenge of breaking down complex problems, the application of tools and technology to solve real-world problems, the close relationships formed with our clients and users, and many more. Thanks to you, I was able to start my final year of my undergrad with clarity and confidence. Currently, I am happily working as a research engineer with our IE department on building solutions for the Singapore port.

Lastly, I would also like to apologize for not able taking up your kind offer to work with you for the summer and the Fall semester. I often regret not being bold enough to delay my graduation and take up this rare opportunity to work with you. I am extremely grateful that you recognized our team's efforts and your validation meant the world to me who at the time was still filled with self-doubts. If not for the bond that I am serving with Singapore due to the financial aid that the government provided, I would have applied to Gatech for a post-grad degree in a heartbeat. However, depending on my situation near the end of my three-year bond, I hope to still be able to come back to Gatech and work with you again.”

This testimony shows the global impact Cornerstone can have as we expand its capacity.

**Measure 2: Do students who completed SD but took Cornerstone Design feel that Cornerstone Design helped them prepare for SD?**

In collaboration with Dr. Chen Zhou, the Associate Chair of Undergraduate Studies, we conducted a survey at the end of SD in Spring 2020 and Fall 2020, asking students who took Cornerstone Design to respond to questions on a 4-point Likert scale. The number of respondents = 68 student. The results are shown in Table 1.

<table>
<thead>
<tr>
<th>How much did cornerstone design help you prepare for senior design along the following criteria: -</th>
<th>Interpolated median (out of 4)</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Collecting and analyzing data</td>
<td>3.41</td>
<td>46%</td>
<td>43%</td>
<td>7%</td>
<td>3%</td>
</tr>
<tr>
<td>Identifying opportunities</td>
<td>3.82</td>
<td>73%</td>
<td>22%</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Proposing solutions</td>
<td>3.72</td>
<td>64%</td>
<td>25%</td>
<td>7%</td>
<td>3%</td>
</tr>
<tr>
<td>Writing a technical proposal</td>
<td>3.74</td>
<td>66%</td>
<td>25%</td>
<td>9%</td>
<td>0%</td>
</tr>
<tr>
<td>Preparing and delivering a technical presentation</td>
<td>3.82</td>
<td>73%</td>
<td>16%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>Working productively on a team</td>
<td>3.66</td>
<td>60%</td>
<td>31%</td>
<td>7%</td>
<td>1%</td>
</tr>
<tr>
<td>Setting goals, developing a workbook, and executing tasks</td>
<td>3.64</td>
<td>58%</td>
<td>27%</td>
<td>12%</td>
<td>3%</td>
</tr>
<tr>
<td>Conducting research about a specific aspect of the project</td>
<td>3.26</td>
<td>42%</td>
<td>34%</td>
<td>18%</td>
<td>6%</td>
</tr>
<tr>
<td>Overall preparation through cornerstone design for senior design</td>
<td>3.72</td>
<td>64%</td>
<td>30%</td>
<td>6%</td>
<td>0%</td>
</tr>
</tbody>
</table>

94% of respondents feel that Cornerstone Design prepared them for SD. This is a very encouraging outcome because that was one of the primary goals of Cornerstone Design: Preparing undergraduate Industrial Engineering students for Capstone senior design.
Measure 3: Among all students who completed SD in the past two years, did the students who took Cornerstone Design achieve better grade outcomes in their SD project compared to those who did not take Cornerstone but completed SD?

I analyzed the grades of students who took SD from Spring 2019 – Fall 2020. The comparison between the grades of students who took Cornerstone vs. did not is shown in Table 2 below.

<table>
<thead>
<tr>
<th>Table 2 Comparison between Cornerstone and Non-Cornerstone Design takers by examining their SD grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 2020, Fall 2020</td>
</tr>
<tr>
<td>Number of Students</td>
</tr>
<tr>
<td>Received the following letter grade in SD</td>
</tr>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>SD GPA</td>
</tr>
</tbody>
</table>

While the SD GPA of Cornerstone Design students is higher than the other group’s course GPA, the difference is not statistically significant (p-value = 0.19). There is, however, a statistically significant difference (p-value = 0.049) in the percent of students who took Cornerstone and received “A” in SD. One might think that there is a self-selection bias in that Cornerstone Design students have higher cumulative GPAs in general. Therefore, I compared the overall Georgia Tech GPAs coming into SD of both groups of students, as shown in Table 3.

