# An Architecture for Learning:
# Designing an Initial Curriculum for Olin College

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Introduction

This paper describes the initial process of curriculum design and the study of implementation methods at the new Franklin W. Olin College of Engineering in Needham, MA. Commencing with a broad-gauged discovery process, curriculum design at Olin College sought, from the outset, to incorporate the best ideas in engineering education pedagogy. We hope that our systematic investigation of innovative learning methodologies and content organization has enabled us to move rapidly toward our goal of creating an ideal learning community. We re-examined and reconsidered both traditional delivery processes as well as experiments in engineering education that have taken place worldwide. We also commenced reevaluation of how content could be reorganized in the disciplinary areas offered at Olin College[1].

Curriculum design was one part of the set of activities at Olin College, known as Invention 2000 (I2K), consisting of discovery, invention, implementation and test phases. In addition to curriculum design, other design activities included: (1) determining policies and procedures, (2) performance evaluation, (3) assuring innovation, and (4) establishing a culture of change and continuous improvement. The discovery process for the curriculum was essentially complete at the end of 2000, although discovery will continue throughout the life of the college. The invention cycle occurred during the winter of 2001 and the implementation and test phases will commence in 2001-2002. By the time of the ASEE conference, this work will be only partially complete. This paper provides a snapshot of the status of the curriculum development as of winter, 2001; the conference presentation will provide an update as of early summer, 2001.

The Processes

The processes employed to create the curriculum for Olin College were many and varied. They included: (1) visits to many institutions to investigate a variety of pedagogical approaches, (2) study of the literature on engineering education, including reviewing results from the engineering education coalitions, (3) seeking advice from a wide range of experts, and (4) comparing and contrasting alternatives for designing the curriculum. In

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[1] Degrees will be offered in Electrical and Computer Engineering, Mechanical Engineering and Engineering. The latter category will contain general topics, probably including Biomedical Engineering

general, we have proceeded as shown in Figure 1 – from alternatives that describe a vision of the future, study of various learning methods, teaching methods and infrastructure support for teaching and learning. The multiple items in each column below represent multiple alternatives; the dotted circle indicates that we were able to only choose a limited number of possibilities from among the sets of alternatives. At the end of the design, the vision will have solidified, basic learning methods understood, the set of teaching methods that support learning studied, and an infrastructure chosen for supporting these activities.
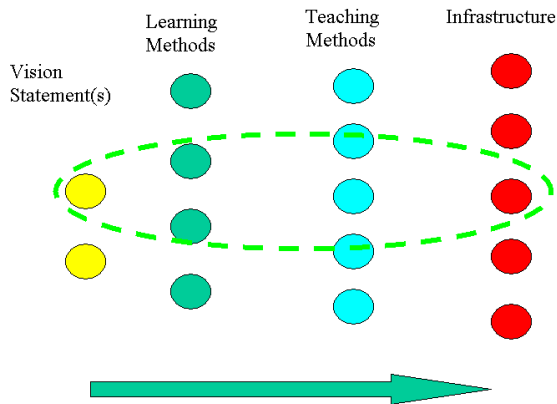


**Figure 1. Elements in the design of the curriculum**

## *Vision*

### *Invention 2000*

The objective of the Curriculum Design activities is to understand the processes that should be used at Olin College for creating the curriculum and to make recommendations for how the curriculum design should proceed. The <u>curriculum</u> could be defined[2] as the "set of learning experiences undertaken by students during their tenure at Olin College". These learning experiences encompass both "in-class" and "outside-the-classroom" experiences, both academic and non-academic. The methods for transforming novices (entering students) into experts (graduates) have not yet been determined, nor have the desired characteristics of the ideal Olin graduate. Nevertheless, we have discussed, debated and organized our thoughts about the desired transformations. In order to create the curriculum, Invention 2000 is designed to permit discovery of the current best practices available and to invent and test a new curriculum based on desired characteristics and extensions and modifications of existing theories and findings. One objective was to understand how to create a graduate who is the best prepared to deal with her future whether her career is in engineering or other areas. The curriculum was designed in a way to meet individual needs, produce agile and adaptive learners who are able to deal with a world in which knowledge is constantly changing and ensure that graduates greatly exceed common standards in the disciplines in which they graduate.

