Session 1653

2nd and 3rd Order Refinements/Improvements to an Experiential Design and Introduction to Engineering Course for First-Year Students

Sandra Shaw Courter and Jay K. Martin
University of Wisconsin-Madison

ABSTRACT

A three-credit course for first-year students with the objective of providing an authentic engineering design experience and an introduction to engineering has been in place at the University of Wisconsin-Madison since 1994. From the inception, the course has been centered on real projects the students carry out in collaboration with bona fide clients.

During the last eight years, the course has evolved through a series of refinements and improvements based on systematic evaluation and reflection. The basic concept and structure of the course remains the same; however, activities and assignments for the students have seen fundamental changes. For example, when the course was established, in addition to the weekly lab, there were two 1-hour lectures per week that involved all ~200 students. The educational objective of the lectures was to provide an introduction for the students to many different aspects of engineering and design ranging from discussions of engineering ethics and engineering and society to introduction to strength of materials and elementary electronics. As a result of observation of student response (in class, via discussion, and survey), numerous changes have been made to this format. Now, students attend one large group meeting per week where active learning is used in all the activities. Faculty share an example that demonstrates the desired educational concept, and then ask students to apply the concept with their peers to something of specific interest to them. The second lecture each week is now a small group meeting where the content is determined "just-in-time," as the result of a formal method for determining what the students are most interested in learning to best complete their project.

Other changes include

- Incorporation of writing into all aspects of the course
- Recognition that the design process is similar to the communication process
- Peer review of presentations and writing
- Philosophy in the types of projects that are selected and the clients that work best with the course and students
- Forms of presentation by the student teams
- Use of course notes
- Means for development of a cohesive and functioning faculty team
- Introduction of engineering majors and disciplines to students
- Training and identification of responsibilities for the undergraduate assistants.

Introduction

An introduction to engineering course for first-year students has been in place at the University of Wisconsin-Madison since 1994.[1-3] The course has been centered on providing an opportunity for students new to the university and engineering with an actual engineering design and project experience. Through carrying out a project, students experience many important aspects of engineering, such as working on teams, determining engineering specifications, and designing. It was assumed that students would get exposure to technical information through the engineering project process, but it was not a primary goal for the course that students learn specific engineering technical content.

It was hoped that this course would assist in developing student confidence in the ability to be successful in engineering and have a positive effect on both retention and in the rate at which students assimilated into engineering departments. Results from tracking of students show significant increases in retention rates of students that have completed this course versus students that did not take the course. In addition, students that have completed the course move from pre-engineering classification to department classification earlier in their academic programs.

Details of the course as originally designed are shown in Table 1. As shown, the course enrollment accommodates one-quarter of the entering freshman. The students are divided into 16 sections with each section having a different project. The students originally attended two lectures per week, and had a three-hour laboratory. The laboratory included teamwork exercises, dissection exercises, and other activities, in addition to direct work on the project. There is a relatively large number of teaching staff associated with the course, with one faculty member associated with two sections. In addition, a senior undergraduate student (called a student assistant) is associated with each of the sections.

Table 1: Description of Original Version of Introduction to Engineering

Number of Students	~200
Number of Laboratory Sections	16
Number of Lectures Per Week	2 – 50 minutes each
Number of Laboratories Per Week	1 – 3 hours each
Number of Teaching Faculty	~10
Number of Student Assistants	16
Number of Teaching Assistants	2
Number of Projects	1 Overall Theme – Each section had a related project

The basic objectives of the course have remained unchanged during the entire time it has been taught because it seems that the course is meeting the stated objectives. In addition to the retention results, it is popular with students and it is likely that enrollment of the course could be doubled, if student interest is an indication, and if additional resources to support the course could be found.

Although the basic idea of the course remains unchanged, the course has evolved through a series of what we call 2nd and 3rd order refinements and improvements based on systematic evaluation and reflection. Because these changes are evolutionary in nature, they tend to be somewhat subtle. Nevertheless, we have found these changes have resulted in improvements in the course, and they may be of significant interests to others engaged in teaching freshman engineering courses.

