MAKING CURRICULAR CHANGE: CASE REPORT OF A RADICAL RECONSTRUCTION PROCESS

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ABSTRACT

Educational change is technically relatively simple but socially complex. Making effective change in engineering curricula is problematic and often fails by too high ambitions, too short development time frames, inconsistent design and a lack of a systems approach, but also by poor leadership, lack of ownership and low faculty engagement. Literature tells that typically only 30% of the original objectives of an intended curriculum change are achieved in the as-built programme. In the period 2006-2010 TU Delft Faculty of Aerospace Engineering has re-established the profile of the bachelor and made a radical reconstruction by recalibrating the content and introducing a state-of-the-art active teaching approach. The innovative bachelor educates tomorrow's engineers in the context of conception, design, implementation and operation of aircraft and spacecraft systems and processes.

The paper gives an inside look in the reconstruction process. It shows that curriculum change is engineering and not science; it is politics and not always rational. The paper starts with an update of the educational vision that resulted in the prime objectives of change. It follows the systems approach with the student as the user and co-producer of the education always in mind. It addresses the design and development plan of the reconstruction, its organisation and leadership, and the role of upper management. They change over time and depend on the phase of development.

KEYWORDS

Educational change, curricular change, education reform, change process, colour-thinking

CONTEXT

Delft University of Technology in the Netherlands was founded in 1842 and currently offers 15 bachelor degrees and 38 different master degrees and hosts over 17,000 students. The Faculty of Aerospace Engineering has a reputation for excellence in education that includes advanced active tuition forms and a strong presence of project-based learning, with a capstone project running already for over 10 years. With about 1650 bachelor, 650 master students, a current undergraduate intake of 400 per year and 70 (full-time equivalent) scientific staff, the faculty is a middle-large faculty and a major player in the Western world of aerospace engineering education. Its education and research covers almost all technical and societal issues related to aeronautical and space engineering, design and operation. The bachelor curriculum relates to

the aerospace domain from the first study year onwards. It is appealing ("rocket science") for young people and is a favourite study for talented students with high ambition and strong motivation.

DRIVERS FOR CHANGE

It is a natural thing that external pressures and incremental changes lead to increasingly incoherent and overstuffed curricula. A curriculum gradually loses part of its profile and structure. But also, over time new pedagogical methods are developed since the learning and teaching environment changes: today's students have different styles of learning, graduates need different competences in their jobs than ten to fifteen years ago.

Each change process starts with the thought about the relevance and necessity of change. The bachelor degree programme has been highly rated by students and international accreditation committees. Showing the stakeholders the relevance of change when one has already one of the top rated programmes on Aerospace Engineering is asking for trouble one would think. Still, the principal drivers for the change of the Bachelor in Aerospace Engineering were dissatisfaction by staff and management about the **Study Effectiveness.** The dissatisfaction had its origin in the combination of an overstuffed curriculum, fragmentation, low coherence, imbalance between aeronautical and space engineering, and between basic and aerospace engineering sciences, only little connection between the project-based learning and disciplinary content. And there were concerns about student engagement, and feelings that the bachelor was no longer "fit for purpose". It did no longer respond to the needs of tomorrow's engineers. We believed that these facets were also a cause of the unsatisfactory student retention rate and long study duration, in brief the **Study Success**.

It were these internal concerns that show us that change and a sense of urgency do not always have to be realised under external pressure. The adoption of change is generally higher when the motivation is not an external cause but an internal drive [6]. In this we could certainly state it was the drive for quality and staying on top as crucial drivers for success.

Table 1 Urgency/Preparedness for change in an organisation

1	High urgency	low preparedness	create support and do not start before clear leadership commitment has been established.
2	Low urgency	high preparedness	work bottom up and explore the capacities of the employees
3	High urgency	high preparedness	a piece of cake, get going, but inform all parties such that everyone will stay involved.
4	Low urgency	low preparedness	don't even start

Starting a change process, however, one needs to consider the sense of urgency and the preparedness to change. As the involved stakeholders all claimed the urgency for change, we presume, preparedness for change would be high. Strategy 3 (Table 1) seemed to be the first change strategy to be explored. Being prepared and being committed is, however, not the same thing. "To make eggs with bacon the chicken has been prepared, but the pig has shown real commitment" [10]. It was the latter we needed. We thus had to revert to strategy 1 very quickly.

EDUCATIONAL VISION

The educational vision of the Faculty of Aerospace Engineering is based on the so-called T-shaped professional [7]: The complex multidisciplinary problems and challenges in our society, and in aerospace engineering in particular, require deep problem solvers who are capable of interacting with and understanding specialists from other disciplines. Industry refers to these people as T-shaped professionals: deep problem solvers in the science and engineering who are also capable of interacting with and understanding specialists from a wide range of disciplines and functional areas. The T-shaped professional is an important reference for our degree programmes: The bachelor represents the bar of the T. It provides the broad academic background with consolidated knowledge of aerospace engineering, the development of academic intellectual skills, personal and interpersonal skills and attitudes to analyse, apply, synthesize and design, a critical attitude, and an awareness of the scientific and societal context. It is a vision that is highly CDIO compatible. The master represents the stem of the T. It develops the student's in-depth working knowledge by providing a specialised course programme, an expert view on a sub discipline, followed by a focused research programme.

