Session 1463

Experiences and Lessons in Accelerated Learning

David L. Wells
Academic Dean
Focus: HOPE
Detroit, U.S.A.

Abstract: Focus: HOPE's Center for Advanced Technologies and the NSF-sponsored Greenfield Coalition are partnered in a program aimed at radical and systemic change in manufacturing engineering/technology education. Among the targets for change are graduates more fully in-tune with the needs of 21st century manufacturing companies, integration of experiential and academic learning and compressed time for attaining the learning objectives of undergraduate. The latter topic is the prime focus of this paper. Against a backdrop of a brief description of the environment in which learning takes place within this program, results are presented from two highly compressed learning periods in Winter terms of 1996 and 1997, where substantial acceleration was achieved in completion of academic credits. The paper closes with an attempt to extract some lessons that will be incorporated in future compressed learning periods and may be applicable in other venues.

The Stage: The Center for Advanced Technologies at Focus: HOPE produces both automotive parts and new manufacturing engineers and engineering technologists. It its production mode, the CAT operates an advanced-technology factory, employing the latest-generation machining centers and computer-controlled inspection apparatus in flexible manufacturing cells. A broad variety of power-train parts are produced from aluminum and cast iron castings, purchased in as-cast form from foundries in several states. Characteristically, output products must be held to very close dimensional tolerances and high surface finishes. Current customers are Ford, General Motors, Chrysler, Detroit Diesel and the Department of Defense. Parts are shipped to customers' assembly plants in several regions of the U.S., Canada and Mexico.

In its educational mode, the CAT is a teammate in the Greenfield Coalition. This is one of the National Science Foundation engineering coalitions, established to create radical and systemic change in the content and methods of engineering education. Greenfield concentrates on exclusively on manufacturing. The degrees offered are Associate of Science in Manufacturing, Bachelor of Science in Manufacturing Engineering Technology and Bachelor of Manufacturing Engineering. The Greenfield university partners are University of Detroit Mercy, Lawrence Technological University, Lehigh University, University of Michigan and Wayne State University. The industrial partners are Cincinnati Milacron, Chrysler Corporation, Detroit Diesel, Electronic Data Systems, Ford Motor Company, General Motors Corporation and the Society of Manufacturing Engineers. The thirteenth partner is Focus: HOPE.

All degrees are awarded by one of the partner universities, but all five partner schools contribute substantially to all three degrees. Thus, the degree-awarding school provides less than a majority of the credits for the degree. The AS degree is awarded by Lawrence Tech, the BSET by Wayne State and the BMfgE by Detroit Mercy. Up to the present, all of the students have been Focus: HOPE candidates. One of the long-term objectives of the Coalition, however, is to migrate some or all of the new instructional paradigm back to the partners' home campuses and, thence, to other engineering and technology schools.

By design, the coursework is highly interdisciplinary and presented through a variety of non-traditional methods. Lectures are minimized and computer-based-learning modules are heavily stressed. Learning is designed to be modular, in-context, inquiry-based and competency-measured. Many of the modules are self-paced, employing only minimal instructor intervention. Greenfield courses vary widely in number of credits and in duration. Most of the courses are of two or three credits, but there are many at one credit and a few at four or five credits. Duration is planned around the amount of time for a 'standard' student to absorb the designed subject matter. Thus, planned duration of course varies from five to fifteen weeks. However, with the emphasis on self-pacing, methodologies are being devised to permit students to accelerate their learning and complete courses in shorter periods. Under this paradigm, 'completion' is defined as attainment of pre-defined learning objectives and standards, rather than by 'seat-time' or other passive measures.

The Normal Learning Environment: By design and definition, there are no students at the CAT. There are 'candidates' -- candidates to become manufacturing engineers or engineering technologists. A candidate is part student and part production worker. The key players in both operating modes at the CAT are the candidates; they are the students and perform key functions in manufacturing, from cell leader to quality technician to fixture designer. Candidates commit to an eight-hour production shift and a three-hour learning shift -- every day. In addition, candidates, as well as all employees in Focus: HOPE. are subject to strict policies on attendance, professional attire and personal decorum. There is also a zero-tolerance substance abuse policy. Candidates are paid for production shift, but not for learning shift; they also pay no tuition.