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[2] An ad-hoc working definition

| Table 1[3]:  The Phases of Invention 2000 | |
|---|---|
| • Discovery | • Fall Semester, 2000 |
| • Invention | • Winter, 2001 |
| • Development | • Spring, Summer and Fall 2001 |
| • Test | • Winter 2001 to Summer 2002 |

In the discovery phase, we sought to discover the best pedagogical practices around the world.  In invention, we plan to create specific educational goals and processes.  The development phase will include specification of courses, including course work from other institutions.  The test phase contains study of assessment paradigms, and evaluation of materials and methods.  The targets for the different elements of the curriculum (by time) are shown in Table 2.

| Table 2: Curriculum Design Targets | |
|---|---|
| • Partners year[4] | • Design complete by June, 2001 |
| • Freshman year | • Design complete by June, 2002, in collaboration with the partners |
| • 4 year curriculum | • Broad outline completed by June, 2002 |

Background: Theory-driven areas of inquiry

During the design process for Invention 2000, we have kept in mind educational theories as the basis for driving the design of the Olin College Curriculum.  A debt of gratitude is due to John Bransford, who introduced the faculty at Olin College to many new ideas in his edited book "How People Learn" (HPL, Bransford et al., 1999).  This book has been influential in shaping our thinking.  Below, we adapt some ideas from the HPL book to the prospective Olin learning environment.

*Student-Centered Paradigms*
Learning should be student centered.  Student-centered environments[5] are those that take into account the ideas, skills, knowledge and attitudes that learners have.  In contrast to lecture delivery methods in which "one size fits all," student-centered environments are much more adaptable to the needs of the learner, either as an individual or as part of a team.  For example, a curriculum could be implemented based entirely around undertaking multiple projects, with fundamental information brought in just-in-time.  Such a learning environment could be adapted to individual learner's needs by providing

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[3] For the details of Invention 2000, please see: http://www.olin.edu/news/news_stories/Invention2kf.html
[4] Partners are the group of about 25 students slated to join the curriculum design effort in the fall of 2001. These partners will work with faculty to create and test curriculum and then become part of the entering freshman class in 2002.
[5] Also known as learner-centered environments.

individual learners self-paced modules that help hone skills, provide specialized knowledge or provide remediation or additional knowledge.

*Assessment Centered*
It is critical to be able to <u>continuously</u> evaluate how well students are learning and how well the faculty teach (parenthetically, we may have to define what it is to be a good teacher in a dominantly non-lecture-based curriculum).  Hence, outcomes must be specified at the outset for students, along with techniques for appraising these outcomes in a reasonable way.  Moreover, in an innovative curriculum, we may be able to create methods for assessment that are (1) non-intrusive, (2) operate more-or-less automatically (built-in) and (3) provide real gains in instructor and learner productivity.

*Knowledge Centered*
Once, it was "known" what constituted an engineering education (…a significant amount of math, statistics, thermodynamics, circuits, physics, etc.).  Now, it is less clear what the corpus of knowledge is that students need to be most successful in life.  What is needed for the upcoming century may well be completely different from the traditional curriculum – for example, one may guess that biology and information technology might become a centerpiece of every engineer's education.  Likewise, the knowledge mix at Olin might well contain a robust dose of entrepreneurship due to the superb opportunity for collaborating with Babson in this area.  Informed "guesses" may need to be made to provide a knowledge mix that covers a wide set of possible futures.

*Community Centered*
Better learning appears to occur in community.  What are the best practices; how can we design learning communities that work best, function at a distance, and persist past graduation?  Of special interest are methodologies for maintaining a learning community as students engage in learning experiences in industry, government and international settings.

