Application Summary

Competition Details

Competition Title:	2019 Innovation and Excellence in Laboratory Instruction Award
Category:	Institutional Awards - CTL
Award Cycle:	2019
Submission Deadline:	02/01/2019 at 6:00 PM

Application Information

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Appplication ID:	3074
Application Title:	David MacNair
Date Submitted:	02/01/2019 at 5:53 PM

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Primary School or Department

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Primary Appointment Title:	Academic Professional, Director of Laboratory Development

Application Details

Proposal Title

David MacNair

2019 Innovation and Excellence in Laboratory Instruction Award Nomination – Dr. David MacNair

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Overview

The Mechanical Engineering (ME) instructional laboratory progression includes two core courses, Experimental Methods (ME 3057) and Systems Laboratory (ME 4056), and prior to 2015 both were in trouble. The last refresh of the courses had been in the early 90's, and between the 90's and 2015 the course material became a disjointed collection of boring cook-book style laboratory experiences with little educational value. Skills learned in the labs were not transferable outside of the lab experience, there was no vertical alignment between labs, and no connection to other courses in the ME curriculum. Both courses rated among the worst in ME, with students seeing them as little more than a waste of time. Since the courses were strongly disliked by students, faculty members did not want to remain associated with the labs and the resulting revolving door of instructors prevented long-term vision for the course. Furthermore, the instructors who did want to improve the course were only able to engage in small course changes within a single semester, and generally these changes served to further segment the course and frustrate the lab TA's and staff.

In 2015 the School Chair and Associate Chair for Undergraduate Studies formed a committee to address the laboratory challenges, and Dr. David MacNair was given the task of redesigning and modernizing the entire laboratory progression.

To best understand the redesign effort, it is helpful to understand the instructional laboratory courses. ME 3057 and ME 4056 each have between 240 to 300 students each semester, with labs running from 8:00am to 9:00pm every weekday. In ME 3057 this is divided across around 17 three-hour lab sections with 18 to 21 students per section. In ME 4056, the course is sub-divided into two halves (Mechanical and Thermal) and students switch halves half-way through the semester. Each half has around 11 sections with 12 students per section. Running the course requires training/mentoring around 36 different TA's who lead their lab sections, guiding students through the exploration of difficult topics while also maintaining a lab that is constantly in need of repair due to the sheer volume of students and nature of Mechanical Engineering experiments. ME 3057 and both sides of ME 4056 have 2 lectures per week (6 total) which must also be kept synchronized with the course content to remain relevant. It is also important to note that there is no textbook or similar reference to guide the design of ME labs, so the task is more complex than redesigning a lecture course.

The redesign effort focused on five core principles:

1. Curricular Story: The curriculum should tell a "story" internal to a lab experience, between lab experiences in a course, between laboratory courses, and between the laboratory courses and the rest of the ME curriculum. Students should similarly tell a story through their written reports.
2. Cognitive Load Framework: The lab experiences should be designed to optimize the relevance of learning effort to germane topics/skills, should avoid needless complication, and should avoid issues related to students feeling ahead or behind the pace of the course.
3. Inquiry-Based Learning: Students should be provided general guidance for an experiment, and then allowed to explore the domain with TA's serving as facilitators instead of direct teachers.
4. Laboratory Culture: The lab TA's and full-time staff have a core role in the operation of the labs and should both have their time respected and be recognized for their efforts with the courses.
5. Modular Resources and Ecosystem-Based Equipment: The labs should create or utilize resources and equipment that is common across all ME lab courses, across the ME curriculum, and can be shared between other labs both internal and external to Georgia Tech.

Curricular Story

The core mechanical engineering (ME) instructional laboratories are Experimental Methods (ME 3057) and Systems Laboratory (ME 4056). Historically neither course matched up to its name, and both were made up of a collection of independent and unrelated 1-week laboratory experiences. As instructors rotated through teaching the lab course they would redesign a single laboratory experience related to their research and try to implement that lab within a single semester. When redesigning the progression, the courses were refocused on their original intent. Experimental Methods was designed to be a lower-level introduction to sensors and thinking critically about what sensors could tell an observer about the real-world. Systems Laboratory, which is still under re-development, then introduces students to more complex challenges and asks students to use the sensors from Experimental Methods to perform a systems-level analysis. This approach focuses on both breadth and depth, simultaneously exploring a range of ME domains while introducing the sensors in a scaffolded approach of increasing complexity and difficulty.

One example of the Systems Laboratory experiences is the Internal Combustion Engine. In this experience students perform a complex work/energy analysis on an engine to experimentally derive properties of the system. Sensors on the engine include a force transducer configured to measure torque, a proximity sensor configured to detect student-indicated angles, and a proximity sensor coupled with a toothed wheel to detect wheel angle and angular velocity. From these measurements, students can determine piston and fly-wheel inertial effects, air pressure effects due to the piston motion, and energy transfer to and from the back-drivable motor/generator. On the input side, students can connect a pneumatic line to the piston and control the pneumatic valve opening/closing timing to drive the engine. This mimics the motion and control of an engine powered by fuel without the risk of explosion when students get timings wrong.

