AC 2010-1125: COURSE CHANGE AS A DARWINIAN PROCESS

John Robertson, Arizona State University

John Robertson is a Professor in the Engineering Technology Department at Arizona State University Polytechnic. He was formerly an executive with Motorola and now participates in many senior technical training programs with the JACMET consortium.

Course Change as a Darwinian Process

Abstract. Continuing Professional Development programs provide access to the industry professionals who are developing new and complex engineering systems. Through these programs, the evolving features of systems and the background knowledge and skills deemed essential by the industry can be derived and used as the basis for academic program updating. Results from an executive training program on managing large systems are presented to show that some courses require continuous modification based on two inter-dependent components: a deterministic structure and an opportunistic or Darwinian experience-based rapid adaptation. The interplay of the two components has been applied to the training courses themselves and the principles have been extended to managing change in technical academic courses in general.

Evolution of Courses. Change is endemic in engineering education. The ASEE Conference demonstrates more than a thousand examples every year but there is surprisingly little attention given to either the scope or priority of the drivers for change. The indicators of inadequacy are usually indirect and derived from economic effects [1]. For example, academic programs in the sciences and engineering are often accused of teaching the history of the subject. The result is persistent gap between typical graduate skills and the requirements of current jobs [2, 3]. While there may be truth in these accusations, change is rarely comfortable or as simple to execute for future technology as it appears with the benefit of hindsight.

This paper is concerned with the fresh challenges posed by the rapid developments in engineering systems. They range from the 50 interacting microprocessors in a car to the networks that handle 20 PB of internet traffic daily. Since these systems are created and managed only in the business world, direct academic experience and access to them is limited. However, they promise major engineering challenges such as the smart grid [4] so they justify a place in forward-looking academic technical programs.

A simple representation of the factors that drive change in academic courses is shown in figure 1.

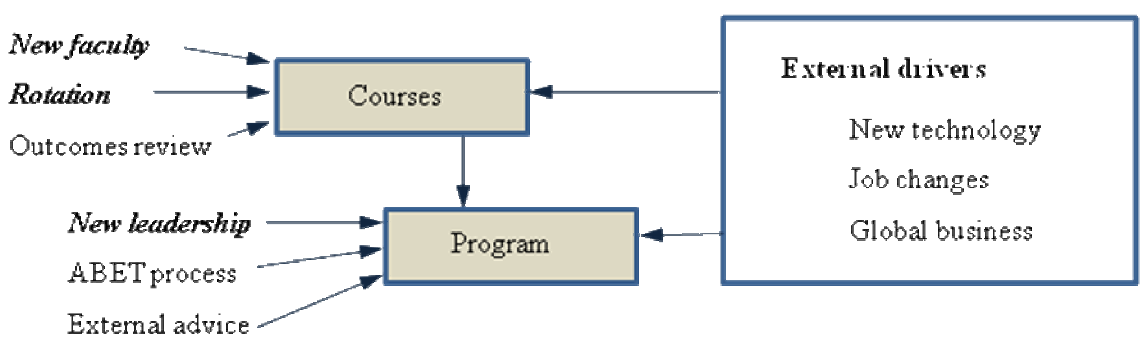

Figure 1. Drivers for change

The factors on the left represent the familiar institutional processes. Typically, they have an annual review cycle and are built into job specifications. Some (in bold italics) benefit from new blood and the surge of enthusiasm that comes with a new appointment and a fresh look at the subject. The other factors (outcomes reviews, ABET processes in non-accreditation years and external advice) rely on institutional professionalism. They are more difficult to keep dynamic and focused.

To stay current and relevant, the academic system relies heavily on two factors:

- The diversity of faculty research interests. The summation of these interests allows the program as a whole to stay up to date and relevant.
- The basics never change.