*The Impact of New Media*
New media will radically change the way students learn.  We must understand how to best make use of the capabilities of new media.  Can we improve learning effectiveness, provide better communications, improve satisfaction and simultaneously reduce cost using these media – how do these media affect what is taught and how things are taught (learned)?  For example, can much of the basic knowledge required to support challenge-based environments be relegated to module-oriented learning? (*Just–for-you*[6] theories apply.)

*Curriculum Invention Process*

<u>*Curriculum Study Teams*</u>

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[6] In contrast to just-in-time and just-in-case delivery, materials created just-for-you imply a different set of learning experiences for each student.

The general format of the initial curriculum recommendations included the following steps:

1. Create, revise, debate a vision statement for the curriculum.
2. Define the Olin graduate.
3. Define the learning methods needed to produce the Olin graduate.
4. Define the teaching methods that support the learning methods.
5. Define the technology infrastructure (db support, assessment, new media) that supports the teaching and learning methods.
6. Realistically determine the resources needed to implement any given elements (by assigning cost and time) and rank order results.
7. Create an implementation plan.

An example drawn from one exercise we conducted is shown below in which teams created Ishikawa (fishbone) diagrams (Ozeki, and Asaka, 1990) to demonstrate the contributing factors to the education of an Olin graduate.
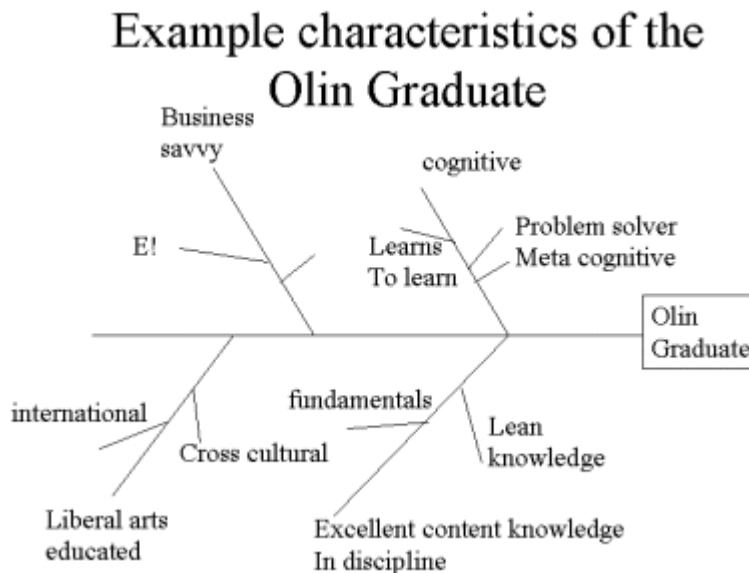


**Figure 2.  Ishikawa diagram of the ideal Olin graduate.  E! = Entrepreneurship.**

More detailed curriculum study: I2K – CURRICULA STUDY TEAMS

In the next set of steps in studying curricula, the faculty divided into five teams as shown in the table below to investigate different issues.

TEAM 1: TEACHING (DELIVERY) METHODS
- Project-Based, Challenge-Based Learning
- Student Teaming
- Learning by Discovery
- Tutorial Style Teaching
- Multi-Disciplinary / Integrated Curricula

- Peer Instruction (student centered learning)

TEAM 2: ISSUES
- Assessment
- UG Research
- AP (Advanced Placement)
- Advising/Admissions
- Learn from Other TYPES of Schools (architecture, music, etc.)
- NSF Coalitions

TEAM 3: CONSTITUENCIES
- Global Partnerships
- Internships/Industry Relations
- Virtual Alumni
- Relationship with Students

TEAM 4: CONTENT

- Educating Whole Person
  Pervasive Liberal Arts
- Design
- Entrepreneurship
- Curriculum Constraints
  Limits of time, credit hours
- Support Subject Issues
  Math
  Physics
  Chemistry
  Life Sciences