The Experimental Methods course scaffolds students' understanding to prepare them for this systems-level analysis. The course starts with a characterization of an amplifier to determine input/output characteristics of an unknown system. This exploration provides a connection to their electrical engineering course material including how to use function generators, oscilloscopes, and properties of signals. The course then explores the calibration of sensors, essentially requiring students to formulate and run two separate experiments to determine the gain and offset of a linear calibration function. Students then use the sensors and a motor to represent input-output characteristics of a Mass-Spring-Damper. The material is from System Dynamics, and the experimental process requires deriving a result from two different styles of sensors (which is directly applicable to the IC Engine progression).

The Experimental Methods progression next goes through a vibrations lab block where students use a non-contact Laser Doppler Vibrometer (LDV) to characterize a fixed-free beam that is excited by a shaker. The device serves as a stand-in for an aircraft wing where an engine running at different throttle levels causes varied excitation frequencies, and could excite a natural frequency and damage the wing. The LDV requires integration of the output sine wave, the same integration needed in the IC Engine progression to determine energy change as the crankshaft rotates under torque.

A stress/strain lab block follows vibrations where students are again asked to go through a calibration process for a force transducer. This time students are challenged to fully understand the signal path of the transducer strain gauge measurement through Wheatstone bridge conversion from resistance to voltage to amplifier, filter, and finally signal acquisition. Each component is fully characterized which allows the separation of errors due to circuit path components from overall errors of the sensor. This separation is a core component of the energy analysis students perform on the IC Engine in Systems Laboratory, where students first determine a method of measuring energy change, then determine friction effects, then determine the inertia of the piston, crank shaft, and flywheel. Finally, fluid (air) compression effects can be separated and all the components are combined to model the full engine.

The final block, acoustics, challenges students to see how time can be used as a sensor output. Students work with two encoders (angle and distance) along with microphone data. To reduce errors, students gate the signals, so one test generates multiple data points. Gating is used again in IC Engines since many of the properties of the IC happen within a single cycle.

Across the Experimental Methods course students are also expected to gain greater autonomy. By the Acoustics block, the lab materials provide little guidance, and following that block students propose their own experiment which they then run as their final lab. This final lab also carries a report where students must fully develop their own technical narrative to explain their experimental problem, experimental approach, conclusions, experimental justification for those conclusions, and an analysis of error to provide a level of trust for the conclusions. The quality of reports hugely improves throughout the course, which allows students to adeptly express themselves as they tackle more difficult challenges in the Systems Laboratory.

Cognitive Load Framework and Inquiry Based Learning Model

The course redesign methodology stems from two best practices in Engineering Education Research. The course assumes students don't begin with a blank slate, but rather a "complete" mental model of how they believe the world works. This model is not always correct, but even when students have no experience with a topic we have an intuitive concept of how it might function. The goal of the lab is to provide a framework for challenging mental models and the associated assumptions. Labs aim to create real-world experiences that either verify, or more often provide cognitive dissidence between observations and a student's internal mental model. This creates a question in the student's mind, and a relevant connection point for new knowledge. Labs provide students with challenges, but not step-by-step guides to a solution. Students can memorize information (like step-by-step guides), but can rarely determine the importance of a process until they develop the process themselves to solve a challenge. Finally, students are given a way to internally validate whether they have solved the challenge. Sometimes this means providing an expected final value, an expected graph shape, or a set of standards. This is like playing darts. The goal is to hit the bull's-eye, but it takes a lot of practice to become consistent. Players know a successful throw, however, when it lands on target.

Cognitive Load Framework defines a vocabulary behind the effort students must put forth to acquire a particular skill, and splits the effort into Germaine Load, Extraneous Load, and Intrinsic Load. Germane Load is the minimal load required to learn a subject or skill, and is the "good" cognitive load. Extraneous Load is an unnecessary load due to a Sub-Optimal Presentation of material, confusing examples, or overly complex data that is not focused on the learning objective. Labs try to avoid this load by limiting needless busy work, focusing student effort on observations related to mental model errors, and ensuring equipment is consistent while limiting challenges which are unrelated to the learning objectives. Intrinsic Load is a load due to starting at a higher or lower level of understanding than that of the student. On the low end, this makes intuitive sense as a student would need to expend extra effort to "catch-up" to get to miss-matched starting point. On the high side, students are forced to deal with different variables, different explanations, and different examples which must be compared with existing knowledge to properly assimilate into their mental model. This comparison created additional load. Labs seek to avoid intrinsic load by carefully scaffolding the presentation of lab challenges, and getting lab TA's to "Facilitate" as mentors instead of "Teaching" with lecture-style explanations. Instructors emphasize that TA's should answer questions with guiding questions, so the TA can evaluate the student's level and point the student toward the appropriate learning resources or an additional experiment which will provide an answer. Learning resources are designed to meet a student's starting point. For example, a top-level experimental challenge or explanation will not contain all needed information on how to use the equipment. Instead, it will contain links to additional resources so the students who are unfamiliar with the equipment can learn more while students with prior experience are not bogged down. This is like Wikipedia providing links inside its pages, and like with Wikipedia the intent is to make the resources available both across Georgia Tech and to other peer universities. Since lab manuals provide challenges instead of procedures, students will still need to dive to the appropriate level before they are able to be successful, which ensures they do not leave lab without meeting the learning objectives.