<table>
<thead>
<tr>
<th>Table 3 Cumulative GT GPA of Cornerstone vs. Not Cornerstone Design course participants when they entered SD semester</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spring 2020, Fall 2020</td>
</tr>
<tr>
<td>Number of Students</td>
</tr>
<tr>
<td>Overall GT Cumulative GPA</td>
</tr>
<tr>
<td>p-value</td>
</tr>
</tbody>
</table>

The overall GPA analysis indicates that the GPA of students who did not take Cornerstone Design is higher than those who took it prior to taking SD, and the p-value shows that the difference is not statistically significant. Therefore, one can conclude that the better “A” performance in SD by students who took Cornerstone is not due to their higher academic performance in general.

4. Description of the potential for others to adopt or adapt the innovation
The framework for this course makes it easy to be adopted and adapted by other majors. Some of its features are unique to engineering because of the focus on design thinking and would be easily adaptable by engineering schools at Georgia Tech or other institutions. However, some of its key features are not engineering-specific including 1) The use of past capstone projects in earlier curriculum courses, 2) The gradual increase in independent work expectations through a project-based learning approach, and 3) Intermittent use of class time for work sessions with coaching from the instructional staff.

Adaptability within ISyE

For the first time since Fall 2018, this semester, I am not an instructor of Cornerstone Design. There are two sections offered by a colleague. She is offering the course according to the described structure, but
she easily refreshed the Georgia Election systems datasets, and replaced two of the problem-framing projects with alternative ones from our SD database. It was helpful for my colleague to co-teach the course with me the semester prior to her becoming a primary instructor.

Adoptability by Industrial Engineering departments outside Georgia Tech

Being the number 1 ranked Industrial Engineering (IE) program in the nation makes ISyE a leader in curriculum development. Cornerstone Design structure and content is readily available to any other IE department. I presented this innovation at the 2019 Institute of Industrial and Systems Engineering (IISE) [5] conference to a wide audience of faculty members in Industrial Engineering or Operations Research departments nationally and internationally. An article about the innovation appeared in the ISyE alumni magazine [6]. We have a repository of Supply Chain Course Teaching material shared among numerous IE faculty across the nation. Moreover, the python simulator of the voting data is available on Github [4].

General Adoptability

An IRB protocol is in-process to collect research-purposed assessment data in preparation for two articles. The first one is to Journal of Advances in Engineering Education, an ASEE publication. This article would be for a general engineering education audience and therefore the focus will be on the approach and its assessment. I have previously published in that journal on my work on integrating sustainability into the IE curriculum. The second paper will be for the Industrial and Systems Engineer magazine focusing on design education in the IE discipline.

Recommended Resources

- **Physical layout**: It is beneficial for the classroom to have movable tables and chairs to facilitate group work sessions. Having multiple whiteboards, fixed or movable would also be helpful. However, with the proficiency we all had to gain as a result of remote education, virtual whiteboards can be an adequate substitute for brainstorming activities during team work sessions.
- **Organized repository of capstone projects**: Creating realistic projects and case studies takes enormous time. To make this process efficient, in ISyE the capstone senior design students must submit all their organized project folders to the capstone coordinator at the end of each semester.

References

February 12, 2021

Dear selection committee,

It is a great pleasure to offer my enthusiastic support for the nomination of Dr. Dima Nazzal, Director of Professional Practice and Senior Academic Professional in the H. Milton Stewart School of Industrial and Systems Engineering (ISyE) for the CTL Curriculum Innovation Award.

A few years ago, ISyE recognized that there is a significant need for a project-based Design course early in our curriculum, both to expose our students to design concepts and to get them excited about the BS in Industrial Engineering (BSIE) major. Our curriculum is heavy on methodological courses in the early years, with limited context for the use of these methods in practice. This deficiency exists not only at Georgia Tech’s undergraduate IE program but across most Industrial Engineering curricula in the US. I know this because of my role on the Council of Industrial Engineering Academic Department Heads (CIEADH).

ISyE entrusted Dima with addressing this problem because of her proven dedication to student learning, expertise in advising Capstone Senior Design projects, and strong background as an industry practitioner. Dima’s unique expertise, combining over 15 years as a faculty member in academia and an R&D director of a global engineering design company, made her the ideal fit to address our need.

In Fall 2018, Dima offered the first pilot of Cornerstone Design, a course she designed through researching engineering design pedagogies and conversations with faculty who have worked closely with Capstone Senior Design teams. Since then, the course has been offered every fall and spring with increased enrollment, and with a remarkable impact on the Senior Design students. My first glimpse into its impact has been through a presentation by a group of ISyE students who completed the course to our School’s Advisory Board. The advisory board members were so impressed that they wanted to know how they can support scaling up the program.

