MAINSTREAMING AN INNOVATIVE 31-CREDIT CURRICULUM FOR FIRST-YEAR ENGINEERING MAJORS

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Abstract *— In September of 1998, the College of Engineering at the University of Massachusetts Dartmouth piloted an innovative, integrated, first-year curriculum that dramatically changed 31 credits across two semesters. Preliminary assessment data was very encouraging after the first semester of operation and the team started an effort to adopt it. A storm of intense resistance and controversy erupted, however, catching nearly everyone by surprise. Argument, rational and seemingly irrational, threatened to eclipse the benefits of the new program and could have easily led to its termination.*

In retrospect, the nature of the controversy and opposition was predictable. With earlier understanding of responses, adoption would still have been resisted and people would have disagreed but the team would have been better able to respond productively.

This paper will present the story of the adoption of the IMPULSE program so that others can learn from our experiences. It will focus on the process that led to rapid adoption of the new curriculum and will point out important steps and pitfalls.

The paper will include discussion of the important, and predictable, human reactions that were seen. We could not make progress until these were appreciated. Human reactions had to be understood and worked with. We hope that our experiences will encourage and help others to become more aware of the human factors that often dominate change processes.

Index Terms — Academic change management, first-year engineering curriculum, integrated courses, program assessment.

BACKGROUND

The Beginning: In 1994 at the University of Massachusetts Dartmouth (UMD), a team of six faculty members from the College of Engineering and the College of Arts and Science began looking for methods to improve the first-year engineering curriculum. Their objectives were to improve:

- learning in the fundamentals
- teamwork skills
- communication skills
- cross-disciplinary problem solving
- attrition rates and recruiting, especially of women and minorities.

The team built on the results of several previous successful undergraduate experiments at other universities such as those at RPI [1] and in the NSF Foundation Coalition [2]. The new program, called IMPULSE (**I**ntegrated **M**ath, **P**hysics and **U**ndergraduate **L**aboratory **S**cience, **E**nglish and engineering):

- integrated multiple subjects
- taught and required teamwork among students and faculty
- used active and cooperative learning
- encouraged formation of a learning community of students and faculty
- included rigorous assessment to evaluate and improve performance.

All of the courses in IMPULSE, including English, were also developed to exploit a technology intensive classroom to improve learning. References [1]-[14] give some background for many of the innovative methods used in IMPULSE.

With funding from the Davis Educational Foundation and UMD, a pilot of the first integrated 17 credits began in the fall of 1998 for 48 first-year, calculus-ready, engineering students. The second set of 14 credits in the sequence began the following semester.

IMPULSE and Traditional Programs: See Table I for a list of the IMPULSE courses. References [3] and [4] should be consulted for additional descriptions of the courses and their relationships. Most departments chose the second English course, ENL 102, as the department specific course so the entire first year was common for most majors.

Table II shows the basic structure of the traditional program for most engineering majors and illuminates some important structural differences. For example, the traditional program varied considerably by major. Each had its own introductory course in the first semester and specified additional unique courses in either or both semesters.

Another important difference was that IMPULSE integrated and sequenced the teaching of calculus and

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physics so that the subjects could be taken together. Both semesters of physics could be completed before students entered fundamental engineering courses in their sophomore years. Two engineering courses were also integrated with the calculus and physics sequence in IMPULSE to motivate learning of science and math fundamentals while providing engineering foundations.

TABLE I.
THE IMPULSE CURRICULUM

	Credits	
IMPULSE Freshman Courses	**Fall**	**Spring**
Physics for Sci. & Engr. I, II	4	4
Principles of Modern Chem. I, II	3	3
Intro. to Applied Chem. II	0	1
Critical Writing and Reading I	3	0
Intro. to Applied Sci. & Engr. I, II	3	2
Calc. for Applied Sci. & Engr. I, II	4	4
IMPULSE Total Credits	**17**	**14**
Program Specific (not IMPULSE)	**0**	**3**
Total Credits	**17**	**17**
IMPULSE Sophomore Courses		
Calc. for Applied Sci. & Engr. III	4	

Integration of the courses required careful faculty work between subjects [3]-[4]. For example, engineering problems were developed that required knowledge and methods from the other courses and calculus was sequenced to provide "just-in-time" development of the mathematics to deal with physics and engineering problems. In addition, papers were required in the technical subjects and these were worked on and graded jointly with the English course.