TEAM 5: ORGANIZATION / INTERFACE
- Interface with Babson
- Interface with Other Schools
- Infrastructure Support
- Process of Optimization

As shown, the issues were broad. By splitting up the various topics, the faculty could deal with examining the issues deeply. The results of the studies were quite informative: team one reviewed learning methods in detail, team 2 attacked understanding a variety of issues, team 3 considered the types of constituencies that Olin would serve, team 4 examined content and team 5 worked on relationships with other institutions and began to define a process for reaching the short-term endpoint of working with the partners who would be admitted to Olin in the Fall of 2001.

*Curriculum Delivery*

The following elements concerning delivery of the curriculum are not complete and will likely change during the I2K processes for design and test. Figure 3 below shows a concept that has been discussed as a possibility for an architecture. In brief, the ideas shown in this figure can be explained as follows:

1. Learning periods are divided into approximately 8-week periods, roughly equivalent to a half semester. Segmentation of these periods is a possibility, as well. An alternative plan of 5/4/5 week segmentation of a semester was discussed, as well.
2. A thread concerned with curriculum design persists across the entire educational experience. In figure 3, this thread is labeled: "Olin Curriculum Design Thread." From the outset, every student will spend some time continuously developing and

improving the curriculum. This thread is one element of the Olin curriculum that is quite different from curricula found elsewhere.

3. Courses taught elsewhere (Babson, Wellesley, Brandeis, etc.) are shown persisting across the modules.

4. Each module has problem-based components (indicated here by the label "PBL" for problem-based learning) that we and others[7] have called learning mosaics. Each problem-based learning scenario or mosaic (e.g., an anchored authentic experience) is connected to learning modules that are available online and can be taken just-in-time. These modules are mostly self-paced (e.g., a calculus review from Harvey Mudd) but can contain instructor-led components. Shown below is a sample semester demonstrating the supporting methods – e.g., electronic portfolios, libraries, course builders, and other supporting constructs. Below this plan in the figure is the IT infrastructure. This system is based on a standard course management package, extended to implement the various support methodologies.
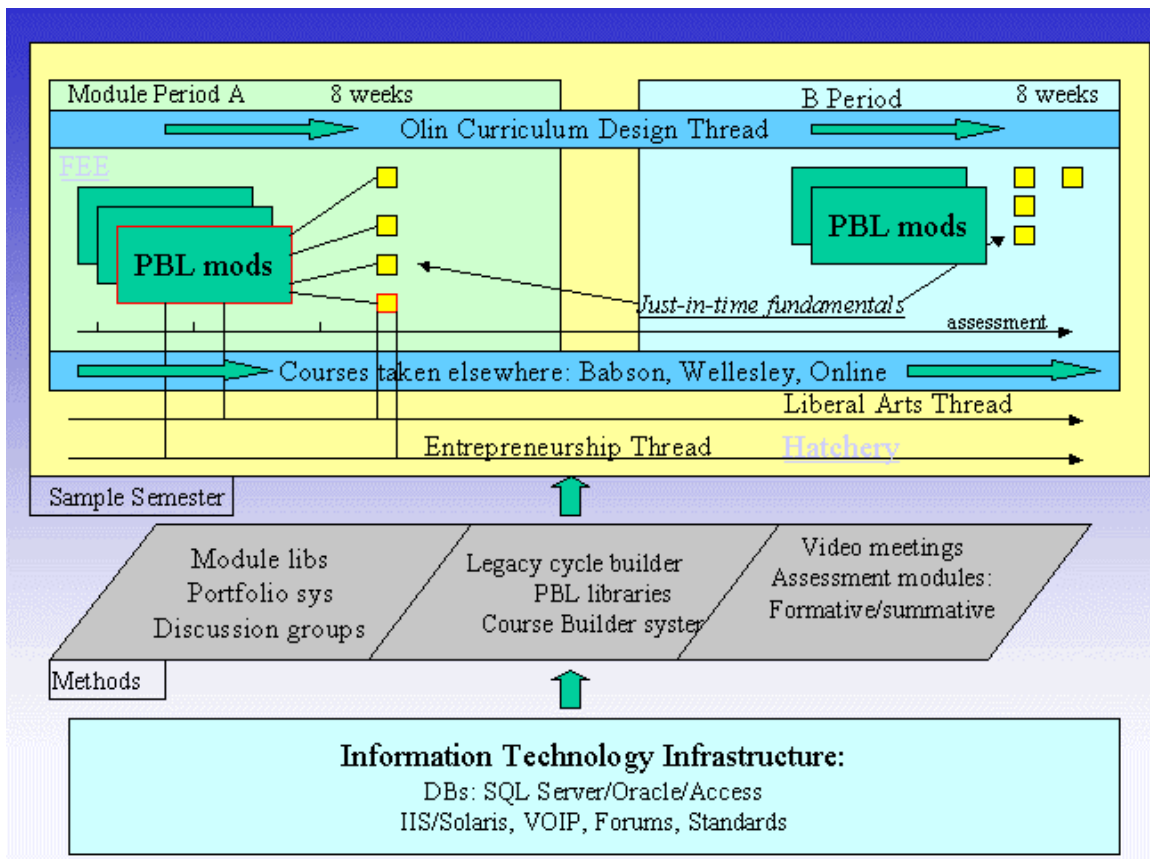