Before describing the details of the changes we have done, it is also interesting to note the incredible creativity that is being exhibited by so many that are involved in freshman engineering. For example, review of recent education conferences shows that people are doing the following: 1) freshman-senior collaboration, [4] 2) retreats with Freshman in log cabins, [5] 3) providing industrial experience for freshman, [6] 4) providing opportunities for collaboration with professional designers,[7] 5) using robots [8] and imaging [9] to introduce engineering to freshman, and 6) providing an opportunity for international experience for freshman.[10] Of course, this list is not exhaustive, but it is certainly inspiring.

2nd and 3rd Order Refinements/Improvements

The following section provides the details of the changes we have implemented in this course. We begin with changes in pedagogy and content, not because this is necessarily the most important, but because it is often the most discussed by the teaching staff.

Changes in pedagogy and content **:** The original structure of the course involved two lectures per week to all the students. The educational objectives for the lectures were complex and ambitious. For example, it was desired that students would learn about: 1) all of the different engineering disciplines, including what you do if you are a specific type of engineer, and what is required academically to receive a degree in the specific discipline; 2) details of design, including things such as problem specification, brainstorming, and formal methods of decision making; 3) many other aspects of engineering, such as engineering ethics and engineering and society; and finally, 4) engineering science where appropriate. Student response (in class, via discussion, and survey. Student response (in class, via discussion, and survey), indicated that students did not see much importance in these lectures. They consistently reported that the lectures were a waste of time.

After considerable reflection as to why it was faculty thought the lectures were so important and students just the opposite, numerous changes have been made to this structure. First, active learning was utilized in all large group meetings. Students are provided with an example that demonstrates the desired educational concept, and then asked to apply the concept with their peers to something of specific interest to them.

Next, the second lecture each week has been replaced with a small group meeting. In the small group meeting the content is determined "just-in-time" and is specific to their project. The method used to determine content for the small group meeting involves developing material that is in response to questions from the students about their project, a result of a formal method for determining what the students are most interested in learning to best complete their project.

To begin this process, shortly after students have been on a site visit to learn about their project, they are asked to write a list of questions they have about the project. Any and all questions are encouraged. Students are provided examples of "good" questions, such as "What is the best way to join to pieces of wood together in this part of the design?" In addition, it is emphasized that there are no bad questions. Students produce many questions (sometimes more than 100) about the project. Once a list has been generated, the faculty and senior assistants classify the questions. One example of a classification scheme that has been used is the following: One type of question are those questions that can be solved by a visit to a hardware store or discussion with a skilled tradesman. There are often many questions like this. The next classification would be questions that could be answered by reference to an engineering handbook or someone skilled in design or machining. Questions that seem to be of most interest to faculty are those that would best be answered via engineering analysis. And finally, questions that are more philosophical in nature are common.

Once the questions have been sorted in the different classes, students are asked what answers would be most important to the success of their project. Once this is determined, the content of the small group meetings can be planned. For example, questions about fasteners are very common, so we ask someone from campus who is an expert in fasteners to come in and teach the students about fasteners. The subjects that are discussed are extremely wide-ranging and varied, depending on the project and the interest of the students.

<u>Philosophy in the types of projects that are selected and the clients that work best with the course and students</u>**:** As has been described, the projects carried out by the students in this course have always been authentic projects with real clients. Each of the individual sections meets with the client, develops a problem statement, brainstorms, designs, and fabricates some artifact during the semester. Originally, the idea would be that each of the 16 sections would work on a problem of common interest, however, with different clients. For example, an issue identified for the third year of the course was corrugated paper recycling and/or disposal. In this case, the clients included several local grocery stores, the local zoo, and one of the local hospitals. By having a common problem, it was thought that lectures could be framed around the problem and still have direct relevance for all of the sections.

Our experience with one general theme was that we (the faculty) needed to generate interest among potential clients in a project and working with freshmen engineering students. In some cases, this was easy and resulted in enthusiastic customers who where very interested in the proposed project and the work the students did on the project. In many cases, however, the client was not convinced that the project was important to them, and the interaction with the students reflected this feeling.

In response, we have evolved to individual projects, meaning that there are normally 16 different projects that are carried out in the class. Now, however, the projects come from the clients themselves, meaning that the client always has interest in the project. The projects themselves are generated by offers we make to organizations within the university and community. We ask them to submit project ideas for engineering problems they have that they would like us to work on. We believe that the student sense of responsibility to the project is strongly dependent on the interest expressed by the client.