For a typical-size academic unit, these two factors deal with the need for change in the upper and lower divisions of the program. That is a workable strategy, but no technical program can be isolated from the changes in the outside world. What happens if the external drivers on the right of figure 1 demand more than the changes being implemented through the channels on the left? It is all too easy to say that charting responses to the tectonic shifts due to new technology and global markets is (conveniently) someone else's job. However, some tools can be borrowed from other applications of change management to provide experimental comparisons. This paper examines the parameters that qualify change and uses industry executive training experiences to link change management of systems with continuous adaptation of courses.

Measures for Change. An academic program can be considered as a professional formation process. Students enter with individual and diverse skills and capabilities and leave with a quantified and calibrated capability in the discipline. The process to enact change can be represented by figure 2. It is executed after every delivery cycle and it demonstrates a continuous improvement process in action.

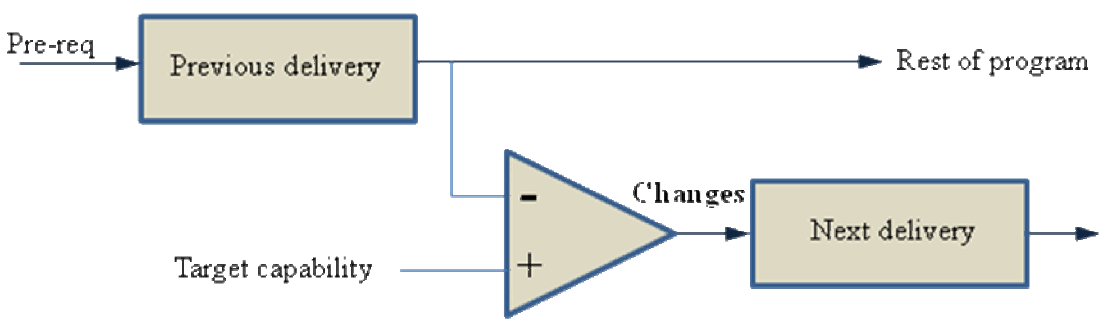

Figure 2. Process to enact course change

The presumption in this model is that there is a clear statement of the desired target capability. It is derived through faculty discussion, advice from industry mentors and direct awareness of technology trends so it is continuously evolving. The changes made for the next course delivery bring the course into line with the new target capabilities.

This is a good deterministic model but it is harder to implement for the multi-disciplinary requirements of large engineering systems.

The rapid industry adoption of new technology presents educational challenges in three dimensions:

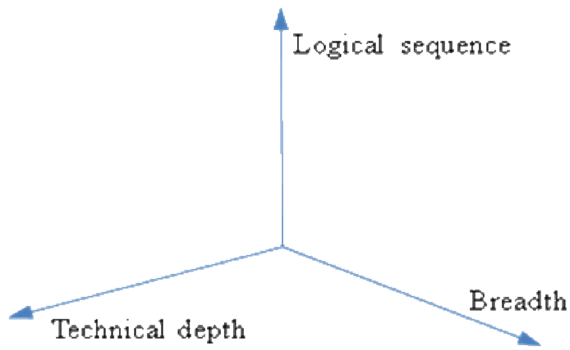

Figure 3. Dimensions of change

For example in a course in wireless communication, an emphasis on breadth might lead to inclusion of wi-fi, cellular systems, GPS and radar while depth might cover the many digital modulation and signal processing options. For presentation, there is always the dilemma whether to follow the evolution sequence or decompose a current system or use the bottom-up approach starting with components. The selections are made according to local preferences and customs but once settled, the course has the characteristics of that framework and any later change in the framework becomes very difficult. In this respect, a course takes on many of the attributes of an engineering system and its evolution has to be managed in a similar way.

Systems Management Applied to Course Change. The characteristic feature of today's large systems is that they are almost impossible to replace. Each system represents and investment of hundreds or thousands of man-years of effort. A replacement would require even more to be invested before it can be used and by that time it would be obsolete. System evolution and change is therefore done by substitution or extension of segments. There is an important corollary; the system must be designed to allow adaptation in segments.

