Design-Centered Introduction:
3-year Experience with the Gateway to the Aerospace Digital Library

Narayanan Komerath
Professor, Aerospace Engineering
Georgia Institute of Technology

Abstract

An experiment is described where conceptual design of a large system, usually reserved for the senior year, is introduced to the undergraduate in the very first week of college. The Design-Centered Introduction to Aerospace Engineering is described, from its inception in 1997 to its current state, where most instructors of the introductory course have adopted it. The experiences of three senior instructors are considered. The evidence indicates that students at this level can perform well in many aspects of conceptual design. This opens the possibility of a design-centered curriculum, where traditional discipline-centered rigor need not be compromised. The impact of internet-based capabilities is presented. The Design-Centered Introduction has been developed into an intuitive interface which learners at any level can use for guidance to the entire knowledge base of engineering, through an Aerospace Digital Library. Student assessment of web-based learning using this course completes the paper.

I. Introduction

Engineering design is usually viewed as the "capstone" and culmination of the undergraduate's curricular experience. Students of aerospace engineering await this opportunity to exercise their dreams, eagerly, often to the frustration of the teachers charged with ensuring that they learn the other technical subjects which are less glamorous and more difficult to the undergraduate. Professors who as undergraduates have taken Capstone Design courses, cannot help feeling that such a course is a dubious use of scant senior-year time, since the level of the material is not as challenging as that of the upper-level courses and independent projects in our disciplines. On the other hand, there is no argument about the need for students to have significant design experiences in the curriculum.

At the other end of the curriculum, there is a strong need to give students the time, opportunity and motivation to gain a perspective of their chosen field, and try their hand at design, which is one of the strongest reasons why they come to engineering. The problem here is that to many faculty, a "design" experience for a student just entering school could not be imagined as being anything other than a high-school level entertainment session. In a tightly packed curriculum, it was hard to justify spending several leisurely hours on such a course. In writing this, the author acknowledges that reality can be far better than this, as shown by many teachers in several forms of freshman design experiences [1-12]. The difficulty, again, is that many faculty cannot imagine this being the case, have negative anecdotes to reinforce their superstitions, and will not devote time to learning otherwise. Their votes count in curriculum decisions as votes of "experience" and "standards". The course described here was developed as a solution with high risk and high potential payoff, to the problems described above. In addition, the course had to inspire the enthusiastic participation of the students, and yet not discourage students from a wide variety of backgrounds.

In Fall 1997, we offered a Design-Centered Freshman Introduction to Aerospace Engineering (DCI)[13], where the conceptual design of an entire aircraft was used as the focus of a course taught to first-quarter freshmen. This was at the time viewed as an extreme measure, implemented to stem the attrition among the best students in the first two years. Using a "runway across disciplines" concept[13], (Figure 1) students straight out of high school were shown that they could learn well enough in six weeks to do a credible conceptual design of a large aircraft. They could also predict its performance over the flight envelope, lay out its interior, and draw the whole machine. As the course unfolded, the students learned so eagerly and well that there was time left to teach them a little about space flight mechanics. Performance in the course was as rewarding as the quality of work on the "designs" was eye-opening.

Since its description at the ASEE'98 meeting, the DCI concept has been adopted, and adapted, by three senior professors who teach Introduction to Aerospace Engineering. This paper focuses on the design-education aspect. The paper will describe the author's own experience of teaching this course 3 times, and the experience gathered by the other instructors from their efforts. The emphases and pedagogical routes taken by the instructors vary, but the results achieved are similar. Several kinds of aircraft designs have been used, and the concept has been extended to make independent searching and project-oriented thinking "routine" to students at this level. The advantages of internet-based learning have been incorporated into the course as well.

II. Related Work

Work on using design in freshman experiences, reported prior to 1998, is listed in Refs 1-12. Burton and White [14] report on a survey of models for teaching engineering design at the freshman level. Such courses were classified into: a.Reverse Engineering, b. Creating Something Useful, c. Full Scale Project, d. Small Scale Project, e. Case Studies, f. Competitions, g. Non-Profit Project, h. Redesign of a Local Project. Of these, they selected Reverse Engineering as most appropriate for their needs, using a Weighted Factor Scoring Model.