As a testimony to the success of the Cornerstone Design course: 1) ISyE created and hired a new full-time lecturer to support delivering the course to support increased enrollment, with Dima supervising the curriculum and delivery, 2) The ISyE faculty voted in support of a permanent presence for the course in the curriculum, and 3) the ISyE undergraduate curriculum committee led by the Associate Chair of Undergraduate Studies are now looking into options for making the course required for all IE students, much like Capstone Senior Design.

In Spring 2020 and Fall 2020, ISyE conducted an assessment to measure how Cornerstone has helped Capstone Design students in their projects. The results have been spectacular. 94% of the respondents indicated that Cornerstone Design helped them prepare for Senior Design. In
response to the question “To what degree has the ISyE curriculum prepared you to be successful in senior design?” there were comments like “Cornerstone Design was very very helpful, and I’m glad it’s becoming a bigger class for more people to take, ...”, “The most impactful courses were Regression, Simulation, and Cornerstone”, and “Cornerstone design class was very helpful for this [technical writing]. Working in such a large group was difficult at times with no previous experience”.

With Dima being in charge of both the junior Cornerstone Design and the senior Capstone Design courses, she has been able to observe any issues or challenges with Senior Design and immediately circle back to address them earlier in the curriculum through Cornerstone Design, when possible. The combination of Cornerstone and Capstone Design courses have been very valuable to our students and has the potential to impact IE design education across the nation. Dima presented this innovation at the flagship conference of the Institute for Industrial & Systems Engineers (IISE) and is working on preparing publications and further sharing of the developed course materials with other departments to expand the impact. The benefit of this program has extended beyond our US campus as evidenced by testimony from our exchange students from Singapore who took course in Atlanta and recognized its value for their education and career path as Industrial Engineers.

Dima is highly deserving of this CTL recognition. I give my strongest recommendation to the committee to recognize her significant efforts with this important award.

Sincerely,

H. Edwin Romeijn
H. Milton and Carolyn J. Stewart School Chair and Professor
February 25, 2021
To: CTL award committee
Re: Nomination of Dr. Dima Nazzal for Curriculum Innovation Award

Dear Members of the Award Committee:

I would like to nominate Dr. Dima Nazzal for the Curriculum Innovation Award.

I assumed the Associate Chair for the Undergraduate Studies in 2008. I have noticed that most students struggle for many weeks in ISyE 4106 Senior Design. The students struggle is due to our curriculum design.

BSIE includes several components: general education, engineering electives, IE Core, IE Concentration Electives and senior design. Industrial Engineering (IE) Core includes methodology classes with tools such as regression, queuing, optimization and simulation. These courses are abstract and solutions are unique. The Core provides tools similar to hammers and drills. IE Concentration Electives provide application context such as manufacturing, logistics, quality, layout, financial systems, health systems using the tools they learn from the Core, in silos. Although homework and tests are broad, there still exists a single solution in an isolated scenario such as a facility, a schedule or a process.

In senior design, the students meet clients and learn the challenges they face, such as too much travel, too much delay or waiting, or in insufficient throughput, or poor quality. There can be many reasons for these challenges that often cross the single facility, schedule or processes. By the time they take senior design, our students have learned the tools and have sharpened their skill in using these tools in isolated application contexts. The most obvious and default thing they do is use their hammers and drills to find nails and places to drill holes among different application domain they have been exposed to in the concentration electives. They often struggle for weeks to change their mindset to finally put their effort in the right places.

We have discussed this issue with undergraduate curriculum committee, alumni, advisory board for several years. One of the things we have done is encourage instructors to add term projects to their classes that push students to apply what they learned to less structured problems. The strategy helped, to some extents. However, the instructors are busy, there is limited room in their classes and therefore, the projects tend to be small. Moreover, the instructors are expert in the subject matter and in research. They may not have the right set of skills to teach students how to tackle open-ended practical design problems in which there is no single solution.

We have talked about a Junior Design course to engage the students in solving open ended design problems for many years. The purpose is to get the students familiarized with the design process for complex problems across domains and use their tools after they identify the problems and opportunities. However, Industrial and System Engineering discipline offers an additional challenge. Most engineering disciplines involve hardware. The design methodology within their discipline has evolved over the years. Industrial Engineering designs processes, organizations and flows. Although the end results are design alternatives with different performances, similar to those in other disciplines, the
process of design across many systems are less developed. After several years, we were still contemplating how to find an innovative way to solve this challenge.