OBJECTIVES OF THE CHANGE

At the very beginning of the curriculum innovation process, the main objectives of the change were formulated as follows:

1. The curriculum shall be **foundational**
    - Students are versed in fundamental mathematics and physics, engineering sciences, and the engineering design process, all within the context of aerospace engineering.
    - Students are broadly prepared, both with respect to disciplinary content and to the development of academic and engineering skills, so that they can succeed in the master as well as in their future workplace.
2. The curriculum shall be **coherent** and **integrative**
    - The curriculum has clear lines of advancement in disciplinary knowledge and skills.
    - The curriculum has a logical thematic structure.
3. The curriculum shall be **compelling**
    - Students learn and apply disciplinary knowledge and the engineering design process within the concrete, multidisciplinary context of authentic aircraft and spaceflight projects.
    - The curriculum employs effective pedagogical approaches that engage students as active participants in the learning process.

The objectives focused on the enhancement of the Study Effectiveness. The retention rate and study duration (Study Success performance indicators) were expected to improve by the implementation of the above objectives through a recalibration of the curricular content, a transparent curricular structure, contextual and more collaborative learning, and using factors that promote a higher intrinsic motivation of the students.

CHANGES IMPLEMENTED

The curriculum has been reconstructed around the engineering, design and operations of aircraft and spacecraft. We have introduced a thematic structure in which each theme ties the content together per semester, but where the content is driven by the disciplinary and skills lines of advancement. Besides the semester themes we have structured the curriculum in three mainstreams: Aerospace Design (design projects and design courses), Aerospace Engineering & Technology (aerodynamics, aerospace materials and structures, production engineering, flight and orbital mechanics, systems and control, flight dynamics, propulsion), and Basic Engineering Sciences (mechanics, physics, mathematics). We have made the programme compelling by six design projects in a row with authentic design problems and professional roles [9]. The courses in the Aerospace Engineering & Technology mainstream relate to the theme and the design projects in the mainstream Aerospace Design. The content of the curriculum has been recalibrated with emphasis on the fundamentals of (aerospace) engineering [8]. The development of engineering and design skills, information literacy, team building, communication skills, including the writing of scientific papers have been explicitly embedded in the design projects.

The curricular change comprised the development of 17 completely new courses with new learning outcomes, content and active tuition forms; a significant reshaping of 13 existing courses that had to be reworked or turned into a different tuition form, and another 13 existing courses that had to be slightly updated. Although the faculty was unfamiliar with CDIO when writing the blueprint and innovating its curricular framework, we learnt afterwards that we had adopted the CDIO approach [5] and comply with most CDIO Standards to a very high level.

SYSTEMS APPROACH AND COLOUR-THINKING

Educational change is multidimensional. Firstly there is the perspective of the innovation (what changes have to be implemented, what objectives do we aim to achieve). Guidance of the innovation itself requires educational leadership. Secondly there is the perspective of the process (how do we want to achieve the innovation, how do we have the people embrace the innovation). This requires managerial and political leadership [6].

In literature we find various approaches of curriculum development or innovation processes [1][12]. The approaches differ in working method, breakdown of the development process in phases, and transitions and overlaps between the different phases. An innovation project mostly adopts a paradigm that matches best with the existing experiences, culture and change to be achieved. Table 2 describes the paradigms. Because rationally planned strategies for curricular change are not always rational when the social dimension comes in we used varying change management strategies over time to realise the final results and get everybody on board and motivated. These management strategies are best described by thinking about change in five different colours, as a language that facilitates discussions about change [3][4], see Table 2.

In 2006 faculty management realised that the change we were aiming for would not be achievable through an evolutionary approach and decided to go for a major and radical overhaul. We took the drastic decision to start from a blank sheet of paper, as if a brand new programme had to be developed. It meant that nobody's existing course was safe.

Table 2 Paradigms and management styles in colours

	Description	Colour characterisation	Strategy	Potential flaw
Instrumental paradigm	planning-by-objectives, defining and meeting standards, following a rational process in a logical order.	Blue: procedures keeping the eye on the ball	Rational design approach	Forgetting the human aspects
Communicative paradigm	focus is on relations. The best design is the one for which all developers and stakeholders reach consensus	Yellow: (political) lobby and networking	Creating win/win by matching interests	No defined outcome
		Red: benefits and punishment	Incentives to meet organisational goals	No match organisational goals/personal level
Artistic paradigm	based on "connoisseurship". In this approach design and innovation is primarily seen as a subjective and creative activity, where the vision and expertise of all designers are combined, traded and compromised. There are no objective measures, standards or procedures	Green: the learning organisation	Motivating/inspiring people to learn	People are not always willing to learn/change
Pragmatic paradigm	an evolutionary approach based on interactive and repeated try-out and revision.	White: organic growth	Stimulate spontaneous actions	Chaotic