The choice of conceptual design as an integrative tool in our curriculum is based on the experience of listening to Georgia Tech Aerospace Engineering students and alumni for many years. In the traditional curriculum, the Capstone Design course in the senior year is cited by students for providing perspective on the various disciplines of aerospace engineering. The first six weeks of the 2-course Capstone Design sequence are spent on conceptual design. Hence it was argued that covering some of these concepts in the first year would have a dual benefit. The students would obtain perspective early, and the Capstone Design Professor could move quickly to more advanced topics. This would enable a large improvement in the scope of the senior Design course. A third benefit is expected to arise as other instructors begin to realize that their students have good perspective on the field: cross-disciplinary projects would become feasible, enabling an iterative revamping of the entire curriculum.

III. Approach: The Runway Across Disciplines

The first challenge to address is that of teaching students to design a vehicle before taking any course in the various disciplines involved. In addition, the students come in with no knowledge of calculus, only high school level physics and chemistry, and no engineering mechanics. This is the traditional problem which daunts teachers who try to use this course to save time in the rest of the curriculum. However, by careful examination of the course content, and suitable use of computer software such as Microsoft Excel, it was found to be feasible to reduce all of the subject matter to a level which could be logically presented and comprehended by an attentive high-school graduate.

As an example of this process at its most complicated level, the integration over time needed to compute the trajectory of a rocket, can be reduced to a series of time steps calculated using an Excel spreadsheet. Likewise, finding the minimum of a function using differentiation can be replaced by plotting the function, (as has of course been known for ages), but with the effort greatly reduced using the function repetition feature of a spreadsheet. At the end of the process, one can show the students how one could have saved a lot of effort by using integration. This conveys the idea of *"Its smarter to use Math "* instead of *"You Must Pass Math Before You Take My Course"*)

The truly exciting feature of conceptual design is the process of constructing a new vehicle, from a few specifications. The student gets an opportunity to exercise creativity, bold guesswork, and judgement, and see the results. Real aircraft designers do still have to make such decisions in the conceptual design process, then let the specialists fill in the details and validate the guesses through intricate calculations and testing procedures. We provide the freshmen with a similar opportunity, with empirical constants, benchmark data or simplified expressions. These bridge the deep and intractable “canyons” between the various disciplines. Thus, for example, the variation of thrust of a jet engine with altitude and Mach number, is a complex relation to calculate. This is approximated by a simple expression from data on various engines. The resulting expression has enough physical texture to allow a discussion, but remains simple enough for repetitive calculations on a spreadsheet, checked by hand calculations.

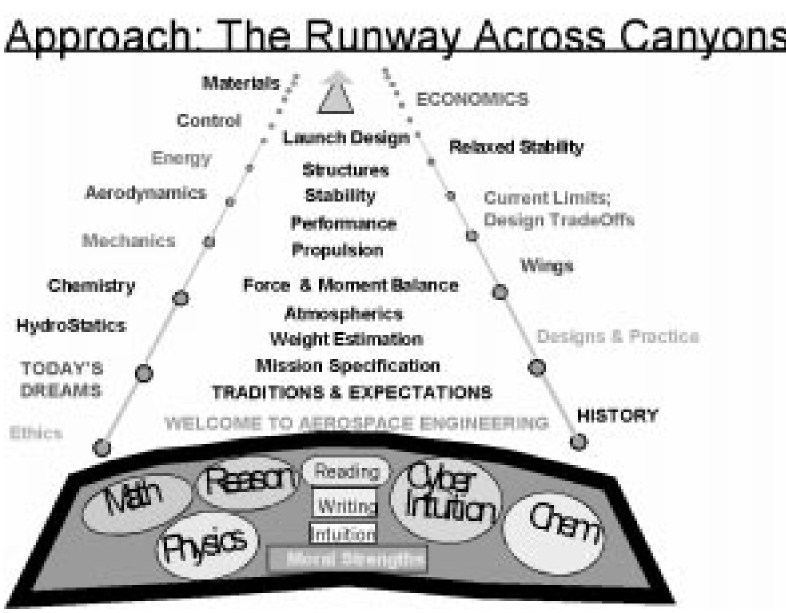

Figure 1: Conceptual layout of the Design-Centered Introduction (DCI) Course. The student starts with high school memories and knowledge, and accelerates in 8 weeks along a direct path to a vehicle design