Given the size disparity between and industry-based system and an academic course, what does the latter have to learn from the former about change management? The common features are:

- Retaining the status quo is not an option. The stark choice is to be ahead or irrelevant.
- Change may be essential but the resources to make it happen are limited.
- An accurate statement of the target capability (figure 2) is required.
- There are many interactions so validity needs a contextual demonstration.

- Many stakeholders (often with conflicting interests) have to be satisfied.

However, there are also a number of major differences which are summarized in table 1.

Engineering systems	Academic courses
Top-down ownership	Bottom-up ownership
All stakeholders participate	Self-review by responsible faculty
Continuous review process	Done after each course delivery
Look ahead, anticipate problems	Fix problems that showed up
Capabilities follow product needs	Product follows capabilities
Manage the product life cycle	Undetermined life cycle

Table 1. Comparison of attributes of systems and courses.

The most significant difference is that in a company, systems change management takes up a lot of time and creative resources. It frequently involves experts from outside the project who can bring 'lessons learned' from other similar experiences. It is a thorough and painstaking example of deterministic change management. Throughout the process, the emphasis is on teamwork to eliminate problems before they arise.

Engineering system design for adaptability or extendibility invariably relies on:

- Modularity
- Knowing what does NOT have to change
- Standard formats for interfaces
- A good roadmap for future requirements
- A critical design review process for prioritized change.

This methodology can be readily applied to course development to reduce the response time for change and to keep the most essential features up to date.

Short Course Benchmarking. Experience from training programs for senior engineers has been used to derive benchmark evidence for the application of systems management principles to course design and change. All the course designers and participants were familiar with the systems principles and since the courses were given several times per year, the feedback cycle was also fast. The following experiences are derived from two industry certificate programs [5,6] delivered over the last five years.

The initial scope and specification for each course was defined by a review team of industry and academic leaders. This was the target capability input in figure 2 and it was updated regularly. The short courses typically last one or two days (plus some additional reading). The boundary conditions for the short courses are demanding. The participants are senior engineers from a number of major aerospace and communications companies. The courses aim to extend the application skills to improve the job capabilities of the immediate next generation of engineering leaders. The emphasis of a short course and a typical academic course is shown schematically in figure 4:

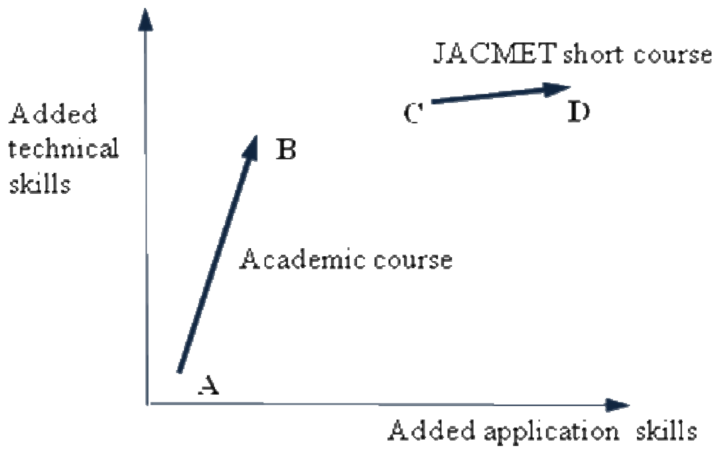

Figure 4. Representation of added skills in courses

The incentives to meet user expectations in the CPD courses are strong; if a course does not meet the goals as defined by the participants, its delivery frequency is reduced, eventually to zero. Of course, given the expertise that went into the planning and structure of each course, absent incompetent delivery, the reception should be good. This was mostly the case but it didn't always turn out quite that way. The participants liked the courses but they had many constructive suggestions. There followed a long list of suggestions for improvements. The changes were duly made but next time there was another (different) list of suggestions. Although there has been some spiral development, most changes have been new. As a result, the evolution of some courses has followed a Darwinian process where the participants' needs to enhance their job performance became the dominant factor in course change. It completely eclipsed the deterministic path that had initially been defined by the experts. In subsequent reviews, the same experts fully acknowledge the validity of the changes to their plans.