TABLE II.
THE TRADITIONAL CURRICULUM

	Credits	
Freshman Courses	**Fall**	**Spring**
Classical Physics I		4
Principles of Modern Chem. I, II	3	3
Critical Writing and Reading I, II	3	3
Anal. Geom.and Calculus I, II	4	4
Program Specific	**4-6**	**2-4**
Total Credits	**14-16**	**16-18**
Fundamental Sophomore Courses		
Anal. Geom. And Calculus III	4	
Classical Physics II	4	

IMPULSE instructors met once per week during the semester to coordinate the integrated aspects of their subjects. In this way, they could point to material from the other courses and expect students to use it. Weekly meetings were also used for coordination on student and team performance issues.

In order to keep student loads reasonable, the first chemistry course was revised to reduce the number of hours students spent in class. IMPULSE chemistry met three hours per week, had two wet lab experiences and used computer tools extensively for exercises, activities and visualization. Traditional chemistry had the usual lecture classes, recitations and laboratories totaling seven hours per week.

Students in IMPULSE could not drop any course except chemistry because of the integration of subjects. Chemistry was more loosely integrated so that most of its content was not necessary for the other courses. Traditional students had only the usual timing restrictions on dropping courses during the semester.

Learning from Other Programs: During planning and implementation, the IMPULSE team at UMD worked closely with the faculty members from universities in the NSF-sponsored Foundation Coalition. In addition to learning about programmatic issues, the team was able to study the problems and solutions that others had found while attempting to get innovative programs adopted.

For example, rigorous assessment was shown to be critical to decision-making processes that came after a pilot; however, we noticed that faculty and administrators placed dissimilar weights on assessment data and required different levels of detail. Faculty members placed great value on direct comparisons of learning performance such as would be seen in common exam questions. Often they were suspicious of conclusions drawn by others and wanted data in the least refined form so they could reach their own conclusions. Administrators, on the other hand, wanted conclusions and tended to place emphasis on success rates, retention, and cost of delivery.

Assessment for Decision-Making: Since both faculty and administrators were going to be involved in the modification and adoption of IMPULSE innovations, the team structured assessment activity to provide the best information possible for both. Common exam questions were used on finals in all IMPULSE and traditional sections for courses where such comparisons were possible. Admission data, such as SAT and Calculus Placement Test (CPT) scores and semester enrollment and grade information were extracted from the Student Information System and put in a database.

We knew that faculty members were going to be suspicious of the assessment effort. To ensure credibility, it was assigned to people who did not work in the College of Engineering. The Office of Institutional Research (OIR) hired an Assessment Specialist for the task. She reported through the OIR Director to the Associate Vice Chancellor for Academic Affairs. A faculty member from Psychology, with experience working in educational assessment, was hired as Faculty Assessment Coordinator. Her task was to work directly with instructors to establish practical and effective assessment plans and practices.

Even before the pilot began, a great deal of effort was put into finding appropriate comparison groups and being careful to understand the statistical limitations associated with the modest population sizes in the pilot as well as the traditional program.

After a study of the factors that correlated with academic performance of first-time-full-time freshman engineering majors from 1997-98, we developed two matched comparison groups in their calculus CPT and high school GPA as follows:

- IMPULSE – 48 engineering majors, CPT=70.4%, H.S.GPA=3.03.
- F'98 control group – 42 science, math and engineering majors, CPT=69.2%, H.S.GPA=3.01.
- F'97 control group – 38 engineering majors, CPT=69.2%, H.S.GPA=2.99.