Finally, we work primarily on projects that come to us from the non-profit sector. In spite of our preconceived notion, for-profit organizations seem to have difficulty in finding appropriate ways to work with freshmen engineering students. In contrast, non-profit groups have been very willing to accept the "intricacies" of working with students having this level of experience, and it seems to work very well.

Use of course notes: When the course was started in 1994, a set of course notes was developed.[11] These notes included topics such as teamwork, the design process, safety, liability, engineering ethics, and specific technical content, such as strength of materials and energy storage. The topics that were included for a given year depended, in small part, on the project that was chosen, but mostly on the faculty actually teaching the course. In reality, the contents did not change much from year to year.

Unfortunately, review of the end-of-the-semester evaluations consistently indicated that the students did not view the notes as being useful. This was in spite of the fact that there were weekly reading assignments, the notes were referred to in lecture, and the notes were used by the students, for example, when attempting to implement a decision matrix or some other form of formalized decision making for their design. Apparently, the lack of exams associated with this class seems to result in changes in how students view the class and the need to read course notes.

In response, the teaching faculty has changed this drastically. First of all, all of the reading we want the students to do is accessible to the students via the web, rather than in paper. Second, this has provided the additional opportunity to select from an infinite variety of sources, in addition to what has been written by the teaching faculty. Many different references are now included. As a result, it is likely that the students do not view the combined reading assignments as a "set" of notes anymore, but in fact, view each reading assignment as a self-contained unit. Anecdotal evidence suggests that students prefer this. In addition, the faculty are happy with this because there is an organized set of reading and reference material available for the students.

Introduction of the different engineering disciplines: Originally, at least one half of eight of the lectures were devoted to a description of each of the eight different engineering disciplines represented in the College of Engineering. This seemed to be an important component of the course; however, we had many different types of feedback from the students. Despite very good effort, for certain some of the following were true: 1) Sometimes the speaker was boring, and very often did not present information that excited, or was of interest to, the students. 2) Academics tended to focus on details of courses, particularly courses they taught, while representatives from the non-academic world talked of details usually associate with project management. 3) Students often decided that a major or discipline was not of interest to them, and would tune out the lecture completely. To improve this process, we now have gone to a two-period "Engineering Discipline Fair." During these two periods, students visit four different disciplines, actually going to selected places in the college, where representatives from each of the disciplines are ready to talk with the students and answer questions. Here the emphasis is on two items: First, if I get a degree in "blank," what will I do? And second, How do I get a degree in "blank?"

Means for producing a functioning and cohesive faculty team: Teamwork is an essential part of this course. Thus it makes sense that the faculty team be an "example" of a properly functioning team. Through the tenure of this course, the faculty have come to realize how difficult this is and how much effort must be devoted to team maintenance activities, if we expect that to be the case. For example, we now develop faculty team "guiding principles" and "operating rules." A guiding principal is a principal that we want our team to meet. For example, respect everyone on the team is a common guiding principal. In order to ensure that the team functions following this principal, an operating rule we follow is the use of round robins on decisions for important issues.

Another thing that has been helpful is the use of well-defined roles and responsibilities. Each week of the semester is assigned to one faculty member who is then responsible for all activities that occur in the course that week. This includes setting the agenda and running the weekly teaching staff meeting.

<u>Training and identification of responsibilities for the student assistants</u>**:** The Student Assistants (SAs) are an important component to this course. The freshman view them as mentors, sources of information about their project, academics, and social life. In fact, in many ways, the response of the freshman to what occurs in the course is keyed from the response of the SAs. As a result of observations of the SAs in the large group meeting, and feedback received directly from the SAs, recently a training program was instituted. In the first of two training sessions, the new SAs meet and get to know each other. They review the course philosophy. They work together as a team in defining what they think the responsibilities of the SAs should be. For the second of the training sessions, SAs participate in a workshop on active learning to prepare them for the activities in the large group meeting, and they get time to discuss all of the details associated with the actual operation of the course. Before this training, it was not unusual to see an SA reading the student newspaper during the large group meeting, to the enormous surprise of the teaching faculty. With the training, SAs understand better both their role in the class and the theory behind the pedagogy used in the class, resulting in much better participation by the SAs.