To understand the reasons for the user-driven change process, the historical evolution of six courses was analyzed. The courses are:

A. Decision-oriented risk management
B. Role of the Chief Engineer
C. Data acquisition
D. Working with data
E. A Chief Engineer case study
F. How to make a business case.

The approximate change made per delivery is shown in figure 5. The course identifiers A – F are defined in the list above. Change means new slides, examples, activities or sequence of presentation. In the case of A, an average 25% change for each of 15 deliveries means that there is now almost nothing at all left from the original expertly-crafted structure or content.

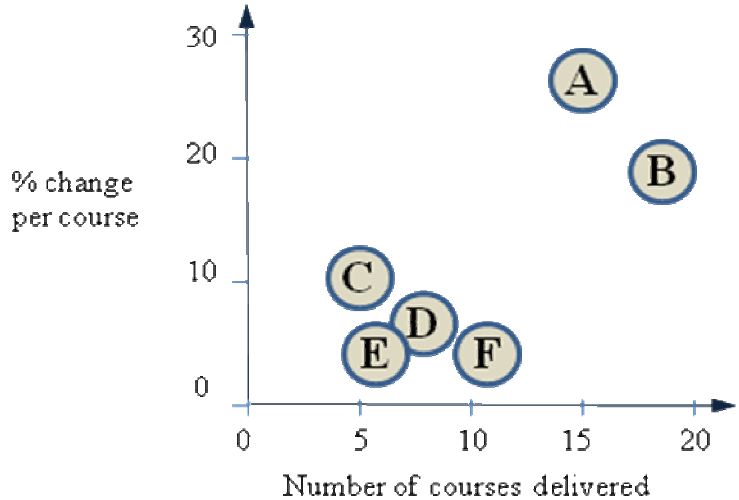

Figure 5. Changes made per course

The cluster of courses C – F demonstrates the feedback response that was expected. Why are A and B so different? It's not due to the participants since E and F are in the same certificate and have been very stable. It's not an infant development effect. That has been evident in course C but it is now stabilizing. However, continuing change after 15 – 18 deliveries points to other driving factors. The subject matter of courses A and B (technical risk management and the role of the engineering executive) is difficult to define in detail yet everyone knows what the job needs and has an opinion on what should be in a preparation course. With more than 200 individual feedback comments for these two courses to date, the search for the elusive ideal continues.

Although every component of both courses has changed completely in five years, it should be emphasized that could not have been achieved without the thorough system design approach that went into defining the framework. As a result, there is a modular structure that roughly defines each one-hour block of each course. The sequence of blocks can be readily changed to give different emphasis. Within each block the treatment of rationale, principles, examples and class activities can be varied to suit the participants or the suggestions made by the last group. Thus the structure makes it easy to incorporate changes quickly and selectively. Without this rapid adaptation capability, it is doubtful if the continuous evolution effect would have been noticed.

Conclusions. For more than five years, an engineering executive preparation program has been delivered to participants from a number of large companies. It covers specification, design and management of complex systems. In the course of the work, it became evident that there are many similarities between the formal process to manage system evolution and what is done to ensure continuous improvement in the training courses. Both require extensive reviews but there is rarely enough time or effort to do a thorough job. However, both face the challenge of changing expectations that are difficult to predict. In these cases, it is possible to use a much more Darwinian evolutionary process that adapts the last generation to the conditions and expectations of the next. The concepts were tested by a benchmarking activity using six short courses.

If the course framework is built using the standard principles of effective system design, it is possible to introduce prioritized changes for every delivery with reasonable economy of effort.

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