When Dr. Nazzal rejoin us in summer 2018, we talked about this. She came up with an innovative idea she called “Cornerstone Design” course. In this course, she would teach the students how to take an unstructured set of challenges a client may have, and put a structure to it, frame it into a workable proposal. The objective is not to find the alternative solutions. Instead, she would teach the students how to comb through complex set of qualitative and quantitative information, identify the problems and opportunities, and propose alternative solutions. In the process, the focus is on directing the energy to understand the problem, frame the problems into a format for potential solutions. She would refer to design principles from other disciplines, discuss with experts who are working on design theory for Industrial and Systems Engineering, such as Dr. Leon McGinnis and those in outside of Georgia Tech who have been studying design theory for Industrial and Systems Engineering.

In fall 2018, Dr. Nazzal launched the first prototype course. She reviewed many prior senior design projects in the archive that did not have non-disclosure agreement. She identified a set of representative senior design projects in different areas. She designed sequence of instructions, discussion sessions, teamwork sessions, presentations and proposal writing to go with each prior project similar to case studies. The students would learn to dissect the problems, perform analysis, quantitatively and qualitatively, teamwork and communication. In the end the students would develop an acceptable proposal that focuses on the description of the system, identified opportunities, the objectives of the project and potential alternative solution strategies and the metric to measure the design alternatives.

Over several semesters, she continuously improves the course. In 2020, the course receives a permanent number. ISyE is working on scaling up and finally make it a required course. Currently, she is working innovatively to scale this up to cover approximately 350 BSIE students each year!

She and I designed a survey embedded in the mandatory survey at the end of senior design in spring 2020. 33 students in the class had completed Cornerstone Design course. We wanted to find if the students took the Cornerstone Design course benefited in the experience. The results are very positive. The students took the Cornerstone design reflected that they are better prepared for senior design, less frustrated, spend effort more efficiently. They can even help the entire team to perform at higher level.

Dr. Nazzal’s innovative Cornerstone design course has made a great contribution to BSIE contribution. Since ISyE has ranked at the top for 25 years, many other programs learn from us. The long-term impact will go beyond just Georgia Tech. You can find more details on her innovative work in her own documents.

I strongly recommend Dr. Dima Nazzal for the Curriculum Innovation Award.

If you have further questions, please contact me: cz3@gatech.edu

Sincerely,

Chen Zhou
Assoc. Professor and Assoc. Chair, ISyE, Undergrad Studies
February 15, 2021

Dear Award Selection Team,

I am writing in support of Dr. Nazzal for the Curriculum Innovation Award. I had the good fortune of taking her first offering of Cornerstone Design in the Fall 2018 semester. Subsequent to completing the course, I was offered a teaching assistant position for this class for the following two semesters. In my opinion, the addition of Dr. Nazzal’s Cornerstone Design course to the GT curriculum is an invaluable asset in that it prepares students for both success in the senior design course and in one’s future career.

Georgia Tech is ranked the top Industrial Engineering program in the country. Throughout our time as students in ISyE, we develop a toolbox of analytic skills including optimization, regression, and simulation. Prior to the addition of Cornerstone Design, students were not challenged with big picture situations of problem identification, what tool to grab and when, until their final year at Tech.

Dr. Nazzal developed a course that aggregated real life problems that Industrial Engineering graduates might face in various workplace or consulting positions. Students are presented with four case studies that represent what a typical senior design team would be given at the start of a semester. This class emphasizes the value of teamwork with students collaborating to deliver a collective technical paper and proposal presentation. All students in cornerstone design are exposed to challenges you have when working in a team. Team members receive the same grade on a given project and therefore students and teams learn to play to one another’s strengths in completing the projects. In addition, the group presentations are quite valuable in that they show other students developing varying proposal techniques and that there is not necessarily a “correct” answer or approach to these problems.

Not only does this class emphasize the importance of teamwork, but it also teaches students how to interact with clients. Students send data requests and questions about the system to Dr. Nazzal as if she was the client. These requests should be comprehensive and easy to understand. If there is not data for a certain component of the system, students must adjust their strategy to tackle the problem with what is available. They then learn how to interpret the data and must propose a project design that would deliver value to the client. Not only are the above qualities important for problem scoping in Cornerstone Design, but essential for projects in full-time careers.

The format of Cornerstone Design was excellent in the first semester of the course. Though, Dr. Nazzal solicits feedback from students and continuously enhances curriculum objectives.