Incorporation of writing into all aspects of the course

While writing was an informal part of the course in its early years, it has become integral to the learning process, the course expectations, and the faculty team. For the first three years, students wrote in their individual journals and as a team prepared and delivered two presentations, but they prepared only one formal piece of writing, a one-page executive summary for their final project. The need for more writing became apparent.[12] By 2001, students were writing a variety of formal assignments:

- design proposals in small groups before delivering their first presentation,
- technical reports in their design groups and two-minute presentations, and
- final design reports before delivering their final design presentation.

Consistent with the course goals, the writing simulated real-world experiences of practicing engineers so, once again, both the process and the product were important. The assignment specifications written to the students help illustrate how the instructors communicated these critical ideas.

> An important key to effective design projects is clear communication, so make it your business to maintain clear communication throughout the design process. **Attention to both "product" and "process" is just as important in communication as it is in design.** Products in communication include proposals, reports, letters, and email. Processes include planning, drafting, revising, and printing/delivering. You will hear more about "product" and "process" throughout the course. (Proposal assignment)

Adding a colleague from the technical communication staff to the faculty team was key to the development and assessment of the writing component. At the University of Wisconsin – Madison, academic staff teach technical communication courses and are members of the College of Engineering. Two years ago, one technical communication staff member (Courter) worked with the other faculty members to design, implement, and assess the communication curriculum. Together they developed tools that helped faculty; tools included assignment specifications and assessment grids. This past year, two technical communication staff were part of the team. Their separate freshmen writing class consisted of twenty students who were also students in the engineering design class; that is, they were "linked" in both classes. Students who participated in the linked sections strived to meet the following revised learning objectives. They would be able to

- Motivate their own learning of writing and speaking (communication) through their experience of real engineering.
- Motivate their own learning through links between the two courses
- Represent their work effectively and persuasively
- Demonstrate why communication that is good enables people to "get things done."
- Recognize that learning is a process and self-assessment is an important component.

Discussion continues regarding the most effective and practical arrangements for this collaboration to continue. Alternatives include "linking" two to four sections in the same manner, reverting to no technical communication colleague on teaching team, or "linking" most if not all sections.

Recognition that the design process is similar to the communication process

The design process is similar to the communication process in that both consist of iterative steps including the identifying audience/client and purpose, identifying product specifications, planning, drafting/designing, revising, and finalizing all in a collaborative environment.

<u>Audience and purpose:</u> While understanding the customers and their requirements is at the heart of the design process, understanding the audience and purpose is at the heart of the communication. Communication generally involves two kinds of audiences: primary and secondary. A primary audience includes the decision-makers, those who will decide what to do and take action. A secondary audience includes those who are affected by the action. For some assignments including the initial proposal, the other students in the lab were the

primary audience since they decided what proposals had merit and how to proceed toward their final design. Sometimes the final design was the one proposed, had parts from different proposals, or was a new design altogether. Because they were the decision-makers, the other students in the lab were the primary audience. However, for the final design report, the clients were definitely the primary audience because they would decide the merits of the design and future directions.

Regarding purpose, most of the writing assignments were designed to persuade. In the proposal, students tried to persuade peers that their design would solve their clients' problem/s and, therefore, was worthy of support. In the final design report, they tried to persuade the clients that their design had merit. In contrast, the purpose of the technical report was to document answers to technical questions that they had identified as they were developing the design/s. Table 2 includes all the communication assignments related to the design project.

Table 2. Introduction to Engineering Components

Learning Components	**Primary Audience** (decision makers)	**Secondary Audience** (affected by decision)	**Purpose**	**Format**	**Length**	**Draft Due Date**	**Peer Review Due Date**	**Due Date**
Design Proposal	Peers	Clients & Instructors	Persuade peers of design	Formal report with cover page	3-4 pages plus attachments	9/30	In lab	In lab
Design Proposal Presentation	Peers	Clients & Instructors	Persuade	Presentation	10-15 minutes plus 5 for Q & A	NA	NA	In lab
Technical Report	Instructors	Peers	Document answers to technical questions	Memo	Up to 1 page per question	Questions due Friday	In lab	Friday
Two-Minute Presentation	All EPD160 peers	Instructors	Persuade others to attend presentation	Presentation	2 minutes	NA	NA	tba
Final Project Report	Clients	Instructors & Peers	Document final design	Formal report with cover page	5-10 pages plus attachments	In lab	In lab	tba
Final Presentation	Clients	Instructors & Peers	Persuade clients of final design	Presentation	20 minutes plus 5 for Q & A	In lab	Scheduled practice/s	tba

