CREATING CREATIVITY:

FACULTY ENGAGED PROGRAM DEVELOPMENT

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Abstract
Motivation among faculty for internally generated creativity and change, as well as means to promote it, are presented and discussed, resulting in suggestions for a smooth program development method, with the use of an innovation management model, for the Engineering Physics Program at the Royal Institute of Technology as it adopts the CDIO syllabus.

Keywords: Faculty, Engineering Physics, Program Development, Innovation Management, Creativity, CDIO

Introduction
Professor Herbert Simon is claimed to be one of the most influential social scientists of the 20th century. Simon writes in his book *Administrative Behavior* [1] about organizations and individuals:

Having discussed the process whereby the individual becomes a member of an organization, we come to the next problem, which is how the organization fits the individual's behavior into an overall pattern – how it influences his decisions. Two aspects of influence may be distinguished: the stimuli with which the organization seeks to influence the individual, and the psychological 'set' of the individual which determines his response to the stimuli. These may be termed the 'external' and 'internal' aspects of influence, respectively.

We propose here that there is a need for an overview inspired by Simon's great penmanship. The CDIO model has broken many boundaries and come along way by incorporating students as well as external stakeholders (*i.e.* future employers) in the development process surrounding an educational program. Although this progress is well needed, we believe that the instructor's role has implicitly been marginalized to that of an executive and administrative force.

We wish to raise the question of what makes for an environment in which instructors want to participate in a change process, and also want to be creative about their own course development. We want to go further than to just accept the instructor as an element in an optimization procedure, and we will propose that the key to implementing models such as CDIO successfully lies mainly in two factors: the individual instructor's ability to be creative and the communication between the faculty members of an educational program.

First out, we are going to examine the theoretical framework for creativity and semantic concepts, and this will mainly be done by referring to other writers on these subjects.

Next, we report on something a bit more hands-on. In order to work with program development, we believe it to be imperative that each participant sees his or her own gain in contributing to the process. In order to try to map this program opinion landscape, we have made in-depth interviews with a group of instructors participating in the Engineering Physics program at the Royal Institute of Technology. The interviews aim at studying perceived goals and values as well as the semantics used to describe and conceptualize the program environment and mission.

Finally, we will pose what we believe to be practical and efficient measures by which creativity, communication and participation in change can be promoted among the faculty members of an educational program.

Elements of Change

Creativity

We wish to begin our journey towards a toolbox for improving faculty creativity by looking at the very meaning of the concept of creativity. We use as a cornerstone in our discussion, and the following reasoning, the definition of creativity stated by the physicist David Bohm [2].

David Bohm divides our knowledge of the world into *facts*, *orders* and *structures*. Facts are independent elements of the world as we perceive them, which interact, coexist and are coordinated in different relations or orders. Levels of orders in turn form structures, which are in a sense a map as to how we categorize and interpret the world as a whole. Bohm argues that creativity is the ability to find new orders by perceiving facts in a new way, and thus add to or even reorganize structures of orders of facts. In order to be truly creative, Bohm demands of the individual to strive to have a certain quality of originality, which he describes as follows:

One prerequisite for originality is clearly that a person shall not be inclined to impose his preconceptions on the fact as he sees it. Rather, he must be able to learn something new, even if this means that the ideas and notions that are comfortable or dear to him may be overturned.

Bohm also clearly states the impossibility and contradiction of truly defining originality, and thereby also creativity. Still, the notion of the dynamic nature of what it really is to be creative implies that creativity can not be commanded or externally forced in any way.

Li Bennich-Björkman, professor in political science at Uppsala University, specializes in creativity, university organization and research policy. She argues that it is imperative that creativity is allowed to grow internally rather to be forced by external control [3]. Bennich-Björkman uses research results from management sciences as well as social psychology and the science of innovation to map different effects and aspects of how to create a creative environment. She refers to three key elements from social psychology, used to promote creativity, namely *domain-specific knowledge*, *cognitive abilities* and *intrinsic motivation*.

Bennich-Björkman refers to researcher Teresa Amabile, who argues that the individual needs a certain amount of subject knowledge, domain-specific knowledge, which in a sense enables his or her creativity within this domain. The direct effect of such a statement is that a person who is truly creative within one domain may also be unable to be creative within another domain. Another important aspect of domain-specific knowledge, apart from genuine subject knowledge, is the knowledge of *what we do not know*.