Since the Director of Education, instigator of the bachelor innovation project, had been a systems engineer in his former industrial life, and the domain of aerospace engineering is appreciated as a very rational and systematic engineering discipline, the instrumental paradigm seemed the natural way to go. So we adopted the instrumental paradigm and extended it with systems engineering tools and practices: in first instance we considered the curriculum as a complex product that had to be designed, developed, built and tested to meet a set of the to-be-defined needs of the stakeholders (students, staff, university, accreditation agency, government). We broke down the design, development and implementation flow into separate phases with predefined outcome. They were concluded by reviews of deliverable intermediate products. Many reviews were treated as a phase gate (point of no immediate return) to the next phase. In engineering projects such milestone reviews are used to keep moving forward. We were soon to discover that at the time of passing a phase gate strong leadership becomes a crucial anchor in the change process. A strong planning and control (blue) document, for the new curriculum was established, "the Blueprint & Development Plan" to support this process. During different phases we kept documentation, project results, working documents as a means to keep an eye on the final results. It certainly helped to create supportive argumentations for decisions, keeping on track and showing tangible progress. And thus we embarked on the innovation project with the blue **Systems approach**.

It was therefore no surprise that after one year of conceptual development and design definition, a Head of Section advised the development team *"I'm worried about the level of real support for the curriculum revision. So far, the BICA* ("Bachelor Innovation Curriculum Aerospace") *team has treated this like an engineering project – deadlines, milestones, freezes. But this is more complex than an engineering project. You need to get commitment. Offer people an interesting job to do. Talk to them more, in smaller groups."* After more than a year of hard work we learned

that reconstructing a curriculum is not about the curriculum only. The social dimension had to be taken into account to make the change successful. Until then we had primarily focused on a rational pre-action planning. And we learned that rationally planned strategies are not that rational when it comes to dealing with people. Success is not about being right, it is about engaging individuals and groups in the faculty, who likely have different versions about what is right and wrong. Getting to understand the dynamics of change processes had become crucial.

From then onward, in 2007-2008 we changed our approach and followed a strong yellow and green strategy to create the necessary support and buy-in of all stakeholders. The Systems approach was complemented by a political dimension that emphasised communication, building of coalitions, investment and engagement of staff. We kept the Systems approach as the guiding principle throughout the innovation process, but we also exploited the Communicative and the Artistic paradigms further downstream in the development (Detailed Design and Implementation Phases, see Figure 1.

Table 3 Development phase and management roles and colours [3]

Project phases	Activities	Management roles	Colour
INITIATION PHASE		Director of Education and Educational Advisor in the lead	
	Blueprint written	Presentation Blue print to the Faculty Assembly of professors	blue
	Rallying management support Go/no go for the Blue print	Dean forced go moment	green yellow
DEFINITION PHASE			
	Benchmarking; Curriculum framework design; Development planning;	Director of Education and Educational Advisor in the lead; Professor buy- in	blue yellow
	Installation of BICA project team	Change of Dean	
CONCEPTUAL DESIGN PHASE			
	Curriculum organisation; Framework detailing; Communication “offensive”	BICA Project team in the lead Conflict phase	yellow blue green
DETAILED DESIGN PHASE			
	Development of course outlines by Lecturer Development Teams; Staff professionalisation; Offsite retreat; Harmonisation Meetings;	BICA Project team in the lead Lecturers on board; Dean on board;	green red
	BICA project team dismantled;		
IMPLEMENTATION PHASE			
	Detailed development of courses	Team of lecturers in the lead; Director of Education and Educational Advisor monitor	white green blue
DELIVERY PHASE			
	Delivery of the projects and courses	Lecturers in the lead	white green
MAINTENANCE PHASE			
	Evaluation and upgrading		green

The communicative activities typically focused on personal interviews, small group interviews, learning activities focused on just-in-time learning to develop the next level of a course, through working group sessions on and off campus, inspirational meetings, and individual or small group coaching. Especially the 1-week off-site retreat for a working session on conceptual course development in the Detailed Design Phase, followed by the series of harmonisation meetings greatly helped to realise a team-spirit at the end of the Detailed Design Phase, which was dearly needed in the later Implementation Phase, where independent teams of lecturers realised the final course design, ready for delivery.

The change in focus and management style led to changes in leadership. Early in the Conceptual Design Phase early 2007, a BICA (Bachelor Innovation Curriculum Aerospace) team was appointed to coordinate the development of the curricular concept. In the Implementation Phase in 2008-2009 the leadership for the innovation was transferred to the development teams of lecturers. Forcing the Director of Education to become more pragmatic, without letting go of the Systems approach. The innovation process still was monitored in a blue manner by holding to targets, creating formats to keep track of progress and audit meetings to monitor, track and guide the results on several aspects such as:

- Quality of the course design
- Study load during a semester
- Adherence to the conceptual course design as agreed at the completion of the Detailed Design Phase.