In the first week of the course, the students are introduced to the idea of developing technical specifications for a vehicle from a perceived market need, or a future threat due to improving enemy capabilities. This leads to a creative essay written by the students, and gets them thinking about the process of translating ideas and words to numbers and mathematical expressions.

A following assignment is to find data on various vehicles of a similar class to what they will be designing, and to tabulate various parameter values, such as the wing span, the weight, the engine thrust, etc., and to calculate various ratios, in order to get a "physical feel". In the process, the students also make the technical advances needed to find information on the Internet and libraries, and to present such data. They are able to see the multitude of ways in which designers chose to meet essentially similar specifications, by comparing various modern fighter aircraft or commercial aircraft designs.

A simplified sequence of steps used in the design process for a flight vehicle is given in Table 1.

Table 1: Simplified Design sequence

Step	**Issues**
Define the mission	What must the vehicle do?
Survey past designs	What has been shown to be possible? (don't worry about WHY yet)
Weight estimation	How much will it weigh, approximately?
Aerodynamics	Wing size, speed, altitude, drag
Propulsion and engine selection	How much thrust or power is needed? How many engines? How heavy? How much fuel will they consume?
Performance	Fuel weight, take off distance, speed/altitude boundaries
Configuration	How should it look? Designer's decisions needed!
Stability & Control	Locate & size the tail, flaps, elevators, ailerons etc. Fuel distribution.
Structure	Strength of each part, material, weight reduction, life prediction.
Manufacturing: concurrent engineering	Design each part, see how everything fits, and plan how to build and maintain the vehicle. Break this down into steps involved in manufacturing.
Life-cycle cost	Minimize cost of owning the vehicle over its entire lifetime.
Iteration	Are all the assumptions satisfied? Refine the weight and the design.
Flight Simulation	Describe the vehicle using mathematics. Check the "flight envelope".
Testing	Build models and measure their characteristics, verifying the predictions. Explore uncertain regions. Build & test first prototype.
Iteration and refinement	Keep improving, reducing cost and complexity, and extending performance, safety and reliability.

The detailed process of teaching the design-centered introduction is summarized in Ref. 13. Here we consider below the various concepts covered, and the emphases placed by different instructors.

III. Concepts Covered

An important issue is to consider what concepts from an engineering curriculum and a Capstone Design Course can be learned by students at the beginning freshman level. The list of concepts covered in the DCI in the Fall semester of 1999 is given below.

Table 2: Concepts covered

Physics, Chemistry, Atmospheric Science 1. Concepts of vectors, velocity, momentum. Vector addition and vector equation. 2. Newton's Laws of Motion, applied to finding (a) acceleration vectors of aircraft in linear acceleration (b) trajectories of rockets in simple cases, without using calculus. (c) radial acceleration (g) "g-forces" on an aircraft during a turn or other maneuver. 3. Concept of Moment, applied to determining equilibrium. 4. The control surfaces of an aircraft, and how they are used to achieve various changes in attitude. 5. Mean Molecular Weight of a gas mixture. 6. Perfect Gas Law. 7. How to find conditions at different levels of the atmosphere above a planet, given the temperature variation and gas composition. 8. Troposphere and Stratosphere of the Earth. 9. Ratio of specific heats.	*Aerodynamics / Fluid Mechanics* 1. Speed of sound. 2. Mach number. 3. Relation between static pressure, speed and stagnation pressure: Bernoulli equation 4. The dynamic pressure or "q". 5. Lift generation. 6. Nondimensional coefficients: Lift coefficient and drag coefficient. 7. Angle of attack. 8. Lift curve slope of an airfoil. 9. Camber and its effect on lift. 10. Vortex. 11. Lift generation by a vortex. 12. Wings and tip losses. 13. Planform area 14. Aspect ratio 15. Lift-induced drag 16. Profile drag 17. Speed for minimum drag of an aircraft. 18. Finding the slowest speed at which an aircraft can fly at a given altitude. 19. Finding the thrust required to fly at a given speed and altitude.
Propulsion 1. Engine cycle. 2. Conversion of heat to work 3. Thrust variation with altitude 4. Thrust-specific fuel consumption rate 5. Relation between rocket, ramjet, turbojet and turbofan engines. 6. Alternative means of propulsion	*Flight Dynamics / Performance* Coordinated turns, pitch, yaw, roll; climb and descent Static stability Range Takeoff and landing distances.
Space Science / space missions 1. Newton's law of gravitation 2. Kepler's laws; elliptic orbits. 3. Equivalent exhaust velocity, specific	*Structures* 1. Types of loads 2. Types of deflections 3. Moments