Lab material is present similar to a flipped classroom model. Most of the background content is covered prior to lab through lectures, videos, and other resources, and a homework assignment also provides a scaffolded introduction to the lab content. The homework provides guided questions which step students through the laboratory analysis, and requires students to program functions to analyze dummy sets of lab data prior to performing the lab. This allows students to use lab time to build an intuition since they can see the results of the analysis immediately after collecting data (running the pre-made functions), instead of days later while trying to write a report. Homework and Labs also follow the practice of internal validation, providing a way for students to check if they have an appropriate answer. This allows them to internally rapidly iterate throughout the learning process, reducing intrinsic load.

Laboratory Culture

Designing high-quality laboratory progressions requires a team effort and engaging everyone from the 36+ Graduate Teaching Assistants (GTAs), the instructional staff, and the faculty instructors. GTA’s in ME are selected based on advisors having a lack of funding to support their students, meaning GTA’s are not happy about needing to carry additional teaching load to get their funding. We work to provide value to the GTA’s through mentorship and targeted teaching opportunities, and develop a camaraderie among the TA’s through targeted weekly training and grading meetings. The common training also helps TA’s feel confident with the lab material so they can serve as effective facilitators, and the common grading meetings allow normalization of grading across the TA’s and for TA’s to share stories and concerns. Both are light-hearted allowing TA’s to feel valued. Because of the mentorship provided, many TA’s become Graduate Instructors, and at least 3 have received campus-wide awards from CTL.

On the staff and faculty instructor side, the team gets together for weekly lunches to discuss lab operations, blow off steam, and brainstorm lab development. This creates an even playing field between faculty and staff, and allows for friendships to compliment the working relationships between the team members. Doing so has dramatically increased productivity and efficiency.

Modular Resources and Ecosystem-Based Equipment

From an equipment standpoint, the instructional labs have adopted a modular approach to creating resources and equipment. The resources are based on the Wikipedia style approach mentioned above, and are being arranged into 3 tiers: 1) Resources specific to the operation of a single lab, 2) Resources common to anyone using the same equipment, and 3) Resources that are generally applicable regardless of curriculum (like base equations). This allows tier 2 and 3 resources to be shared between labs, whether they are common to GT or external partners. Similarly, anyone operating with the same equipment ‘ecosystem’ can generate additional tier 2 and 3 resources to be added back to the common pool to aid in the common good. The equipment ecosystem consists of a curated set of actuators, sensors, and interface boards which can be used to implement many different laboratory experiences. Anyone with the common set can use any lab built using the ecosystem. Finally, the ecosystem contains custom-built electrical circuits that allow them to easily instrument projects (laboratory, capstone, or personal) at a level greater than the black-box common to industry (blocking learning) and without going to the depth of bread-boarding circuit components. This has greatly increased student proficiency with instrumentation, and their ability to transfer skills to other domains.

Overall, the new laboratory progression dramatically improved CIOS scores for the lab courses (~3.7 to ~4.3 average) and alumni constantly reach out to lab instructors to express their appreciation for the course. In one particular example, an alumni engineer at Tesla commented about having saved the company millions by applying the critical thinking and error analysis techniques to reduce the battery testing time from 8 hours to 20 minutes. This is what keeps the laboratory team engaged, and drives the creation of new laboratory experiences of the future.

G.W.W. School of Mechanical Engineering
Georgia Institute of Technology
Atlanta, GA 30332-0360

February 1, 2019

I write to you to express my strong support for Dr. David MacNair for the 2019 Innovation and Excellence in Laboratory Instruction Award. Over the past 3 years, David has worked tirelessly to redesign the instructional laboratory experience for Mechanical Engineering, creating an engaging interactive progression that has become the envy of our peer institutions. He has a vision for the true potential of laboratory education and works relentlessly to make it a reality. His dedication to his students and passion for enabling the pursuit of knowledge is infectious and has had a positive impact well beyond the laboratory courses.

Prior to my current position as Chair, I was a lab instructor myself for both of ME's instructional laboratories. I've seen firsthand the previous disconnected cook-book lab experiences, and herculean task of redesigning even a single laboratory experience. Redesigning a multi-course progression from the ground up is a truly monumental task. It's a task that cannot be accomplished by an individual alone, so it's perhaps most impressive that David has built a highly motivated and dedicated laboratory team consisting of faculty instructors, staff, graduate instructors, graduate TA's, and students. David constantly empowers this team to create the laboratory experiences of the future.