Yet this Implementation Phase in particular, provided room for organic growth of active working methods in the bachelor courses, for yellow bargaining on contributions of cross disciplinary topic to specific courses and green strategies including peer feedback and learning from each others' expertise. The safe environment of peers created a positive pressure on all developers, not by regulating the people by constraints or enforcing targets, but by:

1. Supportive autonomy, enthusiasm and responsibility
2. Letting the professionals make the choices
3. Sharing the decision making process
4. Trusting on the intrinsic motivation of the staff
5. While enforcing the norms where necessary

Especially, the peer feedback was very successful in controlling the quality, slippage and planning of the curricular innovation.

Summarising, we used the five-colour thinking not only in the minds of the leading BICA team, we also chose the development strategy and working methods accordingly. We used blue strategies to set boundary conditions. We involved more "green" people in periods where learning and innovation were the main themes. We used "yellow" people and working methods in periods where we had to resolve political issues. Thus we achieved results and ensured grip on the process by selecting the most suitable, conveniently-coloured staff and working methods, depending on the development phase.

MANAGERIAL LEADERSHIP OF THE CURRICULAR INNOVATION PROCESS

Strong leadership

Key factor in successful change and project management is the support of upper faculty management [6][10]. During curricular change, however, one often has to deal with a change in upper management, as the whole innovation process often takes longer than the appointment of a dean or its management team. Also shifts in focus during the curricular reconstruction

demands different management and control approaches on the shop floor. Yet the saying is; “if the client is gone the project assignment is gone [10]”. Requiring the highest leader (the client) in the organisation to be the anchor, who makes the ultimate decision on continuing or stopping the change process.

During this innovation project three key moments could be identified in which the anchor point (the highest leader being the Dean) influenced the curriculum change project in a major way. Each time the Dean considered whether the change still contributed to the organisational goal, and took the lead in his or her decisions accordingly;

1. Forcing a decision on the acceptance of the initial blue print. (The first Dean provided strong management support for the execution of the plan).
2. Changing Clients; A new Dean, not being owner of the initial plan demanded changes that violated the initial design principles laid down in the approved plan. After a major clash, the Dean reclaimed ownership.
3. Role modeling the change; the new Dean, by implementing and coordinating the major Introduction to Aerospace Engineering course, has shown major commitment to the entire staff. This step became crucial to the ultimate successful implementation of the entire plan.

Development planning

The very first step in the Initiation and Definition Phases (Figure 1) of the innovation were the discussions in three Faculty Assemblies where all full professors participated. We used the disciplinary expertise of the professors, their visions and their future aspirations to guide the definition process of the profile of the new graduate, and the profile of the new programme. These were collected during off-campus Faculty Assembly conferences with all professors, and during group interviews at the faculty. The conferences certainly yielded a lot of relevant visions and helped establish the primary design requirements for the curriculum in addition to the more educational requirements. The first outcome of these meetings and discussions with the Industrial Board and alumni was the definition of a new profile of the graduate and the final qualifications for the upgraded bachelor curriculum (chapter “Educational vision)”. In the following steps information was combined from benchmarking studies and discussions and surveys with various stakeholders like industry and institutes, university, faculty, lecturers, pedagogical experts, and last but not least students. It resulted in a “Blueprint & Development Plan of the BSc Curriculum Aerospace Engineering”.

In the Conceptual Design Phase the BICA team was appointed to coordinate the further development of the curricular concept. The team consisted of four senior lecturers (one external), the Director of Education, an educational expert and a secretary. Professors were not given a leading role and were not directly involved in the actual creation of the curriculum. They tend to be biased towards their departments’ interests and do not necessarily have the best interest of the student or organisation as a primary priority. Moreover, they seldom have the time to take part in in-depth curriculum work.