At present, the entry pipeline for candidates is successful completion of the entire curriculum in Focus: HOPE's Machinist Training Institute. This is a fifty-seven week, post-secondary program of forty-hour weeks on the job, divided equally between academics and hands-on instruction on conventional and CNC machine tools. Academic subjects include computer graphics (Autocad in the first term; Unigraphics in the second term), mathematics and communications. After over a thousand hours of machining instruction and practice, MTI graduates emerge as qualified entry-level toolroom machinists. Graduates who elect to enter the job market are well-received, while those who opt for continued education in the CAT are well-prepared for university-level work.

The typical candidate will be scheduled for six-to-nine hours per week of instructor-managed courses. The remaining learning shift hours are scheduled for self-paced coursework in mathematics, homework or private study. The mean course-load for candidates is approximately ten credits per term. The Greenfield academic calendar is divided into three four-month terms.

Academic advising is highly hands-on. The CAT Education Team devotes much attention to getting to know the candidates personally and individually. Candidates are scheduled for coursework according to their individual learning styles and capacities, and it is accepted that these will change as the candidate grows in academic maturity. Thus, each term will have a new advising heuristic. Variability around the mean learning capacity is significant. The most aggressive learners pursue as many as twelve-to-fourteen credits of instructor-managed coursework per term, in addition to, perhaps, another three credits through self-paced study. The least aggressive learners undertake as little as two-to-four instructor-managed credits and one-to-two credits in self-paced study.

When fully operational, the Greenfield AS curriculum will contain sixty-nine credits, the BSET one hundred thirty-two credits and the BMfgE one hundred thirty-seven credits. At the mean pace of credit accumulation, the 'normal' associate degree achievement time is seven-to-eight terms (two-plus years). The associate degree curriculum serves as the lower division for both baccalaureate degrees. Sixty-eight of the AS credits apply to the BSET and fifty-five lower division credits apply to the engineering bachelor's degree. This leaves sixty-four upper division credits for the BSET and eighty-two last-two-years credits for the BMfgE. The 'standard' completion times are, thus, seven and nine terms, respectively.

Burst Learning: Much of the pace in the CAT is dictated by production demands. As with any factory serving the automotive industry, production levels vary with customer demand for the finished product. In a just-in-time environment, there are often short-term variations in production schedules. Moreover, model-year conversion and change-over to newer products occasionally interrupt production altogether for a few days to a few weeks. By company policy, Focus: HOPE does not lay off candidates -- they are our most important product -- our raison d'être. Thus, when an extended production hiatus occurs, the company finds other tasks to gainfully occupy the candidate workforce. This provides an opportunity for a much higher level of concentration on learning for selected candidates.

In the Winter terms of both 1996 and 1997, slack production demand created opportunity to free some candidates from manufacturing duties altogether and assign them to full-time learning. In this special environment, 'full-time' means three three-hour learning periods per day -- triple the normal pace. The local parlance for a concentrated learning period is a 'burst', a term borrowed from encrypted telecommunications technology. Both burst learning periods were originally scheduled to last twelve weeks. As production ramped back up towards the end, both phased out gradually, and burst time was extended by up to two weeks or curtailed by one week for some of the burst candidates. The 'official' designation, in both cases, is twelve weeks.

Fifteen candidates were selected for Burst 96 and fourteen for Burst 97. In both cases, the selection criteria were: candidates who had most effectively utilized the normal fifteen-hour learning week; candidates in good standing in manufacturing; adequate prerequisite base (especially in mathematics) to take advantage of accelerated coursework; positioned most closely to the next degree objective. In both bursts, the next objective was the associate degree. Because of the tremendous boost provided by the burst periods, the associate degree graduates in both years emerged from the burst groups.