David also brings together both campus and external partners in the pursuit of effective education. On campus he works across school boundaries, coordinating with laboratory directors, College of Engineering, and the Creating the Next in Education Commission. With these groups, he is driving a conversation about designing a laboratory 'ecosystem' that will allow greater consistency and knowledge transfer across campus (and to peer universities). With external partners, David advises and has gotten investment from companies like National Instruments, ANSYS, Mathworks (Matlab), Dassault Systèmes (Solid Works), and PTC around creating streamlined educational tools that tie together data collection, data processing, modeling, simulation, programming, and report writing into a single robust environment. National Instruments specifically has gifted $120,000 simply to empower this vision and develop the tools laboratories of the future will use.

David is highly involved with informal education, specifically with the "maker movement" and maker spaces. He works to connect members of GT's maker community with each other, with laboratory education, and with external maker spaces so they can all empower one another. Externally, David founded the Atlanta Maker Alliance and the Roswell Firelabs, a non-profit maker support network and non-profit educationally-focused community maker space. He has traveled to the White House and Congress to advise at the federal level regarding interactive learning and is currently helping draft legislation to empower the NSF to offer research grants to further study maker-empowered education.

David MacNair's work sets a new standard for the future of laboratory education, and I highly recommend him for the 2019 Innovation and Excellence in Laboratory Instruction Award.

Sincerely,

Dr. Samuel Graham
Chair, George Woodruff School of Mechanical Engineering
Georgia Institute of Technology

The George W. Woodruff School of Mechanical Engineering

January 31, 2019

To Whom it May Concern,

It is a pleasure for me to write this letter of recommendation on behalf of Dr. David MacNair who is being nominated for the Georgia Tech "Innovation and Excellence in Laboratory Instruction Award." David has had a tremendous positive impact on the required laboratory courses in the School of Mechanical Engineering and is highly deserving of this award. David is currently an Academic Professional and Director of Laboratory Development and has been involved in every aspect of our undergraduate lab experiences. His contributions can be divided into several categories each of which I will attempt to describe below.

Course format: When David joined the School of Mechanical Engineering in 2016, the laboratory courses were badly in need of revision and updating. Student dissatisfaction was fairly high as measured by CIOS evaluations and exit surveys of graduating students. In particular, there were too many lab experiences, too much work, and redundancy with other lab classes. Additionally, most of the laboratory experiences had become very procedural, and students spent the bulk of their time following the steps without really thinking about what they were doing, or questioning whether the results made sense. David applied learning theory and evidence-based learning techniques from the literature to re-imagine the laboratory experience. In the junior-level lab course (ME 3057), David recognized that students were being crushed under "extraneous cognitive load," which was caused by several factors. David implemented his vision for the course to involve roughly half as many lab topics, with each lab topic treated over two consecutive weeks. In the first week, students get acquainted with the theory and apparatus, and then they in the second week they are able to go deeper into the problem. In this way, students cover fewer topics over the course of the semester, but are able to go into greater depth. Long writing assignments were replaced with shorter assignments, but each assignment now requires them to have better understanding of what they are doing.

Development of new laboratory platforms: One of David's most important contributions has been in the creation, design, and development of new laboratory platforms. Several laboratory platforms were designed from scratch, and other labs were vastly re-designed. Two experimental platforms deserve special mention. In the junior lab, David was responsible for the development of a device that could be used to apply very high loads to various objects (up to 10,000 lbs.) Ordinarily, such a device would cost thousands of dollars, and would end up being a specialized, single-function tool. The platform that he developed allows students to really see how it works and they get to develop some of their own instrumentation, thus learning a fundamental aspect of transducers. In the first week, the students make and calibrate their force sensor; in the second week, they actually apply loads to objects such as climbing straps to determine their breaking strength. Loads are

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applied mechanically through a crank and screw mechanism, so that students can actually "feel" how parts yield prior to breaking. A second experiment uses a single-cylinder internal combustion engine. Students have responded very favorably to this experiment, since for many of them this is their first real experience with IC engines, which are so important in the field of mechanical engineering. This experiment is intended for use in the senior ME lab, ME 4056, and is designed to be a multi-week experiment. Activities in each week are designed to teach a new aspect of the system. The lab exercises are carefully scaffolded so that each week builds on the week before, allowing students to gain in-depth experience on this complex system. Every task that students are asked to do has a purpose, and the experimental results are always compared to theoretical predictions based on the material that students have seen from a theoretical perspective in pre-requisite courses. The devices that David and his team have developed have been presented in research papers and presented on stage at National Instrument's *NI-Week* in Austin, Texas, where they have been very well received.

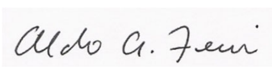
Development of Teaching Assistants: Equally important to the development of hardware resources such as laboratory platforms, David has recognized that the development of teaching assistants is equally critical in creating an effective learning environment for students. David spends a great deal of time training teaching assistants. One key aspect of this training is for TAs to learn how to answer questions during and after the lab period. He trains them to guide students to the answer, often by answer questions with other questions. The TAs are given weekly training on how to get the students to think and reflect on what they are doing, rather than just following a procedure. The written lab manuals, likewise, have many intermediate points where students must pause and think about what they are doing, and answer questions. Another thing that David has brought to our program is a very strong respect for the TAs that work with him. He is very sensitive to their workload and treats them as partners in the lab classes. Another thing that David deserves credit for is team building of the laboratory staff. David works with a very talented group of engineers, other faculty members, and head TAs. David established weekly lunches bringing all of these individuals together to exchange ideas and to discuss current problems and issues.