impulse 4. Velocity increment needed for given missions 5. Relation between mass ratio, velocity increment and specific impulse.	4. Moment of Inertia 5. Geometry of load-carrying elements 6. G-factor and design loads 7. Isotropic materials vs. fibers and composites
Computer/ Communication Skills 1. Using the Internet to browse course notes. 2. Using the Internet to find aircraft design data 4. Using Excel to perform simple calculations. 5. Using Excel to perform a time-stepping calculation to solve a rocket trajectory 6. Using Excel to plot results. 7. Using graphs to determine flight envelope and speed for minimum drag. 8. Error estimation: the effect of different terms on the rocket trajectory. 9. Developing web pages for technical results. 10. Posting graphs on web pages. 11. Professional e-mail communication.	*Design Concepts* 1. Mission Specification 2. Mission Profile. 3. Payload. 4. Gross weight. 5. Preliminary weight estimation 6. Benchmarking against other designs. 7. Wet and dry Thrust of engines. 8. Engine weight fraction of modern fighters. 9. Forming and working with a team. 10. Flight envelope analysis 11. Speed for minimum drag 12. Design report 13. Drawing a 3-view

This certainly does not imply that the students at this level learned everything there is to be learned about these concepts in this course. However, they did learn enough to be able to ask intelligent questions, and solve problems on tests and homework assignments where the questions were asked in words, not equations. These comments apply in general. Particular students went far beyond these objectives, such as the student who came to the instructor's office asking for a physical explanation of how the thrust of a jet engine varied with altitude and Mach number. This prompted the instructor to distill such an explanation from senior-level material, present it at this student's level, and realize that it could be done successfully.

IV. Approaches Used By Different Instructors

At this writing, the three senior professors teaching this class have adopted the DCI method of introducing Aerospace Engineering, using conceptual design of a vehicle to focus the students' attention. The assignments are listed in Table 3, along with the instructor's names.

Table 3: Aircraft conceptual design assignments

Instructor	*Term*	*Type of aircraft*
Komerath	F97	400-seat, 10,000 mile airliner
Loewy	W 98	High subsonic executive jet transport.
Loewy	W 99	Long range, Mach 2 air superiority fighter
Sankar	Sp.99	Air superiority fighter
Komerath	Sp.99	300-seat hydrogen-powered airliner
Komerath	F 99	1. Light combat aircraft 2. Strike aircraft

While each of the design assignments has produced excellent student performance, there are some differences between the approaches used by different instructors. In Dr. Komerath's classes, the emphasis is on reaching a status where one design is flown through a range of conditions to identify the borders of the steady-level flight envelope. This is to provide perspective on the variety of phenomena which would impose constraints, and to get the students to use appropriate technology for the various portions of the flight envelope. The sacrifice in this approach is that there is little opportunity for optimizing the design. There is iterative refinement, but usually to get one design to meet specifications, rather than to find the optimal design. In Dr. Loewy's design assignment, the students go through optimization exercises and select the best configuration, wing loading etc. The sacrifice here is that there is little time left to explore the flight envelope. In Dr. Sankar's assignment, the students do a deeper aerodynamic design, using more sophisticated criteria for the aerodynamics. Again the flight envelope exploration is sacrificed. It is interesting to note that there is no perceivable difference in the quality or enthusiasm of the students' work between these approaches, and in fact some students incorporate all the features of all three approaches to some extent.