Final Project	Clients & peers	Instructors	Demonstr ate working model	Project	NA	Prototype due in lab		

Product specifications: Just as in the design process for the technical component, the communication component consists of both product and process. The written product was the proposal, the technical report, or the design report, while the oral products were the presentations. Just as in the design process, faculty encouraged students to carefully design their formal communication components. Just like most organizations, faculty designed specifications for each assignment. In addition to audience and purpose, the specifications covered content, format, and assessment. Sharing assessment criteria in advance when students received the assignment parallels knowing the criteria used by clients and employers during communication situations in the real world.

The writing process: Just as both faculty and students went through a process to determine the assignments and design, both began to think of writing as a process as well. Especially when the students were writing collaboratively, they began to see the importance of going through process. As a team, they planned together. They agreed on who would do what and when during the writing process. Note the parallels between the writing and the design process in the following details of the four main steps:

Step 1. Planning includes analyzing audience and purpose; generating ideas about your proposal; brainstorming key components of proposal; answering who, what, when, where, why, and how questions to help gather data; organizing the document; using flow chart, clusters, or mind map; researching topics that need more information; and devising schedule and budget, as appropriate.

Step 2. Drafting includes reviewing results of planning; getting comfortable; starting with the easiest topic or section; drafting quickly; writing but not worrying about grammar, formatting, or graphics; and finally formatting.

Step 3. Revising includes letting it sit for a day or more; reading it aloud; adding detail for clarity; deleting dead words and phrases for conciseness; reformating for reader-friendly ease of access; checking tone; correcting errors in data and numbers; avoiding sexist language; and conducting peer review. Peer review includes a special search for the C's of effective technical writing. That is, striving for the following qualities: credible, clear, concise, correct, complete, concrete, coherent, creative, and connected.

Step 4. Printing and delivering includes identifying the most appropriate printer, paper size and capability (color or black and white), allowing time necessary for timely delivery; and ensuring correct way to deliver on time to the right audiences.

Collaborative work: Students experience collaborative writing and faculty are "guides on the side" during this challenging process. Despite the challenging nature of the group process, experience here is important since collaborative writing, that is, people working together to create a document, is common in organizations. As documents, techniques, and tools used to produce them become more complex, the amount of collaboration is likely to continue to increase. Mike Markel, in his book Technical Communication, supports this statement by reporting results of several surveys. For example, 87 percent of 520 professionals collaborate at least some of the time. In another study, more than 400 professionals found that they often write collaboratively. Ede and Lunsford[13] found that 58 percent of writers considered collaborative writing to be very productive or productive, whereas 42 percent found it not very productive or not at all productive. Writing as a team presents both opportunities and challenges. Students come to understand the advantages and disadvantages, as outlined by Markel.[14]

Advantages of Collaboration

- Collaboration draws on a greater knowledge and skills base.
- Collaboration provides a better idea of how the audience will read the document
- Collaboration improves communication among employees
- Collaboration helps acclimate new employees to an organization

Disadvantages of Collaboration

- Collaboration takes more time than individual writing
- Collaboration can lead to groupthink (avoidance of critical thinking and supportive criticism)
- Collaboration can yield a disjointed document
- Collaboration can lead to inequitable workloads
- Collaboration can reduce collaborators' motivation to work hard on the document
- Collaboration can lead to interpersonal conflict

Students found the following suggestions helpful. First, create a style sheet: font, headings, tone, lists; and decide who does what and by when including the establishing tasks, assembling draft, reviewing draft, completing revision, proofreading, printing or sending to print shop, and delivering the document.

Peer Review of Presentations and Writing

Feedback from peers is an important improvement strategy; faculty provided rubrics with criteria for specific feedback. Students' experiences showed that the following suggestions lead to effective revisions and built stronger connections among team members:

- Start with a positive comment
- Discuss larger issues first, i.e. organization, evidence
- Use assessment criteria as a guide
- Use technology effectively
    - Comment, revision, and highlighting features on word processor
    - Email to send files
- Talk about the writing, not the writer.