Fund-raising: Even before David was hired, he had developed a relationship with National Instruments (NI), and was involved in their efforts to improve the products that they developed for engineering education. Once he was hired, NI strengthened this relationship by funding his lab development work. David has also been able to get donations of new NI products and equipment for use in the lab. Finally, he has continued to envision new capabilities that leverage NI products. For example, he has been working on a cloud-based system that can be used by students to capture data and to facilitate data processing. He has also been considering the potential uses of virtual and augmented reality systems in lab courses.

If you have ever met David, you cannot help but be impressed by his intelligence and energy as well as his vast knowledge of engineering education and learning. The improvements in the lab experiences described above are all grounded in learning theory. He takes advantage of those techniques that have been demonstrated to work in motivating students and in strengthening their learning and retention. "Busy work," and long lab write-ups have been significantly reduced, and have been replaced by shorter but, at times, more challenging exercises. This forces students to engage more deeply with the material, making high-level connections in their understanding. It cannot be overstated, also, that because of the very high enrollments in the ME undergraduate program, David has done all of this while running 300 students through ME 3057 and about 300 students through ME 4056 each fall and spring term. With such a large number of students, David has had to ensure that each improvement is thoroughly vetted before rolling it out to students. In many ways, teaching the labs is a full time job, but in addition to teaching, David coordinates an army of GTAs, and also does development of new laboratory experiences.

In summary, I believe that David MacNair is an outstanding choice for the Georgia Tech "Innovation and Excellence in Laboratory Instruction Award." He has vastly improved our undergraduate required laboratory classes, making a positive impact on hundreds of undergraduate students each year. Students graduating from our program have benefited from being exposed to state-of-the-art measurement equipment and systems. More importantly, they have been given the skills to continue learning about experimental methods long after they graduate from Georgia Tech. I strongly recommend David for this prestigious award.

Sincerely,



Dr. Aldo A. Ferri
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The George W. Woodruff School of Mechanical Engineering

Jeffrey A. Donnell

January 29, 2019

To whom this may concern:

I am writing in strong support of Dr. David MacNair's nomination for the 2019 Innovation and Excellence in Laboratory Instruction Award. I am well positioned to speak in this case, as I have worked closely with Dr. MacNair in the Woodruff School's required laboratory courses since 2016. During that time, I have seen him revitalize our laboratory courses and truly engage our undergraduate students and our Graduate Teaching Assistants. It has been a pleasure to work with him, and I am very happy to use this letter to describe his impact on our program and our students.

Let me begin with a word about our laboratory courses. The Woodruff School grants over 500 BS degrees each year, so our laboratory classes commonly enroll 250 or more students in a single term. Prior to David's hiring, these students were deeply dissatisfied with our engineering laboratory classes. In CIOS comments, students complained that the projects were dull and procedure-oriented. The phrase "cook-book projects" was often used. David was tasked to solve the problems in our labs, and he was given great freedom to make changes. He used that freedom to make important, positive changes.

Beginning with our 3rd year course, Experimental Engineering, David reconceived the mission of the course, abandoning the existing procedure-bound approach in favor of an inquiry-based method that would engage the students by promoting thinking throughout the data collection parts of each laboratory project. Laboratory manuals were redeveloped to facilitate exploration rather than procedure-following, and grading was adjusted to emphasize students' ability to show that they understand and can account for the unexpected results that arise on almost every project. Our assessments of the students' submissions indicate that these changes have been successful; compared with the submissions before David began to modify our laboratory program, our students have greatly improved in their ability to explain and evaluate the results they obtain on their projects.

In addition to modifying the instructions the students receive, David modified the labs and instrumentation themselves to address the frustrations that students can experience when a new project requires them to learn unfamiliar interfaces on new data-collection tools. David led the design and production of data-collection equipment and experimental apparatus to create a common "ecosystem" of resources that our students can grow familiar with as they move through our laboratory sequence. This enables the students to avoid the distractions associated with unfamiliar data collection tools and allows them to focus their attention on the concepts that are central to each project.

To enhance students' lab learning, David adjusted the training and oversight of our GTA staff, promoting active engagement with the students. We now teach our TAs to circulate among the student teams, asking the students to explain and validate their results, and verifying that the students' results are within the bounds that we had previously set for them. This helps students to complete their work in a timely fashion and enables our TAs to identify flawed data when there is still time for the students to debug any errors they may have made.