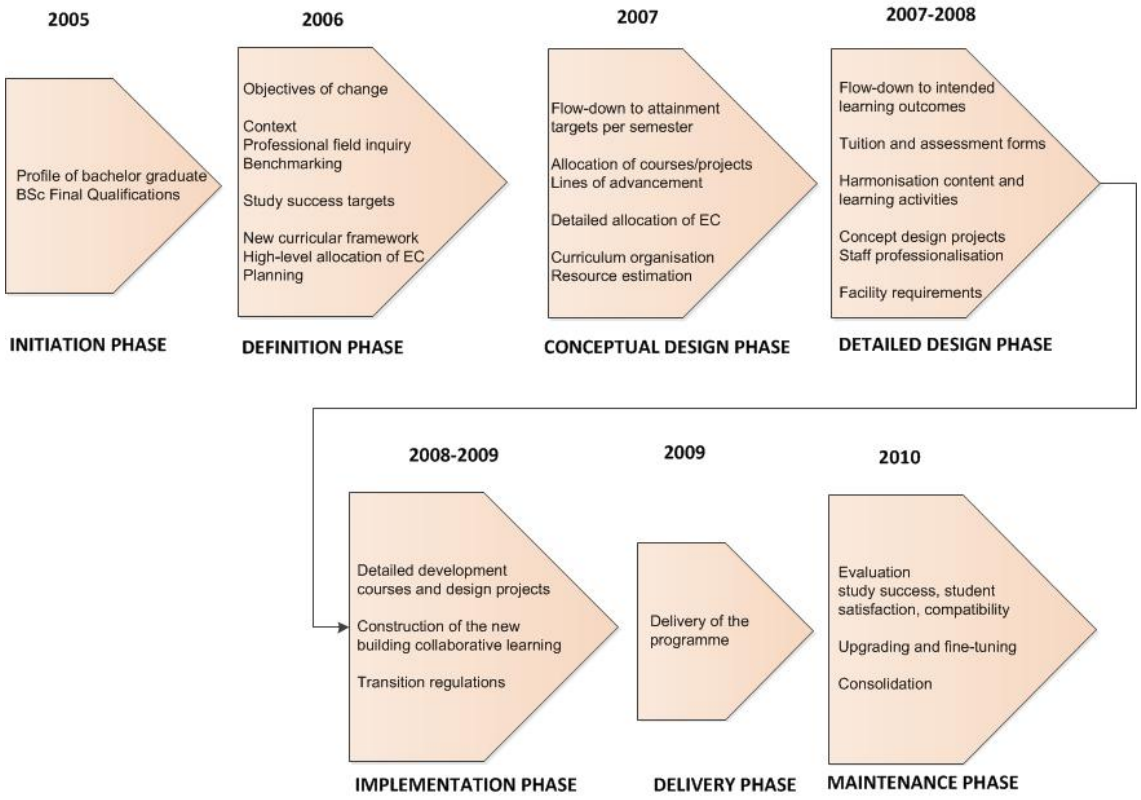

Figure 1 Curricular development flow of phases and activities

Within the ideas and boundary conditions of the Blueprint, the attainment targets for the semesters and the thematic structure were further developed and discussed. In the Detailed Design Phase (January 2008 onwards) the BICA team involved a large number of lecturers who were organised in so-called Development Teams. They were supposed to follow a so-called **Fidelity** approach [6], which is based on the assumption that an already developed concept exists, and the task is to get the staff to implement it faithfully in practice – that is, to use it as is "supposed to be used," as intended by the developers. The Development Teams generated course descriptions, project proposals, lists of required skills, etc. At the end of the Detailed Design Phase there were two posters for each course: one describing the intend learning outcomes and content, and one describing derivatives like the teaching, working and assessment methods, deliverables, in-class time and so on. In addition a number of semester-overview posters and posters for design projects and engineering skills education were prepared. These posters, together with the background information about ideas, decisions, and working principles, were the basis for the next phase: the Implementation Phase of the detailed development of course materials, and the implementation of tuition and assessment forms.

The outcome of the Detailed Design Phase was consolidated in a curriculum baseline document together with all necessary (background) information for the detailed development and implementation of the course materials. The main part of this Curriculum Design Report was the baseline description. It contained the posters for all courses and projects and described the relation between the courses, using the thematic structure and the disciplinary lines of advancement. Especially these interrelations were important in the harmonisation process of the

content and teaching styles. The document was the reference for the Implementation Phase for teachers as well as upper management, and was used as background information for a better understanding and distribution of the curriculum concept faculty wide. The report was distributed in glossy full colour to all permanent scientific staff members so that everybody had the same knowledge and the same level of understanding.

The total reconstruction effort cost about 25,000 man hours (appx. 15 fte). The anticipated drop in scientific output, as a consequence of the extra demand of manpower for the reconstruction, was compensated by allocating extra funds from faculty to the research groups. These funds were proportional to the contribution by the group, the number of study credits of the course, and the level of change (120 hours per credit when course had to be developed from scratch, 90 hours when augmented, or 60 hours when slightly modified; an academic year has 60 study credits). Thus we prevented that money was a dispute when manpower need was negotiated, but available capacity always was.

DEVELOPING OWNERSHIP BY COMMUNICATION

"The funny thing is that you have the BICA team, which consists of people who care very much, and then you have the people who say, 'I'll see what comes out.' You need all people to stand behind the project; otherwise people will be forced to do it, and this won't work." This advice was given by a teacher to the BICA team during the Definition Phase. During that phase the BICA team focused much of its work internally. Furthermore, to the extent that the team engaged with the faculty community, it had largely done so through interactions with the Heads of Department and Heads of Section and formal presentations. While such approach had been appropriate in the early stages of the design process, the next steps required that a much larger fraction of the faculty community (1) would know about the curricular innovation, and (2) would feel invested in and committed to the new curriculum. In this phase of the development, communication with the faculty was more important than ever.

