



## DESIGN4PRACTICE

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*The natures of both the engineering profession and student body are changing. In addition to fundamental technical skills, industry now expects engineering graduates to possess practical hands-on abilities, project management and professional skills, multi-disciplinary insights, computing literacy, critical thinking aptitude, communication skills, interpersonal talents, and an understanding of the societal environment within which the engineer practices.*

A sequence of four undergraduate engineering courses were developed at Northern Arizona University's College of Engineering and Technology (CET) in response to these industry needs and our desire to strengthen our students' skills as expressed by the Design4Practice vision, Figure 1. Industry partners participate in the course design, evaluation and ongoing improvement. NAU's CET requires all of its engineering majors to take the Design4Practice courses.

To prepare all of our engineering students for successful careers as technical **leaders** by developing **professional skills, design, and problem solving abilities**, and an **understanding** of societal needs through a **personalized, multi-disciplinary** program that **actively engages** students, faculty, and practitioners.

Figure 1: *Design4Practice* Vision

This sequence of courses is named the *Design4Practice* program. The program, as shown in Figure 2, consists of four design courses that were carefully structured to provide all of CET's engineering students with hands-on learning and the continuous practice of a broad set of professional skills in a cross disciplinary setting. Thus they obtain an excellent preparation for careers as engineering practitioners. By way of this set of courses our graduates take only a small step as they transition from undergraduates to successful engineers, lessening the post-graduation-training burden. Their peers, from institutions without through-the-curriculum design work, however, have a big mountain to climb upon entry into the workplace as they learn how to be an effective engineering practitioner.

The *Design4Practice* program builds these technical, managerial, and professional skills by increasing project intensity, technical difficulty, and process complexity one step (class) at a time in these sequential courses.

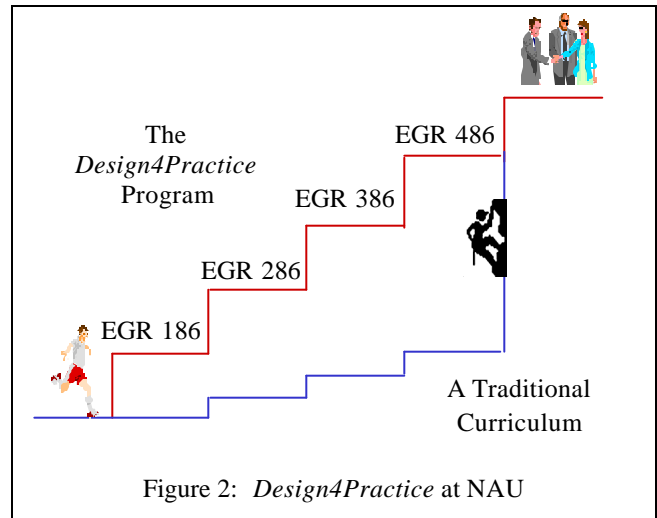


Figure 2: *Design4Practice* at NAU

### Unique features of the program include:

- Cross-disciplinary<sup>1</sup> collaboration in sequenced courses.
- Cooperative teaching and learning teams.
- The active participation of industry executives and engineers through teaching, program evaluation and project sponsorships.
- A required core for all engineering students that incorporates the complete design cycle within industry-simulated product development environments.

### The *Design4Practice* curriculum emphasizes:

- problem definition
- Specifications, high-level design, creativity
- Detail design, analysis, tools, methods
- Machining, prototyping, and building
- Documentation and communication skills
- Teaming and organizational theory

<sup>1</sup> Civil, Computer Science, Environmental, Electrical, and Mechanical Engineering



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- Professionalism and ethics
- Economic analysis and budgets
- Planning, scheduling, risks, and change
- Customer and subcontractor interactions
- Project-driven technical, analytical and contextual knowledge

The *Design4Practice* vision was launched in 1992 with implementation beginning in 1994. This innovative and practice-oriented program of four courses is now a permanent core component of CET's curriculum with over 1/3rd of the faculty participating in the sequence. As a testament to the program's success, the *Design4Practice* program was runner-up to Penn State in the 1998 Boeing Outstanding Educator Award, and won the same award in 1999.