At David's urging, a student-directed project was introduced each term. As the last data collection project of the term, this project requires students to propose, and present for approval by the instructors, a data collection project of their own design, to be conducted using our lab's instruments plus any resources the students are able to safely bring with them to the lab room. To be successful on this assignment, students must propose a data collection project, demonstrate its feasibility, describe benchmarks to which their data can be compared, and prepare a lab manual to govern data collection steps. This project engages the students' interest, as it requires them to plan, execute, and evaluate a project from end to end. Yet the students have managed this challenging task effectively; we have been impressed by the high quality of the proposals and the project reports that have been presented on these student-developed laboratory projects.
David's investment in the success of our laboratories goes beyond the planning and development described above. He also spends time in each of our lab sections, interacting with the undergraduate students and modeling teacher-student interactions for our Teaching Assistants. He makes himself available to students during these lab sessions, after classes, and upon request from the students. And the students appreciate this, and as a result, David always has a crowd of students to talk with, both before and after lectures and lab sessions.

I have made a case here that these improvements to our lab course have had a positive impact on our students, both in terms of their reactions to our course and in terms of their learning the course material. This course redesign has put the students in charge of their learning by giving them an active role in the investigations they conduct, and the students have responded well to challenges presented by these innovations. But I need to add here that this course redesign may have an impact beyond our department. David's approach to delivering laboratory instruction is novel, at least in the universe of mechanical engineering programs. While inquiry based learning is a well-understood concept, implementing this in a lab class of our size has been challenging, and our peer schools have not in the past been willing to take on such a challenge. Now, I believe that they will, and I believe David MacNair will be called on to help other schools develop laboratory courses using similar approaches. In this way, I feel that his work will in the future be seen in mechanical engineering programs beyond Georgia Tech. This is a significant innovation in laboratory instruction, and David MacNair absolutely merits recognition with the 2019 Innovation and Excellence in Laboratory Instruction Award.

Sincerely,

Frank K. Webb Chair in Professional Communication
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February 1, 2019

It is my pleasure to write a recommendation for the 2019 Innovation and Excellence in Laboratory Instruction Award in support of ***Dr. David MacNair.***
I have known David since we were both graduate students at Georgia Tech and have been collaborating with him closely for the last two years. Together we have worked on improving the Mechanical Engineering laboratory class progression, a multi-pronged effort which has taken significant engineering development, pedagogical consideration, and political maneuvering. It's been a tremendously heavy lift getting the laboratory course progression to where it is now, and the vast majority of that motivation and effort has come from David and the countless hours of hard work he has put into the endeavor. There are several parts of this experience that I wish to recount in this letter, but one thing needs to be made clear from the start: *The incredible gains that we have had in CIOS reviews, course feedback, and the student outcomes from the combined series of ME 3057 and ME 4056 would not have been possible without the tireless and thoughtful work of Dr. MacNair.*

As a new faculty in 2017, but as a long term participant in the culture at Tech surrounding engineering education, I was given the task of being part of the rejuvenation of ME 4056, a class that despite all its problems has a very important goal – to teach students the techniques of system level mechanical analysis and how to communicate those results to technical audiences. The former part of that mission statement has existed for a very long time, but the latter part is what really captivated me, and I believe that the focus on communication skills is truly the most important part of the experience. It just so happens that this is one of the parts of the course that David decided to emphasize in his reboot of ME 4056, and I think the wisdom in that is readily apparent. Several students have reached out to me to say that the skills they learned in ME 4056, specifically in the communication related material, has had a direct and immediate impact on their success in their jobs. A letter I received from a student really says it best:

> *"The rigor of 4056 has proved invaluable. I was able to communicate clearly and concisely, because the page limit taught how to structure and summarize ideas. I was able to analyze data quickly and efficiently thanks to the variety of experiments I got practice from… I now appreciate the effort and care you [both] put into designing each experiment. Your passion for teaching trickles down year after year to have an impact much larger than what you get to see."*

I strongly believe that this feedback is directly related to the vision that David has for the laboratory courses, and is one of the most direct results of his hard work and dedication.

Working with David on the technical content has been a wonderful experience and is one of the highlights of my job. We have had countless coffees, lunches, and several hour long heated debates over the role of uncertainty analysis in ME 4056 deliverables, the need for loosely defined problems in encouraging critical thought, and all the other pedagogical content of the course. We may not see eye to eye on every detail, but it's easy to join his altruistic vision for education at Tech and from that we have been able to forge a very effective working relationship on the design of ME 4056. A specific example of this is the development of a laboratory experiment using a fully instrumented internal combustion engine, which is about as real and practical of a mechanical system as exists in this world and serves as a wonderful learning platform for system analysis concepts. This lab was David's brainchild, and the thoughtfulness he put into building it, instrumenting it for data collection, and the learning environment that this device is a part of has made curricular development surrounding it a pure joy. The motivation level of students during this lab is noticeably higher than any other lab we run, and the technical content of the lab is sound, relatable, and teachable. Working with David on the lab has also shown me his willingness to adapt the instructional package of the IC engine experiment, demonstrated by his trust in me to develop content around it and provide helpful feedback without micromanaging the experience. I feel like it's a true working partnership, and the product of that partnership is having a direct, immediate positive impact on the experiences of students in ME.