V. Fall 1999: Internet Usage

A new feature of the Design-Centered Introduction is the central role of the Internet. The entire notes for the DCI are posted on the web; different versions are available from different instructors. We see no reason to demand, or desire, uniformity. The DCI notes also serve as the core of the new Aerospace Digital Library project, (http://www.adl.gatech.edu) where all engineering disciplines are being linked across levels. Using the DCI gateway, an engineering student in any discipline should be able to obtain guidance to navigate to the right part of the right discipline in order to solve cross-disciplinary problems.

The ADL has been used by the students in several ways:

1) Students use the web-based notes to supplement and reinforce classroom learning.
2) Some students download the notes and bring them to class, and jot down additional points.
3) The course page on ADL is used to contact other students in the class,
4) The course page is used to check for updates on assignments, and links to other resources.
5) The ADL resources are used to find relevant data on homework assignments. Examples:
a) Assignment No. 2 was to collect data on 5 out of a list of 8 advanced fighter aircraft designs, and compute weight fractions and other empirical guidance on aircraft design.
b) Assignment 3 was to obtain data on the liftoff weight and thrust of the Space Shuttle, and also data on its trajectory to compare with simple calculations.
c) Engine data posted on ADL was used to select engines for the aircraft designs, and find the sea-level static thrust and the specific fuel consumption

6) From the web page, most students became comfortable with the idea of contacting the instructor or other students on various matters. Over 100 e-mail messages were exchanged in the Fall semester. The messages progressed in confidence and professionalism. They achieve two major, long-desired benefits: the ability to discuss technical details one-on-one with students when they are actually thinking about them, and secondly, the ability to provide essentially unlimited office hours and a support mechanism for 1st year students. The most popular time for e-mail interaction appears to be between 6pm and 10pm.

VI. Assessment

The privilege of teaching this class is generally reserved for senior faculty, who greatly enjoy teaching it, and it is not surprising that the student reactions are quite positive. Some samples of student feelings are given below (specific quotes are from anonymous comments in the author's classes). Fall '97:

- *"Learned a great many things, starting with knowing very little"*
- Spring '99: *"Even though it was a pain to do all the calculations, the airplane project was a good experience."*
- *"Perhaps being sure that we can do the projects would be helpful.."*

Fall '99 (comments before midterm test):

- " *The Teacher assumes we already know this…Most of us are only freshman and haven't had physics …..*" (*Note: performance on the midterm test was outstanding despite this*)
- *"…could slow down the pace a little bit. …very difficult to take notes and fully absorb what he is saying. " (Note: pace was steadily and deliberately increased all through the semester, and students apparently did not notice how much faster and better they were working).*
- "*could be a little more clear in what he expects out of the assignments …" (Note: a persistent complaint in open-ended assignments!)*
- *"The projects take way too long for a 2 hour course. Many people might not do them for that reason. " (Note: everyone did in fact complete all assignments)*
- *"I am a little confused about what we have learned in class so far. I am missing how homework and in class notes correspond with each other… otherwise I am enjoying the class"*.

In Fall '99, the midterm evaluation system allowed the instructor to post the detailed comments, as well as the instructor's views on why things were being done the way they were, on the course web page. This had the desired effect of encouraging the students to voice suggestions, although some were shocked to see their (anonymous) comments on the web, with instructor responses. The final course evaluations are confidential to each instructor, hence only those of the author are given here, with the number of students commenting given in summary form.