**Figure 3. Example Modular Delivery System. PBL= problem-based learning.**

Two threads of learning persist throughout the curriculum – liberal arts and entrepreneurship. It is the intent that every learning module will contain elements of

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[7] Notably, John Bransford of the VaNTH Bioengineering Education Engineering Research Center.

these two hallmark areas of an Olin education. As an example of implementation, a hatchery[8] is shown that will be constructed to permit students to work with creating new ventures. While not yet complete in concept, the figure below demonstrates the idea of creating multiple hatcheries in different disciplines (upper right). As students work with new ventures, the accumulated knowledge produces intellectual capital (in the so-called intellectual capital machine) that builds a legacy of information that can be used by future generations of students. The hatchery is a joint project of Babson College and Olin College. Babson, a college completely separate from Olin College, is physically collocated with Olin College. Babson's emphasis on business education permits Olin to draw on the significant resources provided by Babson in this area.
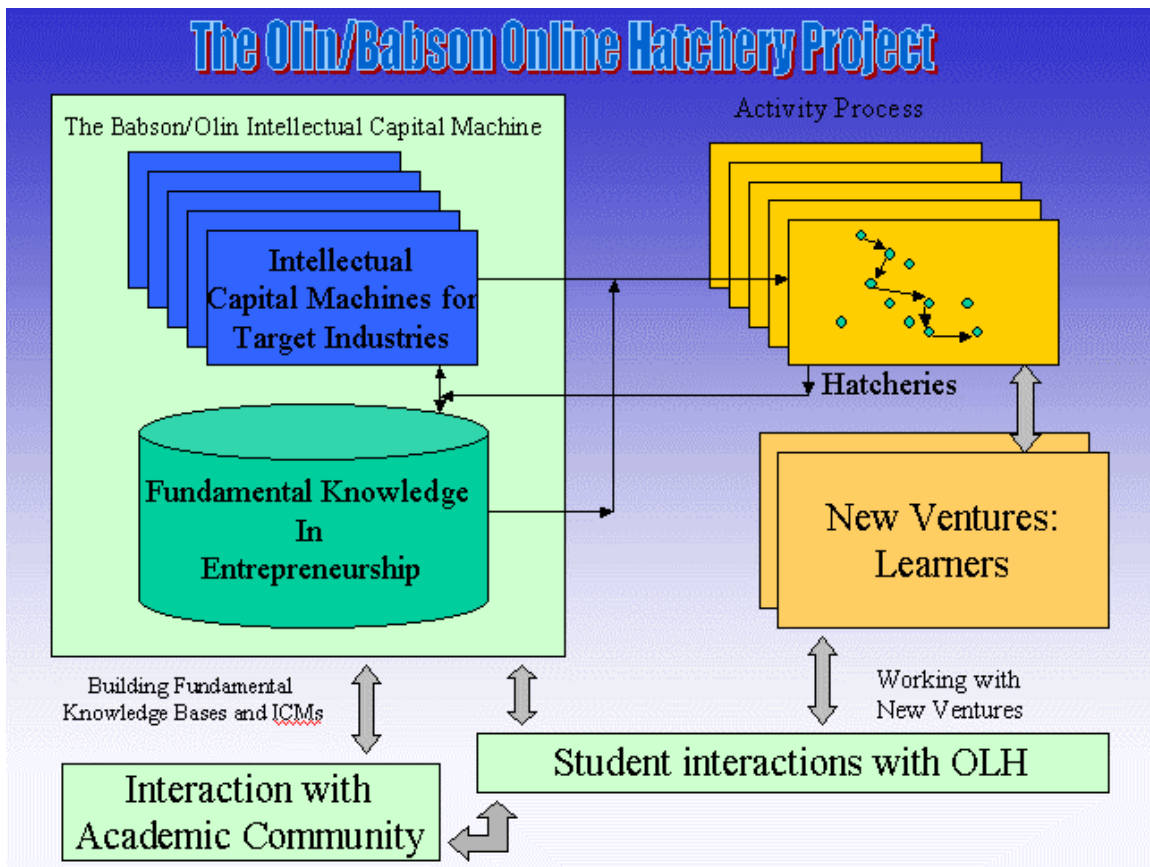