They also matched closely in SAT math and verbal scores.

IMPULSE students were not volunteers although they could have decided not to be involved. They were randomly selected from the calculus-ready population of first-time-full-time engineering majors. All of those selected started the program.

The F'97 control group would have been IMPULSE students if the program had started a year earlier.

First Semester Results: By the end of the first semester, IMPULSE had already informally demonstrated some impressive characteristics. For example, attendance rates were nearly 100% in every class, every day. Forty-eight students started the program and only one withdrew from any course before finals. IMPULSE students didn't even drop chemistry although they knew they could.

Formal assessment results quickly confirmed a significant increase in success rate in the first semester. As shown in Figure 1, IMPULSE students earned substantially more credits during the first semester than those in the control groups.

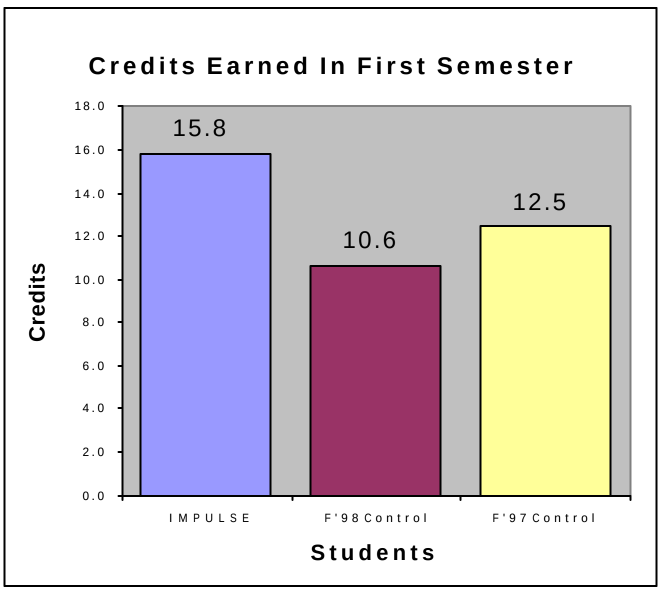

FIGURE 1
SUCCESS RATE COMPARISON

Learning performance in the pilot was also positive. Figure 2 shows that IMPULSE calculus students scored an average one and a half letter-grades higher than the F'98 control group on common final exam questions. Only 4% of IMPULSE students did not take this final compared to 28% of the F'98 control group.

The Force Concept Inventory (FCI) [15] was used for comparisons of learning in first semester physics courses. This test uses conceptual questions to determine the depth of understanding of Newtonian mechanics. It was given as a pre-test at the beginning of the first semester of physics and again as a post-test at the end. A normalized gain was computed by taking the gain from pre- to post-test and dividing by the maximum possible gain for the post-test (perfect score minus pre-test score).

Fair comparison among the physics courses was difficult. IMPULSE students were the only students taking physics during the first semester of their freshman year. Comparison was further complicated because the IMPULSE development caused changes in the way traditional physics classes were being taught. Active learning techniques in traditional classes were first introduced in the spring of 1998 and hands-on exercises similar to the IMPULSE physics were introduced into the standard physics course in the fall of 1998.