Table 3: Course-Instructor Survey, AE1350a, Fall '99. Summary

Question	Agree	No opinion	Disagree
Number of students appropriate to course	18	0	1
Objectives, organization, and coverage of materials	16	4	0
Appropriateness / difficulty of exams and assignments	12	5	3
One-on-one help provided as needed	18	2	0
Explained complex material clearly	16	5	3
Encouraged students to think independently	18	2	0
Sensitive to feelings and needs of all students	13	6	1
Lectures/ discussion increased understanding beyond readings	15	5	0
Instructor demonstrated thorough knowledge of topics	19		1

Student Comments about the Class or Instructor

- *The class included difficult material for an introduction course. The exams were hard because not many practice problems were given. Professor was very approachable and increased my knowledge and interest in the subject.*
- *Enthusiastic, funny, however sometimes unclear about assignments. Would also be nice if he would work more practice problems.*
- *The class is very challenging especially the group projects, however it is difficult to know if one is attempting the different problems of the assignment when it is not discussed or the teacher hasn't given feedback as to how we are doing in our progress.*
- *The professor never seemed well organized and he seemed incompetent when the questions were presented. The material was never fully known by neither the students or the professor.*
- *Good course on aerodynamics, but the topics jumped back and forth with very little detail. exams were appropriate for the class, but the class tries to cover everything there is about aerospace, but yet doesnt really explain why. this course should focus on the basics of aerospace and let the other courses cover everything else in full blown detail. it introduces (which is what its supposed to do) but it leaves students with many questions as to why. in my opinion (like if it really counted) the course should focus on more basic aerospace rather than throwing everything at you and not explaining why.*
- *..Great. I really got a good insight of what it's like to be an aerospace engineer, and be in this field. The examples.. in classes really motivate me to start thinking about working really hard in the future because I want to really know my stuff as well as (the prof)...and the fact that students are falling asleep in your classes is not because of the fraternity rushes, we, students just aren't disciplined enough to go to bed before three even if we have nothing to do.*
- *Sometimes the projects you gave were too long, meaning you should not make students do graphs for fifteen altitudes and twenty different machs. Excel is not as easy as it seems if you want to include this many things. I liked .. class and found it very interesting. It also been full of information and I believe I have learned a lot.*
- *I liked how the instructor almost always replied to e-mail quickly, and how he actually answered our questions instead of acting like we were stupid for not knowing it. I didn't really like how he replied to the midterm course surveys on the web though. Some of the students' comments were pretty silly but..(they should have the last word).*
- *This course should have at least 3 credit hours as far as amount of work you need to do.*
- *I felt the instructor was very knowledgeable and taught the material very well. He was also very fair and helpful with our assignments. Sometimes there was material on our assignments that were not covered much in class, but the instructor was always willing and prompt in offering assistance. I really enjoyed the class.*
- *I suggest giving..more examples for the application of the formulas given in class.*

b) Survey of students who left Aerospace Engineering

The School conducted a survey of 72 students who had transferred out of Aerospace Engineering over the past few years. Of these, only three had any comments about the Introduction course (no information on precise section or instructors), and two of these related to the difficulty of the course, with its attendant prediction of the rest of the curriculum.

c) Survey of ADL web resource usage, Fall '99

The Institute Assessment Office administered a survey of the web usage aspects of AE1350. Only 10 students took this survey, but expressed very positive reactions, with a general comment being that they found the material concise, clear and easy to access. Remarkably, none of the respondents to the Final Course Evaluation had anything to say about the text or the web resources, unless some observation can be made from the comparison of lectures to readings. This is markedly different from the complaints in the midterm evaluations about "why are we having to surf the 'net"? It appears that web usage is seen as another learning tool, but is otherwise accepted as natural. Personal attention from the instructor still counts very heavily.

VII. Observations on the capabilities of freshmen

The students are not shy about stating their views, and at least one person was very unhappy with the entire proceedings. Clearly, time spent in answering questions (mainly late-night e-mail) pays off. Actual student performance in this course was extremely good, so that an "easy-A" reputation might seem warranted by the final grade distribution. The comments show that the reality is very different, and the level of complaint seems about right for people who are being asked to perform at levels above what they thought they could do (a great part of the value-addition of college, in this instructor's view). The challenge to the freshman instructor is to keep the students engaged until they see how well they really did. Despite encouraging words throughout the semester, our students have been top-rankers too long in school to believe anything but the final grade as a measure of performance. Despite strenuous efforts, the problem remains that only about 80% of the students still avail of any opportunity to get help, and the rest remain needlessly frustrated.