**Figure 4.   Example Hatchery Project Schemata. OLH = Online Hatchery.**

*Information Technology Infrastructure*
The curriculum at Olin College will be fully supported with information technology tools. The first activities undertaken to determine which tools should support the curriculum were initiated during the winter of 2001. A workshop (sponsored by the Sloan Center for Online Education (SCOLE) at Olin and Babson Colleges) was produced to help the faculty determine which course management system should be selected. Key criteria to investigate included:

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[8] A hatchery (a.k.a., incubator) is a place (physical and/or virtual) where new ventures are "hatched."

| Table 3: Criteria for course management system (CMS) assessment | |
|---|---|
| Ease of Use | The CMS should be easy to use without having to learn to use any web coding. |
| Features | Materials upload, asynchronous discussion, synchronous chat, slide upload, lecture materials, editable text, equation editor, modular organization, etc. |
| Adaptability | The code for the CMS should be modifiable to customize the learning environment. |
| Scalability | The system should scale to support additional students, including students who are abroad or off campus. |
| Administration | The system should provide easy administration, connection to on-campus utilities (e.g., email, databases), monitoring of use, etc. |
| Modifiability | The system should provide ways to add new features, as desired. |

*Interaction with Other Institutions*
We anticipate working with other institutions in the following ways:

- Babson College – Babson College is a physically collocated, although separate, institution that is dominantly management oriented, with a strong suit in Entrepreneurship. Olin College expects to utilize and provide courses from and to Babson College. An early partnership to build the Olin/Babson hatchery is expected to provide a focus in this area.
- Wellesley and Brandeis Colleges – Discussions are underway to utilize courses at these colleges.
- Online courses – We expect to be able to utilize courses that are available online from any institution that provides course work of interest to our students.
- Modules – We will make use of modules provided by other institutions and from commercial sources.
- Laboratories – We anticipate creating relationships with local institutions to provide additional laboratory facilities that are not easy to duplicate (e.g., clinical laboratories for bioengineering students).