Stakeholders with different and changing roles

In different stages of the development cycle some of the stakeholders have changing different roles and responsibilities (Table 3). These typically were the professors, the Director of Education, the educational staff and finally the students. The involvement cycle for each of the stakeholders groups can be characterised as an adaptation of a change (Figure 2) management theory [10].

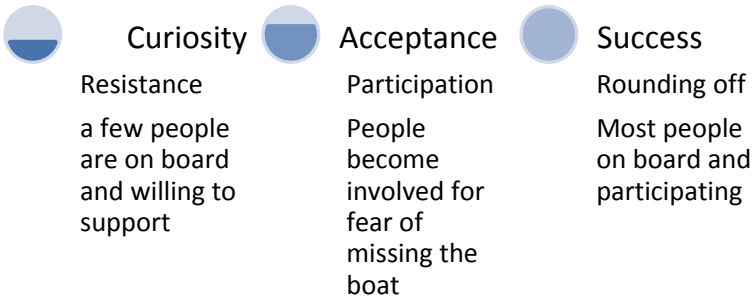

Figure 2 Involvement cycle of stakeholders in a change process

In the first stage we usually find the classical attitude of denial or more predominant curiosity: “what is in it for me?” “How can I use this change to improve my department or personal position?“. Once being informed, the majority of the people go into resistance either passive by no show, no involvement or by making amok. Yet the resistance is a stepping stone to self-reflection, allowing acceptance of the inevitable. Supporting the transition to the acceptance phase by making a communication plan that was adapted to the stakeholders development, helped to realise the eventual success. In the following paragraphs the transition through each stage of the change process is shown together with the communication approach that we followed specifically for these stakeholders.

Early phase of resistance

In the Definition Phase many people believed that the curriculum revision would primarily be a *cosmetic* change: one teacher commented, “People will make some small changes, but mostly it will be the same.” Many people appeared to be taking a “wait and see” attitude.

Individual discussions with faculty staff revealed that most people who thought they knew something about the new curriculum, believed that:

1. The goal of the new curriculum was to address *fragmentation*. Improvements in pedagogy and skill development were typically not mentioned as a goal. (*indifference*)
2. The new curriculum would be *highly project-based* – much more so than the current curriculum. Consequently, the new curriculum would be likely to be less rigorous, to contain less disciplinary content than the current curriculum, and to be highly resource intensive. (*resistance*)
3. The new curriculum would be much more *interlocked*, and consequently less flexible. Study feasibility would therefore drop under the new curriculum. (*resistance*)
4. There was disagreement about what the new curriculum would be *about*. Some people thought of it as being fundamentally about aircraft and spacecraft; others thought of it as being fundamentally about the core ideas in mathematics, science, and engineering that provide the foundation for aerospace engineering. (*curiosity*)

In the Definition Phase the level of investment in the new curriculum had been fairly low. Many people believed that the curriculum revision would primarily be a *cosmetic* change: one teacher commented *“People will make some small changes, but mostly it will be the same.”* Many people appeared to be taking a “wait and see” attitude. Given these conditions, a Communication Offensive had to accomplish an *increase in the overall level of knowledge* about the work of the BICA team. More members of the faculty should know the “headlines” of the curriculum revision. Secondly it had to *address existing misconceptions* about the new curriculum. Most critically, we had not only tell people, but also *involve people*, so that more members of the faculty would feel invested in the new curriculum. Certainly the limited involvement was partly caused by the limited resources – it is hard to get people’s commitment without time – but commitment also comes from ownership (the sense that “my fingerprints are on this curriculum”).

Acceptance

In the second stage of adopting change, stakeholders who are already actively involved, become crucial agents, to make the new curriculum more widely accepted. They are the ambassadors, showing their influence, the good points of the change, the effect on their department or position that help bring the passives into a more constructive attitude. There were a number of different groups who cared about changes in the bachelor curriculum: upper faculty

management, Heads of Section, teaching staff, supporting staff, students, and future employers of graduates. So, although the general goals of our Communication Plan had to be the same for all constituencies, we had to apply different strategies to different constituencies for a number of reasons:

1. Different constituencies *care about different things*. A communication strategy should be tailored to take the values of the audience into account. Students, for example, are not very much concerned about the impact of the curriculum on departmental budgeting; Heads of Section or Department on the other hand, might not be so concerned with feasibility of study.
2. Different constituencies *play different roles* in the curriculum revision process. For example, it was critical that the faculty's teaching staff "owns" the curriculum and that the teaching staff recognises the importance of adopting effective pedagogical strategies, for they will be developing and implementing courses and projects.
3. Different constituencies are best *reached in different ways*. While it is possible to talk individually to every Head of Section or Department, it would be impossible to talk individually to every student.