The associate degree curriculum in place for both 1996 and 1997 was a temporary program containing sixty-four credits in twenty-one courses. Greenfield courses are being developed over a planned five-year schedule; as 1996 was the third year in this project, only the first fraction of newly developed coursework was available for the first Burst. In Burst 96, therefore, instruction included a mixture of traditional courses imported into the CAT, Greenfield modular coursework, and other non-traditional offerings. For Burst 97, more Greenfield courses were available, but timely degree-completion still required a mix of instructional modes.

Directly imported sections of traditional courses and modifications of traditional. on-campus courses accounted for slightly less than half of the individual registrations (events) -- 43.9 percent in Burst 96 and 45.5 percent in Burst 97. New Greenfield courses accounted for 29.7 percent of the events in Burst 96 and 24.2 percent in Burst 97. The remainder came from other non-traditional course offerings.

	Event Fraction	Credit Fraction
Traditional Course	28.4%	29.9%
Modified Traditional Course	15.5%	15.1%
Greenfield, instructor-managed	16.8%	16.4%
Greenfield, self-paced	12.9%	12.6%
Other Non-traditional Methods	26.5%	25.9%

Figure 1: Distribution of Learning Achievements During Burst 96

	Event Fraction	Credit Fraction
Traditional Course	14.4%	14.1%
Modified Traditional Course	31.1%	32.6%
Greenfield, instructor-managed	15.9%	15.6%
Greenfield, self-paced	8.3%	8.1%
Other Non-traditional Methods	30.3%	29.6%

Figure 2: Distribution of Learning Achievements During Burst 97

The most important of the non-traditional offerings were several subjects where candidates acquire significant knowledge and skill in the course of training for and performance of their manufacturing responsibilities. Candidates are, as has been noted above, highly-skilled production technicians. Their knowledge of machining processes, metrology, quality control, safety, computer applications and engineering graphics is substantial. These are necessary skills for successful operation of an advanced technology factory, and candidates rotate through job assignments requiring expert knowledge in these topical areas.

It is characteristic of Greenfield education that the central focus is on attainment of performance-based learning objectives. As a result of an assessment of candidate experiential learning, it was ascertained that the skill portions of several academic courses were satisfied through prior training and work performance. It was also determined, however, that the theoretical backing for these skills was not strong enough to represent adequate engineering preparation. Nevertheless, these situations did not justify requiring candidates to go through the entire academic course. The solution was to provide concentrated workshops in the subject matter not contained in experiential learning and require the candidates to complete a comprehensive examination in each ‘course’.

In both bursts, the specific courses to be offered were selected to directly serve the selected candidates’ degree needs. At the start of either burst, no two candidates had the same needs for degree completion. The offering calendars were pieced together based on a mosaic of candidate needs and instructor availability. Great attention was devoted to selecting means of instruction which could be compressed.

While every burst candidate had a unique academic schedule and every schedule was very tightly packed, care was taken to provide breathers in the academic day and week. In the nine-hour learning day, at least three hours were set aside for homework and study. In a typical forty-five hour learning week, the usual pattern for a typical candidate included fifty-to-sixty percent of the hours in scheduled instruction. Of course, computers and other learning tools were provided for every burst participant on a seven-day, all-day basis.

As it happened, most of the instructional burden fell to Lawrence Tech and Lehigh, and both schools were outstanding in their ability to respond to the highly unusual instructional needs of a burst learning period. Abnormal and very tight instructional schedules were maintained and several non-traditional instructional means were employed -- all with no compromise to academic standards. Throughout both bursts, the administrative and faculty participation from both of these partners were exemplary. This was truly agile education.

Learning Achievements: The academic achievements of the candidates who participated in the two burst learning periods was, to put it mildly, impressive. In Burst 96, the mean number of credits completed during the burst period by the fifteen candidates was 31.67; for the fourteen candidates who participated in Burst 97, the comparable number was 29.14 credits. In each case, the effective duration of the learning period was equivalent to a bit less than a standard semester.