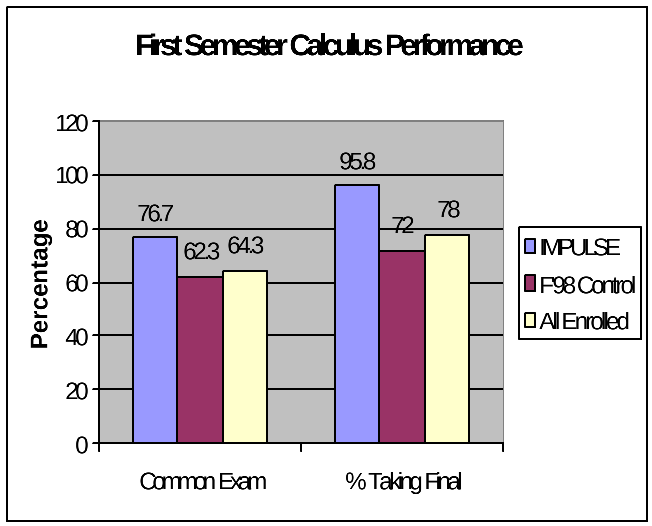

FIGURE 2
CALCULUS COMMON EXAM PERFORMANCE

IMPULSE physics students had an FCI normalized gain of 30%. The F'98 physics class in parallel with IMPULSE (with traditional lectures in class and IMPULSE methods in the labs) scored a normalized gain of 32% but only had 60% of enrolled students take the final compared to 98% in IMPULSE. It was made up of only 37% freshmen. The S'98 physics class (similarly using some active learning methods) had a 25% normalized gain while the S'97 physics class (using all traditional methods) had an 18% normalized gain.

In a study of first-semester chemistry courses in the fall of 1997 and 1998, no significant difference in common final exam scores was found when IMPULSE students were compared with other students who were similar in calculus placement scores [4].

To study the relative merits of the new IMPULSE English course, we used pre-course and post-course writing samples and a process already being used to study freshman English at UMD. IMPULSE students were included in the testing in F'98 and they made a substantially larger gain than the general population.

The engineering course in IMPULSE was so different from the department specific courses that no comparison of course results was attempted.

Please see [4] for more details of first-semester IMPULSE assessment data.

MOVING TOWARD DECISION

A major review of the first-semester assessment results was planned for the spring to determine changes to the program for the following fall. A similar review of second semester results was planned for the summer. Several factors, however, combined to move the IMPULSE team to accelerate the original plan for review and decision about modification and adoption.

Increasing Polarization: Controversy about the relative merits of IMPULSE began when the pilot was first proposed to curriculum committees early in 1998. Initially opinions were not sharply polarized and there was a very large group of undecided people. As the pilot got going, however, opinion began to divide. We realized that with time the faculty would probably become so sharply polarized that there would be little middle ground for productive debate and compromise. Dug-in opinions were going to be hard to work with. There was some evidence of this in the Foundation Coalition and we needed to move quickly to a serious discussion of the facts and data.

Changing Leadership: At the end of the first semester of IMPULSE, it became likely that there was going to be a change soon in the leadership in the College of Engineering. The Dean at the time was an obviously well qualified candidate for the open position of Provost. The College was probably going to enter a time of interim leaders who would not likely press controversial issues. Changes in leadership at several Foundation Coalition schools had previously created similar difficulty. We decided that some decisions on IMPULSE had to be made before an Interim Dean came on board. Otherwise, it could become locked as a perpetual pilot with opinions continuing to polarize around it.

Pressure from Potential Students and Their Parents: When we had to tell some students and their parents that they could not be part of IMPULSE, we first saw evidence of an intense pressure to enter the program. How could we deny to their son or daughter the finest education we could offer? When they learned about it, they determined that IMPULSE was what they wanted. This was reinforced as the recruiting season got underway and we started getting calls from high school guidance councilors, seniors and parents asking about the program and wanting to know what was required to gain entrance. IMPULSE was an enormous recruiting opportunity. On the other hand, if it could only be accessed by a third of incoming freshman, it could become a liability. An early decision to adopt major parts of IMPULSE would be very useful to avoid these problems.

Into The Eye of the Storm: The data seemed to be overwhelmingly positive after the first semester of IMPULSE. For the team, all that appeared to be necessary was to get faculty members of each department to take the time to study it and surely they would see the value and merits of adopting the program for their majors.

In January 1999, we confidently launched an effort seeking to adopt major portions of IMPULSE for all majors beginning in the fall of 1999. We invited a group of senior faculty to review and report on the assessment results and asked the curriculum committees to adopt major portions of IMPULSE.