The courses and their impact on students have been evaluated since 1994. The *Design4Practice* has been successful in reaching our own and our industrial partners' objectives - enhancing our students' ability to contribute and succeed in industry immediately upon graduation. In addition, we have begun an outreach effort, successfully sharing our techniques and experiences with other engineering educators through national workshops.

Development of the *Design4Practice* courses, however, never stops. We are refining pedagogical details, generating new student and instructor materials, evaluating in a continuing effort to improve the existing courses, initiating a manufacturing focus, and creating additional courses such as EGR 476 Engineering Design Procedures Laboratory, and EGR 586 Managing Engineering Design.

A summary of the key features for each of these four courses is provided below:

#### EGR 186 Engineering Design – Introduction

- Small Design Projects,
- Build & Test,
- Problem Solving & Modeling,
- Engineering as a Career,
- Ethics & Professionalism,
- Algorithms & Software,
- Communications & Teaming,
- Planning for Success

#### EGR 286 Engineering Design - The Process

- Cross-disciplinary Work,
- Large & Small Teaming,
- Team Taught,
- Robotics,
- Sequential Design,
- Economics,
- Visual C++,
- Mechanical & Electrical Hardware,
- Documentation & Communications,
- Build, Assemble & Test

#### EGR 386 Engineering Design - The Methods

- Cross-disciplinary Projects,
- Functional Teams,
- Team Taught,
- Analysis Tools & Modeling,

- Interdependent Learning & Research,
- Prototyping & Experimentation,
- Scheduling & Economics,
- Communications,
- Project Management

#### EGR 486 Engineering Design - Senior Capstone

- Outside Clients & Real Projects,
- Client-measured Performance,
- Periodic Progress Reports
- Functional Teams & Discipline-specific Projects,
- Documentation & Communications,
- Application of All Previous Coursework,
- Project Management,
- Professional Conference

The *Design4Practice* program has been made possible due to:

- NAU's commitment to relevant undergraduate engineering education.

We are a small and focused engineering college where the regular and close cooperation between students and faculty in hands-on practice and interaction is the norm. In addition, our traditional classes ensure a strong foundation in the engineering science fundamentals.

- A critical mass of design faculty.

As is further detailed in the references, fifteen of CET's forty faculty from all of the five disciplines teach in one or more of the *Design4Practice* courses. They also bring substantial industrial experiences into the classroom.

- Significant budgetary support from NAU/CET.

Over \$70,000 in internal funds has been allocated to the *Design4Practice*. Much of this money was used to create a dedicated design laboratory with computers, software, project materials, and assembly and machining capabilities. In addition, the extra two to four necessary faculty have been provided because each class requires between three to five teaching personnel rather than the one in each traditionally delivered course.

- Strong and effective links with industrial partners.

The impact of industry executives and engineers is essential in achieving the success of the *Design4Practice* program. They participate in course development and evaluation as well as teaching and bringing relevant industry experiences to the classroom.

In addition, many of the industries represented on the College of Engineering Industrial Council have sponsored Capstone Design Projects. This council currently consists of forty-six organizations, including Honeywell, Intel, Boeing, Lockheed Martin, etc.



## Course Details

Information about each of the individual *Design4Practice* courses is available from the authors at [David.Hartman@nau.edu](mailto:David.Hartman@nau.edu), or [Debra.Larson@nau.edu](mailto:Debra.Larson@nau.edu). Additional information can be found on the web at <http://www.cse.nau.edu/Design>, and in the references.

## Team Member Roles and Course Assignments

Current program leadership is provided by a core group of four faculty members – Mel Neville, Deb Larson, Dave Hartman, and Jerry Hatfield, (Figure 3, left-to-right). This group, as appointed by the Dean of CET, provides program direction and course coordination, handles various administrative tasks, manages the design laboratory and classroom, works on external issues, and teaches in the program. Larson and Hatfield have fulfilled this leadership role since 1994, providing a constancy and consistency of vision.