These numbers are softened somewhat by the consideration that not all of the instruction was delivered during the burst periods. In Burst 96, four of the courses had been underway for a four-to-five weeks before the burst began. In these cases, only about seventy percent of the instruction took place within the bounds of the burst. These four courses embraced thirty-two of the individual event registrations, or just over twenty percent of the total. There were fifteen courses which were completely contained within the burst period, representing the remaining eighty percent of the total registrations. The arithmetic of these discounts leads to an estimate of completion of the actual learning of a mean of 29.94 credits within the duration of Burst 96.

A similar situation applied in Burst 97, where four courses with twenty-one registrations were underway for about two months prior to the start of the burst learning period. The parallel arithmetic yields an estimated mean of 26.76 credits-worth-of-learning actually contained within the burst period.

In order to accomplish this level of credit completion, the average candidate was enrolled in roughly ten courses (events) during the burst learning periods -- means of 10.33 in Burst 96 and 9.43 in Burst 97. Totals of nineteen and twenty different courses were active during Bursts 96 and 97, respectively. The equation of twenty courses, ten courses per learner, fifteen learners, fifteen three-hour blocks per week and twelve weeks further illustrates the complexity of the scheduling heuristic.

	Nr. of Events			Nr of Credits		
	total	range	mean	total	range	mean
Traditional Course	44	0-4	2.93	142	0-13	9.47
Modified Traditional Course	24	0-3	1.60	72	0-9	4.80
Greenfield, instructor-managed	26	0-3	1.73	78	0-9	5.20
Greenfield, self-paced	20	0-4	1.33	60	0-12	4.00
Other Non-traditional Methods	41	0-5	2.73	123	0-15	8.20
Total	155	1-15	10.33	475	3-46	31.67

Figure 3: Learning Achievements During Burst 96

	Nr. of Events			Nr of Credits		
	total	range	mean	total	range	mean
Traditional Course	19	0-3	1.36	57	0-9	4.07
Modified Traditional Course	41	1-6	2.93	132	3-19	9.43
Greenfield, instructor-managed	21	0-5	1.50	63	0-15	4.50
Greenfield, self-paced	11	0-2	0.79	33	0-6	2.36
Other Non-traditional Methods	40	2-3	2.86	120	6-9	8.57
Total	132	7-13	9.43	405	22-40	29.14

Figure 4: Learning Achievements During Burst 97

Whichever of these totals is one's preference, the results of two burst learning periods show academic accomplishments approximately double the usual expectation of engineering or engineering technology students in a standard semester and learning environment.

Lessons Learned: Reflection upon the experience of the burst periods, as well as their statistical results, offers some conclusions and some guidance.

First, some observations about why the learning acceleration was attainable. The most critical factor was and is the high level of motivation of the learners. Candidates in this environment have assimilated a highly-disciplined work ethic, with some notable differences from the typical campus situation. High standards are applied in attendance, professional dress, behavior and personal habits. Distractions from the learning process are minimized. Moreover, people who adopt the discipline of a Focus: HOPE-like environment will be self-selected as dedicated to their task. The sub-set of the learner population that was selected for the bursts had identified themselves through superior prior achievements during normal learning schedules.

Both bursts were also strongly supported by both the in-house Education Team and the partner universities. Contributing faculty were diligent and cooperative, as well as expert. Guidance, counsel and advice were also very liberally supplied. It is estimated that about 2.8 to 2.9 FTE personnel effort was directly absorbed in managing the burst learning periods and in supplying daily and highly-personalized attention to the learners.

The degree of compression from a normal academic calendar would not have been achievable if the process had been confined to traditional course scheduling. The hallmark of both bursts, as indeed it is for the Greenfield concept, was and is defining the duration of instruction through natural and logical flow of knowledge. Course duration is not constrained by the traditional academic calendar, and completion of a course was and is defined by the attainment of measured competencies, rather than the passage of time. Moreover, burst learning cannot be accomplished without extreme flexibility in timing and concentration. It was critical that we were able to begin and end courses at virtually any day required by our schedules and that we had very wide latitude in selecting the frequency of class meetings.