- Focus on the team's document, not the person's draft.
    - Rude: You don't explain clearly…; Better: I'm having trouble understanding how…
    - Rude: Why didn't you include…; Better: I wonder if the proposal would be stronger if we include…

Forms of presentation by the student teams

Students experienced three types of presentations: 1) small four-member team presentations in which everyone presented for their small twelve-member lab (10 minutes); 2) a two-minute presentation in which two members presented a snapshot of the project for all 200 students in the course; and 3) several team representatives giving a team presentation for all 200 students. Faculty stressed that information in a presentation is transferred three ways and that, in an effective presentations, all three are necessary: 1) verbally, 2) by the audience reading what is accompanying the presentation, and 3) particularly for a technical presentation, via visual representation of what is being described through drawings, sketches, and animations. Peer and faculty reviews were integral to the learning process.

Summary

Introduction to Engineering is a three-credit course for freshman at the University of Wisconsin. In place since 1994, the course has been through a series of evolutionary changes. For example, changes have occurred in pedagogy, from lecture to primarily active learning, in the use of writing, and in the types of projects the students carryout. While the freshman course centers around its original objectives and authentic engineering projects with real clients, continuous improvements have led to even more effective student and faculty learning.

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Bibliography

1) Corradini, M., P. Farrell, J. Mitchell, R. Marleau, J. Moskwa, K. Sanders, and J. Webster, "A Team-Based Design Course for Freshman," Proceedings, 1995 ASEE Conference, ASEE, 1995.
2) Courter, S.,S. Millar, and L. Lyons, "From the Students' Point of View: Experiences in a Freshman Engineering Design Course," Journal of Engineering Education, July 1998.
3) Courter, S.,S. Millar, and L. Lyons, "Effects on Students of a Freshman Engineering Design Course," Proceedings, Frontiers in Education Conference, November, 1996
4) Janna, W.S., J.I. Hochstein, M. Racer, A. Phillips, H.H. Lin, "Freshman-Senior Collaboration in a Capstone Design Course," Proceedings of the 2002 ASEE Annual Conference and Exposition, June 2002.
5) Campeau, N. and R.S. Heller, "The Freshman Experience Meets Log Cabins: The Freshman

Retreat at the George Washington University School of Engineering and Applied Science," Proceedings of the 2002 ASEE Annual Conference and Exposition, June 2002.
6) Barnett, S.K., "Industrial Experience and Engineering Freshman: A Pilot Program," Proceedings of the 2002 ASEE Annual Conference and Exposition, June 2002.
7) Hirsch, P., J. Anderson, J.E. Colgate, J. Lake, B. Shwom, and C. Yarnoff, "Enriching Freshman Design Through Collaboration with Professional Designers," Proceedings of the 2002 ASEE Annual Conference and Exposition, June 2002.
8) Zhang, H., and J. Kadlowec, "ROBOTS! –Freshman Clinic in Mechanical Engineering," Proceedings of the 2002 ASEE Annual Conference and Exposition, June 2002.
9) Laplume, P., and M. Ruane, "Using Imaging to Introduce Engineering to Freshmen," Proceedings of the 2002 ASEE Annual Conference and Exposition, June 2002.
10) Gregg, M.H., and Goff, R.M., "International Context for First Year Engineering Students," Proceedings of the 2002 ASEE Annual Conference and Exposition, June 2002.
11) "Teaching Staff. "Introduction to Engineering, EPD 160. A freshman engineering design course class notes."
12) Courter, S. "A Grounded Theory of the Effects of a TQM Curriculum Innovation on Teaching and Learning: A Multi-Case Study of a Cross-Disciplinary Course in Engineering." PhD dissertation, Department of Educational Administration, University of Wisconsin-Madison, May, 1996.
13) Ede, L., and Lunsford, A. Singular texts/plural authors: Perspectives on collaborative writing. Southern Illinois University. 1990.
14) Markel, M. Technical Communication. Sixth Edition. Bedford and St. Martin's Press. 2001.

SANDRA SHAW COURTER teaches technical communication courses in the College of Engineering. As director of the Engineering Learning Center, she coordinates professional development experiences for graduate students, staff, and faculty.

JAY K. MARTIN has led the first-year introduction to engineering course for the past five years and is the principal investigator for the Foundation Coalition on the University of Wisconsin campus. As a mechanical engineering professor, he has recently changed the focus of his research from turbulent combustion in engines to biomechanical systems.