The Georgia Tech freshman class cannot be considered "average" by any means, other than in age. It is useful to note the capabilities and traits that they exhibit, related to learning design.

1. They have excellent skills at using computers. While they do appreciate guidance on how to use formulae on spreadsheets, and on plotting graphs, they had little (real) trouble getting assignments done, using these skills.

2. While students were adept at seeking and finding information on the Internet, they did have trouble creating their own web pages; they did succeed, given some time and patience. Many commented on the discovery that taking a Computer Science course did not necessarily solve the problem of developing one's own Internet page, while talking to classmates did.

3. Given information on design, they had little trouble finding average values, and arriving at engineering judgements. Compared to students of a few years ago, the idea of starting with guessed values and making decisions with inadequate information, seemed quite OK to most of these students. Some certainly find this to be frustrating.

4. Exam problems were phrased in words or pictures, and were not repetitions of homework. Despite their fears, students did well at formulating problems starting with such information.

5. Though none had taken courses on engineering graphics, the idea of sketching 3-views of aircraft did not pose problems. Whether the drawings were accurate is an unfair question.

6. The physical concepts and mathematical expressions needed to do conceptual design can be taught to, and learned very well by, students at this level.

The students' unedited Design Project work, done in teams of 1 or 2 and posted on the web pages which they developed, can be found at:
http://www.ae.gatech.edu/research/windtunnel/classes/dci/aerodesn/design_pages.html
This is a temporary address, since the students may delete the projects as they need more disc space. A more archival resource is being developed, as permission from each student comes in, and will be found linked from the "design-centered introduction" course links from http://www.adl.gatech.edu The web pages speak for themselves.

VIII. Implications

What this course has taught us is that a design-based gateway to the knowledge base is an idea which works well in the context of first-year aerospace engineering undergraduates. This is not to say that *all* of design can be taught at this level; however, it is estimated that upto 6 weeks of present Senior Capstone Design courses can be saved, and the time redirected into more sophisticated aspects of design.

A deeper implication is that a total restructuring of the curriculum is possible, using the lessons learned about the capabilities of freshmen to comprehend and excel at design. We have shown that the simpler concepts of design can indeed be learned very early in college, so that every succeeding experience can build on this foundation. Without this experience, students spend 3 years learning that rigorous, near-machine-like adherence to sequential processes is the life of the engineer. The excitement and freedom of judgement, decision-making and creative engineering come far too late in the curriculum. With a broad experience such as that described here, following teachers can ask students to range far outside the boundaries of each discipline-specific course, and solve grander problems which use knowledge from several disciplines. This would open the way to a true revolution in engineering education. The DCI tries to use as much of the freshman's environment as possible, and to show the student how all the other disciplines fit into the knowledge base. Thus the DCI is an excellent vehicle to introduce users at any level, to the knowledge base of any other discipline. This structure is therefore used as the Gateway to the Aerospace Digital Library.

IX. Concluding remarks

The Design-Centered Introduction to Aerospace Engineering has caught on in the 3 years since it was first tried, with senior instructors adopting and adapting it. Student reaction is very positive, reflecting the experience of coming up with a credible design for an advanced flight vehicle. This course reveals the strengths of the freshman students, their capacity for innovative thinking, and acceptance of open-ended problems requiring bold guesswork and judgement. The implications of this course include the possibility of revamping curricula into a design-centered format. To this end, an Aerospace Digital Library (http://www.adl.gatech.edu) has been developed on the Internet, where students can access relevant knowledge in all disciplines through guided interfaces. The DCI is seen to be a logical gateway to such a resource, and has been implemented as such.