In closing, Dr. Nazzal provided the ISyE curriculum with a class that encompasses what it really means to be an Industrial Engineer. Her course emphasizes the importance of teamwork, communication and problem solving. It is a great new addition to a stellar ISyE program.

Sincerely,
Emma Baubly
Dear Curriculum Innovation Awards Committee,

It is without a doubt that I would recognize Cornerstone Design as the most impactful and beneficial course both during my time at Georgia Tech and beyond my undergraduate experience. This can be entirely accredited to Dr. Dima Nazzal’s innovative development of a curriculum that is directly transferable to Industrial Engineering Capstone Design, as well as other engineering projects that are encountered in various academic and professional roles.

This course transcends the textbook definitions and rigid formulas that are all too often memorized, regurgitated, and forgotten in other college classrooms. Indeed, the Cornerstone Design curriculum teaches students what it truly means to be an engineer. In terms of the creative aspects of the course, Dr. Nazzal specifically tailors countless example projects to teach the scoping and preliminary analysis of a design problem, from football stadium concession stand queues to after-school bus route optimization. As a student who thrives best on memorizing a technique and applying it universally to any problem that the professor devises, I found it incredibly eye-opening to learn that there is often not a black-and-white answer to the challenges that we face in the world. Rather, there are many ways to approach the beginning phases of a problem. Dr. Nazzal expertly teaches students how to ask the right questions, rather than how to memorize the answers.

Dr. Nazzal creates a collaborative and engaging course by granting a wide range of decision-making to students throughout the entirety of the semester. Within the first week of the course, students select a team of four to five Industrial Engineers. These groups are specifically created with the student’s input and the professor’s expertise. By serving on different roles within this team, I was able to engage in the activities that better suited my strengths and that explored and addressed the skills that are not as inherently strong; and by rotating project leaders each month, I was able to act as both a leader and a follower throughout the course. In addition, students are allowed the opportunity to engage with specific industries that they find most interesting, such as coffee shop queue times and bike-sharing inventory optimization.

The accessibility and approachability of Dr. Nazzal and her Teaching Assistants goes beyond what I have experienced in my other coursework at Georgia Tech. Specifically, I gained a myriad of valuable leadership traits, such as teammate accountability, from meetings with Dr. Nazzal pertaining to teamwork and collaboration. She provided tips to work more cohesively as a group and for me specifically to better serve my teammates to a well-organized and successful project outcome.

Furthermore, Dr. Nazzal establishes the standards for professionalism, teamwork, and collaboration that students learn to achieve in Cornerstone Design and aim to exceed in Senior Design. I felt incredibly prepared for Capstone Design, as I had a heightened familiarity with the
objectives and outcomes that are expected in Senior Design. This had a tremendous impact on my experience as a student, as I now have a much more thorough understanding of how to scope, design, and improve a system using my Industrial Engineering knowledge. In particular, this class was unique in that I enrolled in the course during the Spring 2020 semester, in which half the course was completed on campus and the remainder of the semester was undertaken from a virtual platform. The adaptability to virtual project management in Cornerstone Design prepared me and many other students for the entirely online semesters of both Pre-Senior Design (ISYE 4800) and Senior Design (ISYE 4106). However, the takeaways of this course are not merely limited to Capstone Design; it enables the skills of problem solving, critical thinking, and project management that can be directly transferred to many Industrial Engineering courses.

Ultimately, Dr. Nazzal’s innovation in creating the Cornerstone Design curriculum has left me with many applicable skills that I will carry with me throughout my career. In the future, I will not merely recall the minute details of my Industrial Engineering degree, such as the revised simplex calculations or the expected value formula of a Poisson Distribution. Instead, I will remember the comprehensive leadership techniques and problem-scoping methods from Cornerstone Design. Rather than reciting the basic classroom knowledge that is often taken out of a real-world context, I will truly remember the Cornerstone Design curriculum that shaped me into a “Helluva Engineer”, which would not have been possible without Dr. Nazzal’s creative foundation of this course.