The team was almost immediately caught in a storm of controversy. It came from many factions and its intensity was a surprise to everyone on all sides. Innovative parts of the program seemed to be threatening to many people. In addition, IMPULSE had re-ignited turf issues between departments because it eliminated most department-specific freshman courses.

Many strong negative opinions were voiced. Most attacked the assessment process because the results did not correlate with years of experience. For example some did not believe that cooperative learning could improve performance or that teamwork should be taught or used in undergraduate classes. Some feared that higher pass rates resulted from lowering standards or pandering to students.

There were also many positive comments about IMPULSE. One frequent response to the assessment data was astonishment that parts of the traditional program had serious problems that we had not understood before. Discussions started on how to improve the traditional program. These frequently led to the thought that maybe the traditional program was not so good that it should be preserved in its present form. Furthermore, IMPULSE was already here and perhaps it could fix some problems.

UNDERSTANDING HUMAN RESPONSES

In retrospect, we should have anticipated the tidal wave of strong negative comments and emotional reactions and the polarization around the IMPULSE program. These reactions had been seen at other universities where innovative programs had been piloted [16]. In hindsight, the intense negative responses were normal human reactions to new information and to the possibility of sudden and dramatic change. Even in an engineering college like ours that prides itself on objective and rational thought, these responses were likely to be emotional and occasionally fierce.

Myths We Live By: If a response to change or new information is highly emotional, the person may simply be responding in a very human way to a threat to an important, fundamental understanding that has been long held and has been reinforced for years or even decades. We could refer to such understandings as myths without implying that they are right or wrong. They are myths if they are "truths" that form a basis for daily actions and choices in living and working.

Gian Carlo Rota, late MIT professor of philosophy and applied mathematics, offered some useful insight into such myths in an introduction to the book *Indiscrete Thoughts* [17]. He separated them into two kinds. He said, "Working myths are the bedrock of civilization…We could not function without the solid support that we get from our working myths." We are rarely aware of working myths.

Wilting myths, on the other hand, are those that are in decline and have become verbalized as beliefs. He points out that wilting myths are often fiercely defended. According to Rota, "If anyone dares question any of our wilting myths, we will lash out and label him 'elitist,' 'subversive,' 'reactionary,' 'irrational,'…We will seize on some incorrect but irrelevant detail as an excuse to dismiss an entire argument."

Unfortunately, reaction in defense of a threatened myth can easily be misinterpreted as a personal attack or as an indication of faulty thinking. Heated retaliatory remarks may be returned. By misreading each other, disagreeing parties can begin to war without ever realizing the true nature of the problem.

Academics, particularly those in sciences and engineering, may be especially prone to these difficulties precisely because they think they can, or should, be completely objective. Therefore, they often do not choose to face these emotional issues, and the underlying myths, which are very real and may be dominant.

Dealing with the Myths: After we were embroiled in controversy and as people questioned the data, we became aware of several myths. And they existed on all sides of the debate! When a myth did not agree with data, it created a problem until the people concerned could see the flaw in the myth, reconcile the difference between fact and myth, or further justify the myth.

For example, many instructors in math and engineering believed that engineering majors did better in math than did science majors. If that were true, a control group that included science majors should not have been used for comparisons of calculus performance with IMPULSE. An investigation of first-semester calculus grades in a previous year showed no statistically significant difference in calculus performance between engineering and science majors. A myth was replaced by a fact.

If we had simply understood the difficulties presented by myths when we suddenly found ourselves in the eye of the storm described previously, we probably could have reacted better. Once we became aware of the myths, we began to work on reconciling them with the assessment data. We tried to find answers to any significant question that a faculty member suggested.

In some cases, a person was not satisfied until they could study or verify data themselves. They were given access to the database in a situation where student confidentiality could be preserved. Then they were encouraged and helped to cut through the data in various ways, see the statistics, and determine for themselves what was a sound conclusion and what was not.