A sidebar word should be added about the differences between the outcomes in Burst 96 and Burst 97. It will be observed that achievements in Burst 96 were somewhat higher in the quantitative data presented. This is a reflection of both the tangible and intangible results. The background of the Burst 96 candidates included a much higher level of prior college experience. This group came into the program with a total of 147 transfer credits from nine candidates, an average of 16.3 credits each. Only six of this first group had no prior college experience. In Burst 97, only three candidates had prior college work, totaling twelve transfer credits. Eleven had no prior college experience. It may be that the performance achieved in Burst 97 is more characteristic of inexperienced academic learners.

It should also be noted that anecdotal evidence, at least, indicates that learning retention has been quite satisfactory for the burst participants. In a single-subject observation, several candidates compressed two semesters-worth of associate degree mathematics into twelve weeks and have subsequently earned A or B grades in calculus, through ordinary differential equations. More broadly, thirteen of the participants in Burst 96 achieved the Associate of Science degree in Manufacturing/Industrial Engineering Technology from Lawrence Tech in 1996. Two of these graduates left the program to accept other employment. Of the eleven remaining, four completed studies for the Bachelor of Science in Industrial/Manufacturing Engineering Technology from Wayne State in 1997, and the remainder are on-track to complete either the Bachelor of Manufacturing Engineering from Detroit Mercy or the BSET in 1998.

Some guidance can be extracted from these two experiences, which may aid future attempts at orchestrating concentrated learning. There are three observations that leap out from the intensity of the bursts:

[1] Modular, flexible coursework is far more conducive and more effective in accelerated learning.

[2] Instructor attention is a vital ingredient. In accelerated learning, it is absolutely necessary that learners have frequent and easy access to instructors for questions, illustrations and reinforcement. Supporting the front-line instructor-learner interaction, the administration must provide smoothly functioning schedules and processes, and must permit no interruptions or dislocations of the primary business of learning.

[3] There are limits to accelerated learning. The high energy level and intensity of concentration that are required for accelerated learning cannot be sustained indefinitely, nor, on the other hand, can they be ramped up instantaneously. From observations of the two burst learning periods reported here, it appears that twelve weeks is about a maximum. At about that time, the people involved tend to begin fraying noticeably. It also does not appear to be effective or efficient to conduct accelerated learning for less than about eight weeks. Learning energy appears to peak at about eight-to-ten weeks into the effort. Also, the administrative effort and faculty energy involved are substantial. These are mostly concentrated at start-up and ought to be amortized over at least eight weeks.

As a final note, this particular learning population is very strongly attracted to the opportunities and challenges of accelerated learning. During both burst periods, the demand from candidates for inclusion in this high-intensity learning exceeded available slots by over one hundred percent. Since the first burst period, unsolicited informal and formal applications for burst learning have been presented in a continuous flow. An estimated seventy percent of the candidates who have not yet been in a burst have asked for the opportunity. Of those who have been in a burst, the fraction who have requested another such experience is approximately eighty percent.

As one looks towards future opportunities for accelerated learning, similar successful outcomes can be anticipated -- provided that [a] the selected learners are sufficiently motivated, disciplined and prepared; [b] instructors can be found who are both able and willing to participate in highly unusual learning; [c] the administrative structure can manage highly flexible scheduling, registration and record-keeping; [d] an atmosphere of personalized advising and moral support is maintained; [e] needed and useful learning tools (computers, software, texts, course-packs, etc.) are provided when and as required.

David L. Wells has amassed twenty years experience as a professor, department chair and dean in engineering and engineering technology education, following twenty years industrial experience in technology development, design, manufacturing and management. He earned the BS and MS in Mechanical Engineering from Stanford University and the PhD in Engineering Management from University of Missouri-Rolla. He is a Certified Manufacturing Engineer and has been very active in ASEE, SME, ABET and several other professional societies.