*Other Partnerships*
We are planning to create partnerships whenever and wherever possible. For example, one such partnership is expected to be with VaNTH (Vanderbilt, Northwestern, Texas, Harvard/MIT), the NSF-funded Bioengineering Research Center.

*Example of Bioengineering Curriculum Design*
The faculty studying the creation of a bioengineering program at Olin College has begun to devise a curriculum to support learners in bioengineering. The preliminary characteristics of this program are given below as an example of what might be possible. However, no decisions have been made about the actual curriculum.

The characteristics of the bioengineering program are prospectively defined as:

- Problem-based learning guided by experts in targeted knowledge clusters in bioengineering. For example;
    - Cellular bioengineering
    - Computational bioengineering
    - Device-oriented bioengineering
    - Biomedical imaging
- Learning experiences in several universities and industries located at-a-distance from Olin College:
    - Sampling learning via online methods at several institutions (e.g., by taking several short courses)
    - Learning by attending a semester class or classes at a far-from-Olin College for credit. Host institutions might be in the Boston area or elsewhere, depending on the interests of the student.
- Team-focused learning experiences in which student teams concentrate on single knowledge cluster topics while the team is distributed. In this model, teams would remain cohesive via Internet connections, guided by a faculty knowledge cluster leader. A key concept is to permit student teams to retain an identity and to communicate daily with each other about what they are learning.
- A focus in learning as a team about new product development and entrepreneurial thinking in bioengineering. This learning would be made real by participation in the Olin/Babson hatchery. The online component of the Olin/Babson hatchery would permit students to continue to work in the hatchery even if they are physically not present at Olin for a semester.
- Learning from and with the entire bioengineering community worldwide.

A possible sequence of learning activities could be:

Semester 1: A semester could be built from a series of learning experiences that include courses at other colleges and a series of variable length modules. Some examples of modules are shown below.

Modules:
- Introduction to Olin Learning Methods
- Freshman Engineering Experience
- Planning to become an expert in bioengineering (a life plan)
- Targeted foundation experiences in engineering and in management
- Lean modules in
    - Biology

- o Chemistry
- o Math
- (Writing, presentations, ethics, entrepreneurship would be built into each module)

Semester 2:  The second semester could be a continuation of the first, including:

Modules:
- Planning the away from campus learning experiences
  - o Getting ready for the away experience (practicing as a team)
- An entrepreneurial/new product development experience
- Continued biology, chemistry, mathematics, and physics modules
- An online learning experience at a distance campus, where students might physically attend in an upcoming semester.  A key concept is for students to pick one or two knowledge cluster areas for concentration in the upper class years.  The online learning experience might be in one of these cluster areas.  Breadth is to be provided via online learning modules.

Semester 3: An away experience at a local college for one semester could be created in which students take courses at that college.  After this semester, students could continue to take online courses from the same college.  An advantage to physically taking courses at a local institution prior to taking online courses is that the student would become a part of that learning culture.

Semester 4:  On-campus learning experiences.

Semester 5:  A dominantly industrial experience, either in the Boston area or elsewhere.

Semester 6:  On-campus learning experiences.

Semester 7:  International learning experiences.  Continued online learning cohort experiences.

Semester 8:  On-campus learning experiences. Graduation.


**Plans for the Spring Semester, 2001**

*Curriculum Creation Process*

A process currently under consideration for the spring semester, 2001 consists of the following steps:

1. Determination of endpoints, including specification of each degree to be offered.
2. Faculty preferences and discussion of curriculum delivery methods.
3. Creation of an example first year curriculum by listing course titles, content and methods.

4. Choosing a course management system (CMS) and knowledge organization system.
5. Determining content types for initial learning experiences to be created.
6. Each faculty member builds a complete example learning experience.
7. Each learning experience is reviewed by both internal and external consultants.
8. The example learning experiences are tested and improved.
9. Summer vacation 2001
10. Partners year begins in Fall, 2001

An example of the types of decisions that could be made among different delivery techniques using a trade-off analysis[9] is shown in Figure 5.  In this example, five alternatives for different delivery methods were chosen (columns) and 8 different criteria for choosing among the alternatives were selected.  The software employed permits weighting of each criteria.