Not everyone became satisfied with the results of IMPULSE assessment. Nonetheless, we treated every question as a serious one and tried to get an answer. We also tried to give people data in their preferred form with the level of detail they needed. With this approach, we were able to make most faculty members comfortable about the data, the process and the merits of the IMPULSE program. It was time well spent.

Remember that the myths we were threatening had often taken years to build. We were looking for a decision in a few months. Some myths die hard and are fiercely defended.

ADOPTING A NEW PROGRAM

The Turning Point: A string of heated departmental meetings and college faculty meetings had not produced any coherent conclusions about the fate of IMPULSE for the next academic year. The Dean of Engineering decided to create an Ad Hoc Committee made up of the Chairpersons from each of the curriculum committees for the engineering programs. He charged them with producing a freshman program that <u>could</u> be approved and adopted by the engineering departments for the fall. IMPULSE, however, could not continue as a pilot. The committee had to act.

After several difficult meetings, the Ad Hoc committee started to focus on assembling pieces of the traditional and IMPULSE programs to construct the best possible first year. That was the turning point when most polarizing factors began to dissipate. It was no longer a question of right or wrong, IMPULSE or not. It was only a question of determining the best program for engineering students for the coming fall and they had to come up with it.

In the discussions of the committee, completion of physics in the first year was seen as a significant advantage. Integration of physics and calculus was intuitively appealing and appeared to make the two subjects work in parallel. An engineering course in both semesters appeared to motivate learning of these critical subjects and solidify the desire of students to become engineers.

Integration of the English course was desirable but impractical given the size of the student population so it was made an independent course. Nonetheless, its pedagogy and content were kept in the program. Chemistry was never integrated fully and its independence was formalized.

The teaching methodology used in the new program quickly became only a tiny issue in the discussion. Students did seem to like IMPULSE, come to class, and stay in the program.

Once they understood that they could construct their own program, some key individuals who were early antagonists became excited by the opportunity to solve some old problems and improve their programs. They became advocates for change in their departments and they kept the modified program proposal moving forward toward positive decisions in their departments.

The sequence of courses that resulted looked like that in Table I. It was the IMPULSE program except that only three courses, physics, calculus and engineering, were integrated in each semester. In addition the names of the engineering courses were changed to "Introduction to Engineering Through Applied Science I, II" and their course descriptions were modified to ensure that the material presented would appropriately balance all of the engineering disciplines. In May, the new curriculum was approved for undeclared majors and for those in electrical, computer and mechanical engineering as well as physics. The IMPULSE name was kept but redefined as "**I**ntegrated **M**ath, **P**hysics, **U**ndergraduate **L**aboratory **S**cience, And **E**ngineering."

The Civil Engineering Department did not approve IMPULSE for its majors. Nonetheless, Civil Engineering students can take IMPULSE without penalty.

CONCLUSIONS

The IMPULSE pilot program at the University of Massachusetts Dartmouth represented a dramatic departure in curriculum and teaching pedagogy from the traditional program. Despite a storm of early controversy and resistance, the program went from pilot to adopted program in less than a year. It is now the required program for more than 80% of first-year engineering students at UMD.

Rapid adoption of the new program had three critical components for its success.

First, and foremost, the pilot program was built with rigorous, outcome-based assessment imbedded in the courses and program. That was critical in order to help faculty and administrators understand the outcomes so they could replace myth and anecdote with fact as necessary. Nonetheless, good assessment was only the first step.

Second, faculty members' questions had to be treated seriously regardless of apparent motivation. Considerable effort had to be put into understanding the root cause of resistance or criticism so that useful information could be provided. Faculty had to be given information in whatever form they needed to answer their questions. They had to have confidence in the assessment results and conclusions, especially when these contradicted well known "truths," or myths, that had been around for years without measurement.

Third, key individuals had to become motivated to study and make timely decisions about the new program. In order to do that, they needed the power to redesign it.

In the early stages, human stress responses seemed to dominate the change process. Only when the IMPULSE team stopped struggling against these responses and started working to help them did the discussion start to cool and become productive. That was probably the most important lesson learned.

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