Finally, even though we are roughly the same age, I consider David to be a mentor and a leader that I look up to in the mechanical engineering department. Our cause is an uphill battle because of the lower role that education of undergrads serves relative to faculty led research, but David's resilience and his determination to get engineering education on equal footing with research is inspiring. Along with a reboot of a course or courses like this always comes political infighting over resource allocation, and David's willingness to fight those battles strategically is something I admire. So far we have been able to secure the resources that we need to make this whole idea work, and that is largely because David has been willing to put his neck on the line for this cause that he so deeply believes in. I've been part of several working groups and committees that decide on a mission or course of action, and the implementation phase of these plans tends to fall woefully short if it ever launches at all. David is the kind of colleague that makes those kinds of endeavors successful, and it's this drive to walk the walk that truly sets David apart from many others that I've worked with in similar capacities. When he believes in a project, he makes it happen, and I really can't think of higher praise for a colleague at an R1 engineering school than that.

This award is meant to reward those who have "excelled in teaching in the laboratory". David has done that and more. He's changed the way that ME 3057 and ME 4056 are taught, he's changed the experiments in those courses from the ground up, he's changed the way the experiences are perceived by students, and he's fundamentally changed the type of skills that our students learn to prepare them for the realities of engineering in the modern world. To say that David has excelled in teaching in the laboratory is an almost comical understatement of what he has done here in ME for laboratory class instruction. He's changed what it means to be a Georgia Tech engineer, and I'm proud to support and further that mission in any way that I can. It is with great confidence that I give my strongest recommendation in support of Dr. David MacNair for the 2019 Innovation and Excellence in Laboratory Instruction Award here at GT.

Sincerely,

Dr. David E. Torello
Academic Professional, G.W.W. School of Mechanical Engineering
Faculty Mentor, A. James Clark Scholars Program

Michael R Baldwin
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To the Selection Committee:

My name is Michael Baldwin, and I write to you today to enthusiastically express my support for Dr. David MacNair for the Innovation and Excellence in Laboratory Instruction Award. I am a Georgia Tech mechanical engineering (ME) graduate student and have been involved with one of David's labs (ME 4056 Systems Laboratory) for just under three years now. I began as a lab teaching assistant (TA) but have since become the Instructor of Record for the thermal portion of the course. Throughout this journey I have had the privilege of observing David's teaching practices and getting to know him on a more personal and professional level. I can say without a doubt and above all else, David desperately wants to create a laboratory experience that is both beneficial and meaningful for his students. Everything he aims to do is student-focused, and his respect and selfless attitude towards student learning has helped me to become a better mentor to my own students.

David goes above and beyond as a laboratory instructor in a deliberate attempt to help his students learn the goals of the lab. Often times when I pass by his lab, I see him there with the students asking them questions about the data they are collecting. Having taken chemistry, physics, electrical, and radiation laboratories while at Georgia Tech, I never recall the professor actually paying my individual lab section a visit, let alone taking the time to involve us in a discussion about the lab itself for the purpose of learning. I have witnessed this practice from David on multiple occasions across the many semesters that I have been working with him. David is always wearing a smile and is full of positive energy, so it is always easy for students to approach him with questions.

David uses interactive teaching strategies in his lectures to try to engage his students and desires that the labs are also run similarly. He focuses on giving the students a chance to think critically about the content before divulging information. In lab, I know he tries to redirect student questions back at them in order to achieve this goal. These types of strategies can be effective if done correctly, so David holds a pre-semester training for all of the lab TAs for the purpose of imparting some of these teaching tips to them. David wants his students to learn, but he knows that most of the learning happens in the lab and with facilitation from the TAs; as such, he makes this extra effort every semester to train the TAs in hopes that they can enhance the students' laboratory experience and mastery of the learning objectives. In addition to this, the TAs buy into the idea of becoming better facilitators because David has personally invested in them as TAs. This has led to better quality TAs, better TA/instructor relationships, and better TA/student relationships as well. Through his support and determination, I was able to become a student instructor for one of his lab classes. He knows I value student learning as much as he does and trusts that I will run the course in a way that enhances the student experience. I am personally appreciative of his faith in me as an instructor and am happy to work with someone of such strong character.

Finally, David has a clear vision for the future of his lab courses and is actively striving to work towards realizing those goals. He runs two separate labs and has already gone to great lengths to streamline these courses as much as possible. The results of his hard work are evident in the conversations I have with current students; where they used to complain and express frustration in the stark differences in certain aspects of the two courses, they now speak works of satisfaction and gratitude. Currently, David meets with his lab team weekly to discuss the development of future student laboratories. I have been present for several of these conversations as the team works together to brainstorm how to best construct a lab experience worthwhile for the students. David keeps mind to first determine the desired learning outcomes and then to design the experiment around those outcomes. Furthermore, this new lab is designed to be a multiple week experience, which is an innovative concept as far as the ME labs go; all but one of the current labs are single week experiences. This new extended lab will give students more time to truly dive into a real engineering system and to analyze many different areas of mechanical engineering in one laboratory. David is always trying to seek out new ways to reach the students, and it has been a treat to see him begin to build this new lab from the ground up. This project has only been possible because of David's leadership.