So, although in essence the BICA team should be saying the same thing to all constituencies, it was worth thinking about (1) the most important messages for each constituency, and (2) the best way to reach each constituency. To realise (1) and (2) we used an engineering design approach to decide on the best communication strategy for the particular constituency (Table 4) in each development phase. It helped to realise support of professors, a just in time professionalisation of staff, and matching of student profiles on course development work.

Table 4 Designing the communication strategy

Designing the communication strategy
Explore
a. Informing about the state of the art and targets
b. making an inventory of needs/concerns of the stakeholder group involved (landmine questions)
Conceptual Design
c. Deciding on the best next achievable target or formulating requirements
d. Developing different scenarios to realise the target in the best possible way
Detailed Design
e. Choosing the scenario
Test and Simulate
f. Executing the scenario for particular stakeholder group
Verify and Validate
g. Evaluating results

Table 5 outlines important characteristics for a subset of the constituencies that were considered in the establishment of a communication plan. Table 6 suggests some "key messages" for each constituency that were based both on their values, beliefs and needs.

It was important that the BICA team addressed not only the need for knowledge transfer, but also the need for investment. At the same time, most strategies that encouraged ownership would be quite time consuming and expensive and would not reach as many people. It was therefore decided to adopt an approach with a "broad but shallow" component (like email or posters), and a targeted approach that would reach fewer people, but would engage those individuals more seriously. The framework of the presentations would be something like "we're

about to move into the next phase; we're looking for your involvement; here is the framework we've developed and why we've organized it in this way; what do you think should be happening inside this framework?"

The communication with the faculty was established by dialogues with individual research groups (Sections), in which a member of the BICA team held a small group presentation. The first part of each presentation was a wake-up call "*Our curriculum does not inspire, is an outdated curriculum in an internet world; it is fragmented and has lost most of its cohesion".* The second part of the presentation was about investment: *"Here's the framework, it is logical and coherent. It is a boundary condition, arrived after quite a bit of work." "We don't know the details of what "goes in the boxes" yet." "We want you to help us with these details in your area of expertise."* The BICA team summarised ideas from the meetings, sent compiled versions to all individual Sections and used them as input to the next stage of design process.

Table 5 Summary of constituents and their current knowledge and beliefs

Constituency	***Important because…***	***Care about…***	***Knows about new curriculum?***
Management Team	Authorization of programme Strategic planning Manpower and budget allocation	- Educational and research productivity - Reputation - Resources	Dean and Management Team are well aware and reasonably up-to-date.
Heads of Section	Source of political support Allocates manpower for development and for instruction	- Research productivity - Reputation: "AE is hard; we're the best." - Disciplinary content and coherence - Visibility within the faculty - Getting MSc students - Financial resources	On average, reasonably aware. Highly variable knowledge.
Teachers	The people who will actually design and deliver educational experiences	- Research productivity - Reputation: "AE is hard; we're the best." - Disciplinary content and coherence - Workload - "My Boss says…" - Personal careers planning	Generally low knowledge.
Education & Student Affairs	Provides support for educational programme. Provides academic counseling	- Feasibility of study, including effects on rules and regulations - Perpetual students - Complexity during transition phase - Quality evaluation planning	Variable.
Students	The primary customer and co-producer of the programme	- Reputation: "I chose AE because it's hard." (note: students interviewed cited perceived challenge more frequently than interest in aeronautics or space!) - Feasibility of study: "The domino effect" - "Good" classes	Very low; Students in the Faculty Student Council and the Board of Studies have some knowledge about the curriculum innovation
Industrial Board	Hire students	- Reputation - Quality of graduates	Low but are aware of the on-going innovation process

Table 6 Possible key messages for different constituencies

Constituency	***Key messages***
Management Team	"We shouldn't expect results overnight." "The new programme is an appropriate answer to the university's focus on education." "The quality of the new programme will be better than the current program."
Heads of Section	"The new programme will be better than the current one." "I am willing to devote resources to the new program." "Students will find this new programme compelling."
Teachers	"I am excited about developing new courses/projects and about using new pedagogical approaches in the new program." "Skill development matters as well as content delivery." "The thematic structure is as important as the disciplinary threads." "The study expectations are reasonable."
Education & Student Affairs	"I understand how I will be able to guide students through this program." "I understand how students will transition from the old programme to the new programme."
Students	"I understand how I will transition from the old programme to the new program." "The new programme looks compelling."
Industrial Board	"The new programme will meet industry's needs." "Graduates of this programme will be better than graduates of the old program."

The BICA team also held a large scale presentation of the curricular structure and implementation details for the faculty. This presentation was intended to communicate information about the structure to the broader community, and show that input from the individual Section meetings had come into the process. This presentation was aimed more at students and supporting staff and therefore placed greater emphasis on issues around study feasibility, transition plans, and how compelling the curriculum would become. The presentation requested feedback from the audience in a structured form and promised a future report as the detailed design process proceeds.