In 1994, the *Design4Practice* faculty team consisted of seven instructors. Pointing to the program's durability and pervasiveness, this teaching team has grown in membership to fifteen instructors that include the participation of two of the college's three department chairs. Given that each instructor contributes to the success of the program in many ways, it is this entire group of fifteen that is responsible for winning the 1999 Boeing Outstanding Educator Award. (<http://www.boeing.com/companyoffices/pwu/educator/objective.html>)



Figure 3: '98-'99 CET Design Committee

## Other Participating Faculty

Terry Baxter, Spencer Brinkerhoff, Liz Brauer, Chuck Dryden, Pam Eibeck, Steve Nix, Marc Herniter, Stuart Wecker, Willy Odem, Ernesto Penado, Diane Dressler, Bridget Bero, David Scott, Ken Collier, Steve Howell, and George Hoyle. The latter three faculty are no longer with NAU.

## References

Our work in the *Design4Practice* program has been documented in a number of papers, which are listed below, and presented at several engineering education conferences. Also we have provided national workshops – United States Air Force Academy (1997), the 1998 Frontiers in Education Conference, and the 2000 NCIA Conference – on our through-the-curriculum design activities to interested educators.

1. Howell, S., Larson, D., Hatfield, J., Collier, K., Hoyle, G., Thomas, G. (1995), "An Integrated Engineering Design Experience: Freshman to Senior Level", *ASEE 1995 Conference Proceedings*, June 1995, Anaheim, CA.
2. Collier, K., Hatfield, J., Howell, S., and D. Larson, (1996), "A Multi-disciplinary Model for Teaching the Engineering Product Realization Process," *1996 Frontiers in Education Proceedings*, Salt Lake City, UT.
3. Howell, S., Harrington, T., Larson, D., Collier, K., Hatfield, J., (1996), "A Virtual Corporation: An Interdisciplinary and Collaborative Undergraduate Design Experience", *1996 Design for Manufacturability Conference, ASME*, August 1996, University of California Irvine, CA.
4. Larson, D., Howell, S., Collier, K., Hatfield, J., Thomas, G. (1996), "A Four-Year Path to Synthesis: The Junior Interdisciplinary Design Experience", *ASEE 1996 Conference Proceedings*, June 1996, Washington, D.C.
5. Larson, D., Scott, D., Neville, M., Knodel, B. (1998), "Holistic Writing in Engineering Design" *1998 Frontiers in Education Conference Proceedings*, November 4-7, 1998, Tempe, AZ.
6. Gruber, S., Larson, D., Neville, M., and D. Scott, (1999), "Writing 4 Practice in Engineering Courses: Implementation and Assessment Approaches", *Technical Communications Quarterly*, In Press.
7. Larson, D. (1999), "A New Role for Engineering Educators: Managing for Team Success", *MRS Spring 2000 Conference Proceedings*, April, San Francisco, CA.
8. Hartman, D. and D. Larson, "Design4Practice", *Proceedings of the 28<sup>th</sup> Israel Conference on Mechanical Engineering*, June 2000, p. 419-422.

## Biographies

### David Hartman, Ph.D., P.E.

Dr. Hartman is a Professor of Mechanical Engineering and has been teaching in one or more of the *Design4Practice* courses since 1987 when senior capstone design was first introduced. Dave (along with Dr. George Hoyle) crafted the original *Design4Practice* program vision, noting that the senior design students were lacking many of the professional and design skills needed for project success. It was clear that these skills and attitudes - which at the time were considered nontraditional - needed to be deliberately developed prior to capstone. Dr. Hartman has had a long and fruitful professional career in both industry and as an educator, focusing his later years on design and the teaching of design as exemplified by his offering of summer workshops in "Implementing Creativity in the Workplace".



**Debra Larson, Ph.D., P.E.**

Dr. Larson, Professor of Civil Engineering, joined NAU in 1994 after completing a Ph.D. in Civil Engineering from Arizona State University and working in industry as a structural engineer for ten years. Debra has participated in the *Design4Practice* program both as a program leader and instructor since 1994. In addition, Debra is teaching the newly created EGR 586. Debra's research interests include forest restoration, rural economies, and small-diameter-tree-based structural products; web-based learning; and multi-disciplinary design and the engineering problem solving process.