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DECISION PAD                                                    _ □ ×
Title of a Criterion, rating scale EXCELLENCE
 FILE  CRITERION  WEIGHT  ALTERNATIVE  EVALUATORS  DISPLAY  REPORT  QUIT
                                                    D:\D-PAD\CURRIC.DPW
                   Integrated   Projects   Tutorial   Module  Lec/disc.

agility              Poor        Good      U-Good    Excell     Good
integ difficulty     U-Low       High      U-High      Low    Medium
assessment ease      U-Low       Low        High    Medium      High
scalability          Poor        Good       Poor    U-Good      Good
adap to suppliers    Poor        Poor       Good     Excell    U-Good
elect. support helps High        High        Low    U-High       Low
exportability        Low         High      U-Low    U-High     U-Low
prod. good learner   Excell     U-Good     U-Good      Good      Poor
cost                 U-High      High      U-High    Medium       Low



         score was:      ?          ?          ?         ?          ?
         SCORE NOW:     4.0        4.9        3.8       7.9        4.9
         rank was:       ?          ?          ?         ?          ?
         RANK IN 5:      4          2          5         1          2
```

**Figure 5.  Trade-off analysis among different delivery methods**

*The Partners Year*
The partners are a special group of students.  Selected for their interest, capability and desire to play an early role in inventing the college, these students will spend the 2001-2002 academic year working with faculty to build the curriculum of the college.  They will, in addition, participate in the fall semester in a social experience (e.g., building a Habitat for Humanity house) and in the spring, an international experience at Georgia Tech Lorraine in Metz, France.

*Partnerships*
In addition to the partner's year, a series of strategic partnerships will be formed for students to have international experiences at institutions and industry abroad, industries in the US and with a variety of institutions of higher education in the US.  Relationships with foundations, publishers, health care organizations, governmental agencies, various

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[9] The software for the tradeoff analysis shown is from Apian Software (www.apian.com).

non-profit organizations and others will be formed.  Olin will utilize materials, information and other resources from many different venues.

*Completing the Curriculum*
The curriculum design process is never-ending.  We intend to be an agile organization that encourages constant change in the curriculum.  We plan a process of continuous improvement driven by assessment that will permit refinement of the curriculum using both formative and summative means.  Assessment will be facilitated using a technology infrastructure built into the course management system. We hope to be able to create a non-intrusive assessment mechanism that will continuously provide feedback.

Discussion

We are driven by a vision of Olin College as producing agile learners who are well-grounded in engineering but have very significant abilities in business and the liberal arts. To achieve this vision, we are examining multiple pedagogical approaches including, for example, project-driven experiential learning.  The curriculum may include a very significant proportion of liberal arts, entrepreneurial threads (the latter due to our relationship with Babson College) and multiple international and industrial experiences. Coupled with integrated co-curricula activities, we hope that the combination will produce a unique curriculum for Olin College.

The curriculum will be built into learning experiences that include multi-week modules (probably half or quarter semester length) delivered in a variety of ways.  Of special interest is the ability to deliver the curriculum using an information technology infrastructure that will support student learning both in the classroom and when students are away from the classroom and provide continuous assessment of student learning.

What are the characteristics of the curriculum that will help make Olin College unique among engineering colleges?  Of major importance is the strong interaction with Babson College's programs, the modularization of curriculum that includes focused disciplines but with clear threads of entrepreneurship and liberal arts, the utilization of materials, knowledge, information secured from anywhere, delivery of learning in anytime-anywhere modality but with intensive face-to-face components, integration of international, industrial and social experiences and a focus on problem-oriented, team-centered and entrepreneurial learning experiences.

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