I have only worked with David for a couple of years now and honestly have limited insight into all the work that he does for the ME labs, but from the time I have spent with him it is clear he values his students and wants to design the best laboratory courses for them. He demonstrates this in his leadership and innovative lab development ideas but more obviously with his care and devotion to his students and TAs both inside the lecture hall and inside the lab. He has already improved the ME labs from the short time I have been here to such a degree that I have witnessed the change in student attitude towards the labs firsthand. I fully expect the labs to continue to progress, and this is in large part due to the constant care and attention provided by David MacNair. I cannot think of another person more deserving of this award. Please feel free to contact me if you would like any more information; I would be more than happy to elaborate further!

Sincerely,

Michael Baldwin

Nolan Hall
George W. Woodruff School of Mechanical Engineering
Georgia Institute of Technology '17
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26 January 2019

To the Laboratory Award Selection Committee,

I have known David MacNair since August of 2016, where I was a student in his Experimental Methodology lab and lecture. I can say that, without question, this was the most relevant and useful experience I had at Georgia Tech. To this day, David continues to be a mentor in my academic and professional career.

David took advantage of the hands-on nature of his course to a level that few professors care to reach. He maintained consistent, informative delivery of useful information throughout lectures and immediately demonstrated the experiments in the following lab. Despite having numerous lab sections, I constantly could find him in the lab working with students and TAs, ensuring that each and every person in his lab was grasping the material in a theoretical and physical capacity. He was always delighted to stay after lecture or lab to assist students, and he never stopped working to improve not only his course, but the entire mechanical engineering curriculum.

As I got further into the semester, I utilized his office hours more and more. I found myself there not solely for help with labs and reports, but to offer him a student's perspective on the mechanical engineering curriculum as a whole. Never in my time at Georgia Tech had I seen a professor so involved and dedicated to improving the learning environment for students. Each time I attended his office hours, he had ideas for more helpful ways to teach the labs. He not only proposed new ideas, but he implemented them as well. David looked for every gap in understanding that a student may have had, and he closed it immediately through lecture explanations or experimental studies. He made sure that everyone walking out of his lab sessions knew exactly what had happened in the experiment and why.

After I had finished his course and moved on to others, I continued a correspondence with David as many of his students do. Whether it was helping with a job search, assisting with another course, or giving professional advice, David was always there to help. He reached out to friends at companies I was interested in working with to set up interviews, he helped me with an invention I was working on at the time, and he ultimately inspired me to pursue my ideas and start a business. He is an outstanding professor and a deserving candidate for this award.

Nolan Hall

To Whom It May Concern:

I completed my BS in Mechanical Engineering at Georgia Tech in May 2018 and am now a mechanical design engineer for a manufacturer of ergonomic material handling devices. While I was at Georgia Tech, I had the pleasure of both taking a course taught by Dr. David MacNair and working with him as a student assistant. I took ME 3057 “Experimental Methods Laboratory” in the Fall semester of 2017 and I worked in the Undergraduate Instructional Laboratory Development Office from May 2017 to May 2018. During that time, I saw firsthand Dr. MacNair’s commitment to improving the instructional laboratory curriculum, his enthusiasm for positive educational outcomes for laboratory students, and his ability to innovate and create laboratory experiences that complimented the Mechanical Engineering classroom curriculum.

When I started the Experimental Methods course as a student, much of the laboratory equipment and curriculum had been recently updated or replaced, and there were plans to update or replace that which remained. This was largely the result of Dr. MacNair’s efforts. I heard opinions from alumni and department staff that indicated the lab course content had grown somewhat stale in the years preceding Dr. MacNair’s arrival, but it was evident that he was taking action to move the instructional laboratories back to the cutting edge. The result was an engaging experience in the lab and a reporting process that required students to consider and analyze the underlying meaning of the collected data rather than simply following steps in a manual.

Dr. MacNair’s teaching techniques demonstrated a passion for helping students truly learn the course material rather than simply pursuing a grade. He understood that some students were preparing for a career in industry after finishing their undergraduate degree, while others were planning to continue as graduate students. He took care to ensure that the content of the course and the required deliverables would steer both types of students towards the knowledge that they would need. The instruction I received in the course greatly improved my technical writing, and I regularly use the skills I learned in the course for recording and reporting test data in my current job.

In my personal interactions with Dr. MacNair, he frequently spoke about his desire to integrate the lab courses into the overall mechanical engineering curriculum. He frequently asked both students and other professors about the specifics of topics being taught in other classroom courses, and referred to this material in the laboratory lectures to create continuity for students. This helped establish an unmistakable connection between the physical phenomena observed in the laboratory and the conceptual analysis performed in other courses. The breadth of the mechanical engineering curriculum can sometimes make different modes of analysis seem detached from each other, but Dr. MacNair’s efforts helped tie everything together.

Overall my experience with Dr. MacNair and the Experimental Methods course was exceptional. His efforts to improve the labs, exercise the best educational practices, and integrate the labs into the ME curriculum helped me become both a better student and a better engineer.

Sincerely,
Philip Paris