Sincerely,

[Signature]

Laura Hancher
Georgia Tech Class of 2020
February 2, 2021

Esteemed Awards Committee:

I am writing to express my enthusiastic support for the nomination of Dr. Dima Nazzal for the Curriculum Innovation Award as a result of her work on the ISyE course *Cornerstone Design*. My name is Garrett Witt and I graduated from the Georgia Institute of Technology with a B.S. in Industrial and Systems Engineering this past December 2020. In the Fall of 2019, I had the opportunity to take Cornerstone Design with Dr. Nazzal. I then took ISyE Pre-Senior Design in the Summer of 2020 and ISyE Senior Design in the Fall of 2020, where my team received an honorable mention during finalist selection. It is my firm belief that Dr. Nazzal’s class had a significant impact on my team’s ability to perform and adapt throughout Senior Design, as not only myself, but two other members of my team had participated in Cornerstone Design. Within the class, Dr. Nazzal created an environment that allowed students to engage with previous Senior Design projects and solve them, all while following the process and criteria of the real ISyE Senior Design. In this way, Cornerstone Design serves as an unparalleled preparatory tool for students about to begin the final phase of ISyE. However, it accomplishes so much more than simple class preparation. As ISyE Senior Design requires students to bridge the gap between academia and industry, the skills taught in Cornerstone Design will continue to be relevant and applicable in any professional career. By creating a class that teaches students how to excel in ISyE Senior Design, Dr. Nazzal is simultaneously teaching students how to harness the knowledge they have gained at Georgia Tech.

Cornerstone Design features a unique “client oriented” nature. Everything that is done – from data requests to reports and presentations – is done with consideration to the client. Dr. Nazzal heavily emphasizes that, without this, one runs the risk of having the right solution but still ending up ineffective when attempting to implement. No prior class in the curriculum addresses this. Students are split into small teams that are kept throughout the duration of the course, with the “team lead” role rotating among each member. Principles relating to project management and system analysis are covered at the very beginning, after which the real class begins. Students are tasked with going out and observing a real system to determine certain performance measures and answer key questions. In my case, the designated systems were grocery store checkout lines, and my team chose the nearby Kroger. After this hands-on experience, previous ISyE Senior Design projects are presented – one that is broken down into the constituent parts of a “Proposal” report and two where students are given full autonomy to produce the Proposal report and presentation. This Proposal is the first stage of ISyE Senior Design and is critical to the success of a project, which is why Cornerstone Design focuses on it. During each project, teams are tasked with submitting professional data requests, analyzing that data to determine the underlying problem and corresponding solution, and creating the Proposal report and presentation that make the case for the project to continue. This follows the same process of ISyE Senior Design, and Dr. Nazzal, the TA, and any invited faculty provide teams with feedback as they would to an actual Senior Design team.
The course structure itself is what makes Cornerstone Design so effective and unique. What better way to prepare students for ISyE Senior Design than by putting them in an environment that allows them to practice all the necessary hard and soft skills while receiving continuous feedback and support. Teams spend most classes working amongst themselves on the current project and can ask either Dr. Nazzal or the TA for help if they need it. This help is not given in the form of an answer though. Guiding questions are utilized so that students truly come up with the solution themselves. As a result, students learn to adapt to the current project, not just memorize a “formula” for success, which enables them to easily apply Cornerstone Design skills in their own Senior Design project.

I believe that the unique features of Dr. Nazzal’s work would be incredibly beneficial in other courses, particularly the “client oriented” nature. While many classes do not have the luxury of focusing on clients because they inherently need to teach fundamentals, higher level courses that are typically taken in the back half of a student’s undergraduate career could certainly benefit from this. Even when real world examples are used, many students do not see the importance of “translation”. We are trained to solve complex problems, but at the end of the day, the solution needs to be palatable for non-engineers. This is the edge that Cornerstone Design provides. Not only in ISyE Senior Design, where many students end up learning this lesson the hard way, but in industry when working with people from different academic backgrounds. Beyond ISyE, I believe that many other schools within Georgia Tech could benefit from the client focus as well as a Senior Design preparatory course.

Although previously touched on, I would like to emphasize that Cornerstone Design truly does “connect the dots” between academia and industry. It undoubtedly enhanced the education I received at Georgia Tech by teaching me how to be more than just an engineer. And it was refreshing to see the passion for client service from Dr. Nazzal after so many classes where the focus is only on numbers or code. For students that participate in and other professors that begin to instruct it, Cornerstone Design provides a humanizing element to the work we do at Georgia Tech. As I start my professional career, I will surely employ the skills I learned and use them to become a more effective contributor to any team I am a member of. Dr. Nazzal provided a true gift to myself and every student that has participated in this course, which is why I wholeheartedly believe she deserves this award.

Thank you for your time.

Sincerely,

Garrett Witt

Garrett Witt

B.S. Industrial and Systems Engineering (2020), Georgia Institute of Technology