The end of the Definition Phase was the last opportunity for opponents to influence the early adopters of the innovation. The BICA team anticipated an effort by the opponents to break the community of early adopters apart by asking questions to individuals and use their different answers to cause disorder. To make sure that all BICA team members and early adopters would tell the same story, we anticipated on this by formulating predefined answers to such so-called Landmine Questions *"How will it be ensured that things will be aligned?" "Who controls what content is incorporated in a course?" "How will development teams be chosen?"*

Success

This communication effort in 2007, after the design of the curricular framework had been completed by, was key success factor. By actively seeking for feedback from all involved parties, it increased the perceived openness of the BICA team. Secondly, it targeted the message (one message for the Heads of Section and teaching staff; another for a broader community). Finally, by incorporating all input from the teaching staff into the broader community presentation, it was possible to increase community buy-in: people love to see their own ideas presented.

LESSONS LEARNT FROM THE SYSTEMATIC CURRICULAR REFORM

Curricular change is technically relatively simple but socially complex. Understanding the principles of change is essential for successful change. A clear vision on the new programme and objectives of change is crucial. It creates a sense of urgency and the clarity for the need of change.

An innovation project should adopt a change paradigm that matches best with the existing experiences, culture and change to be achieved. Because rationally planned strategies for curricular change are not always rational when the social dimension comes in, change management strategies vary over time to realise the results and get everybody on board. Different stakeholders have different roles that may change over time. Colour-thinking can help in understanding the essentials of curricular change and selecting the best working methods and the most suitable persons to achieve the results and ensure grip on the process per phase of development.

The style of leadership, or the leadership itself may vary over time because of the changing focus in activities. Leadership may vary from top-down (upper management in the lead) at the beginning when defining the strategy, objectives and curricular framework, to bottom-up (teachers in the lead) when defining intended learning outcomes on course level and the course content and didactic method. Professors should not be given a leading role or a direct involvement in the actual creation of a new curriculum.

A Systems approach with clarity in planning and frequent plenary reviews provides positive pressure on the developers. Phase gate reviews (points of no immediate return) are valuable elements in a curricular development flow but require strong leadership: academic professionals take nothing for granted, want to analyse, think, change, re-analyse to get evidence for every step to make.

Different faculty constituents have different concerns and objectives, and therefore different needs of communication. Establishing a Communication Plan that describes which messages are important at what time per constituency, prepares the developers for different communication strategies to different constituencies.

Quality of curricular reconstruction can only be achieved when staff is committed. Positive pressure can be generated by peers in reviews if there is safe environment. The positive pressure enhances internal accountability and thus motivates the teachers and control quality, planning and slippage.

CONCLUSION

Changing an engineering curriculum is at least as challenging as designing complex systems. It is not the product but the social dimension and process that makes it difficult. The technical part will only happen when the leaders have a deep grasp of the principles of change.

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REFERENCES

[1] Akker, J. van den (2003); "Curriculum Perspectives: An Introduction". In J. van den Akker, W. Kuiper, U. Hameyer (Eds), Curriculum Landscapes and Trends (pp. 1-10), Kluwer Academic Publishers.
[2] American Society for Engineering Education (2009), Creating a Culture for Scholarly and Systematic Innovation in Engineering Education, Ensuring U.S. engineering has the right people with the right talent for a global society, ASEE, Washington.
[3] Caluwé de, L.; Vermaak, H. (2006), Learning to Change: A Guide for Organization Change Agents, Sage Publications Inc. 2003
[4] Caluwé de, L., Vermaak, H., Colors of Change, Twynstra Gudde, www.youtube.com/watch?v=RgEvL0aQxoE , accessed 6 March 2013.
[5] Crawley, E.; Malmqvist, J. (2007), "Rethinking Engineering Education", Springer Science and Business Media.
[6] Fullan, M. (2007). The New Meaning of Educational Change, 4th ed., Teachers College Press
[7] Guest, D. The hunt is on for the Renaissance Man of computing, The Independent (London), September 17, 1991
[8] Kamp, A. (2011), Delft Integrated Engineering Curriculum. Proceedings of the 7th International CDIO Conference 2011. Technical University of Denmark, Copenhagen, Denmark, June 20-23, 2011.
[9] Kamp, A. (2012), The Trail of Six Design Projects in the Delft Bachelor Aerospace Engineering. Proceedings of the 8th International CDIO Conference 2012, Queensland University of Technology, Brisbane, Australia, July 1-4, 2012,
[10] Mars, Annemarie (2012), Hoe krijg je ze mee, vijf krachten om verandering te laten slagen, van Gorcum
[11] Ruth, G. (2012), Achieving excellence in engineering education: the ingredients of successful change. The Royal Academy of Engineering.
[12] Visscher-Voerman, I., Gustafson, K.L. (2004); Paradigms in the theory and practice of education and training design; In Education Technology, Research and Development, 52(1), 69-89.
[13] Wijnen G., Kor R., Het managen van unieke opgaven. Samenwerken aan projecten en programma's, Kluwer Bedrijfswetenschappen, Deventer, 1996

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