With students learning many aspects of conceptual design early, it will be possible for instructors in discipline-specific courses to use their perspective and design capability in solving more realistic problems which require learners to go well outside the course notes to find solutions. Overall, this approach will free up the Capstone Design teacher to deal with issues that are far beyond the capabilities of the traditional curriculum.

X. Acknowledgements

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XI. Bibliography

1. Crawford, R.H., Wood, K.L., Fowler, M.L., Norrell, J.L., "An Engineering Design Curriculum for the Elementary Grades". Journal of Engineering Education, Vol.83, No.2, April 1994, p. 172-181.
2. Pols, Y.D., Rogers, C.B., Miaolis, I.N., "Hands-On Aeronautics for Middle School Students". Journal of Engineering Education, Vol.83, No.3, July 1994, p. 243-248.
3. Atman, C.J., Nair, I., "Engineering in Context: An Empirical Study of Freshmen Students' Conceptual Frameworks". Journal of Engineering Education, Vol.85, No.4, October 1996, p. 317- 326.
4. Merritt, T.R., Murman, E.M., Friedman, D.L., "Engaging Freshmen Through Advisor Seminars". Journal of Engineering Education, Vol.86, No.1, January 1997, p. 29 - 34.
5. Ambrose, S.A., Amon, C.H., "Systematic Design of a First-year Mechanical Engineering Course at Carnegie Mellon University". Journal of Engineering Education, Vol.86, No.2, April 1997, p. 173 181.
6. Besterfield-Sacre, M., Atman, C.J., Shuman, L.J., "Characteristics of Freshman Engineering Students: Models for Determining Student Attrition in Engineering". J.Engg. Education, Vol.86, No.2, July 1997, p. 139-150.
7. Demetry, C., Groccia, J.E., "A Comparative Assessment of Students' Experiences in Two Instructional Formats of an Introductory Materials Science Course". J. Engg. Education, Vol.86, No.3, July 1997, p. 203-210.
8. Richards, L.G., Carlson-Skalak, S., "Faculty Reactions to Teaching Engineering Design to First-Year Students". J. Engg. Education, Vol.86, No.3, July 1997, p. 233-240.
9. Carlson, B., Schoch, P., Kalsher, M., Racicot, B., "A Motivational First-Year Electronics Lab Course". Journal of Engineering Education, Vol.86, No.4, October 1997, p. 357-362.
10. Hatton, D.M., Wankat, P.C., Lebold, W.K., "The Effects of an Orientation Course on the Attitudes of Freshmen Engineering Students". Journal of Engineering Education, Vol.87, No.1, January 1998, p. 23-28.
11. Hoit, M., Ohland, M., "The Impact of a Discipline-Based Introduction to Engineering Course on Improving Retention". Journal of Engineering Education, Vol.87, No.1, January 1998, p. 79-86
12. Collicott, S.H., "Increasing Freshman Experience in, and Awareness of, Aerospace Engineering at Purdue University". AIAA Paper 98-0821, Aerospace Sciences Meeting, January 1998.
13. Komerath, N.M., "Design-Centered Freshman Introduction to Aerospace Engineering". Proceedings of the ASEE Annual Meeting, Session 1202, Seattle, WA, June 1998.
14. Burton, J.D., White, D.M., "Selecting a Model for Freshman Engineering Design". Journal of Engineering Education, Vol. 88, No.3, July 1999, p. 327-332.

XII. Biography

Dr. Narayanan Komerath, Professor in AE and director of the John J. Harper wind tunnel, leads the Georgia Tech Experimental Aerodynamics Group (EAG). He has taught over 1600 AEs in 19 courses in the past 15 years. He is a principal researcher in the Rotorcraft Center of Excellence at Georgia Tech since its inception in 1982. He is an Associate Fellow of AIAA. He has won GT awards for Outstanding Graduate Student Development, Outstanding PhD thesis advisor, and Most Valuable Professor (GTAE Class of '91). EAG research projects have enjoyed the participation of nearly 100 undergraduates over the past 14 years. EAG is a leader in multidisciplinary team-oriented projects, including the Aerospace Digital Library Project at Georgia Tech: http: //www.adl.gatech.edu