Cognitive abilities can according to Bennich-Björkman be enhanced by training, of which she writes:

The cognitive abilities, which can be trained, concern aspects such as the ability to make unexpected associations, thinking in terms of contradictions, study chains of reasoning and re-examine accepted preconceptions.

Note that Bennich-Björkman's description of the cognitive abilities is quite similar to that which Bohm uses to describe the intrapersonal process of creativity.

Li Bennich-Björkman emphasizes that intrinsic motivation is the most important aspect of creativity, and states that almost all research points to this as a fundamental factor not to be taken lightly. She argues that intrinsic motivation, when one takes an active interest in the assignment and through curiosity gets the inner drive and genuine will to solve the problem and find the answer, mobilizes the vast amount of mental energy that is required to create something new better than external demands ever could.

In comparison to Bennich-Björkmans reasoning, David Bohm writes:

Evidently, then, the ability to learn something new is based on the general state of mind of a human being, it does not depend on special talents, nor does it operate only in one special field, such as science, art, music or architecture. But when it does operate, there is a undivided and total interest in what one is doing.

It should be noted, that there is of course some differences between knowledge and creativity, as well as between creating and learning. Bohm, however, uses the terminology so that 'learning something new' actually refers to something not previously known rather than something that someone is actively being taught.

Summarizing, it seems that creativity is not a concept that will easily let itself be institutionalized, and dealing with the mission of creating and promoting creativity, this might just be the core value of how to approach the problem. David Bohm retells an interesting story about Anne Sullivan and Helen Keller:

Here, I am reminded of Anne Sullivan, who was the teacher of Helen Keller. When she came to teach this child, who was blind and deaf from an early age (and therefore unable to speak as well), she knew that she would have to treat her with complete love. However, on first seeing her 'pupil', she met a 'wild animal', who apparently could not be approached in any way at all. If *she had seen only to her preconceptions she would have given up immediately. But she worked with the child as best she could, with all the energies at her disposal, remaining extremely sensitively observant, 'feeling out' the unknown mind of the child, and eventually learning how to communicate with her.*

The key step here was to teach the child to form a concept (which she had never learned, because she had not been able to communicate with other people to any significant extent). This was done by causing her to come into contact with water in a wide variety of different forms and contexts, each item scratching the word 'water' on the palm of her hand"

Keeping these theories and perspectives in mind, it is still important to remember that creativity is something subjective rather than normative. In the story above, Anne Sullivan is being creative when she finds a (new) way of communicating concepts to the child. Helen Keller in turn, is equally creative when she herself gains understanding of the element of concepts. Thus, it would be unfair to say that someone who has found a new order among certain facts is per default creative when she or he teaches it to someone else, or that this person is creative when understanding what he or she is being taught.

Creativity, Faculty and the CDIO Approach

Given that *creativity* might actually be impossible to institutionalize and control by rigid procedure, and given that it is in fact a research area of its own, why should educational programs and their faculty be so concerned with teaching to students and/or implementing it amongst themselves? The concept of creativity is central to the faculty of an educational program from two distinctly different points of view, namely that of the individual students and that of the program management.

From a student perspective, it is desirable to have creative instructors because this causes the educational process to at least implicitly encourage creativity among students and aid them in mobilizing the mental energy needed in a fruitful learning process. If indeed the instructor explicitly focuses on creativity, the students can at least get the opportunity to practice their cognitive abilities in connection with their subject knowledge, which yet again promotes creativity.

From a program management perspective, creativity is central to facilitate change and development, and to maintain a dynamic and qualitative educational structure. In order to implement change and improve educational programs, the faculty members of that program needs reasons and incentives to adopt change. On one hand there are the possibilities of economic and authorial incentives, but for faculty to adopt a policy of change such as that of the CDIO-initiative, we believe it to be imperative that each instructor can be creative in adopting the changes at hand. Otherwise, the change will in fact be a conflict in which program management strives to maximize the effect of the policy and faculty wants to minimize the workload the change requires on their behalf.

D. Boden writes on the topic of *Adapting and Implementing a CDIO Approach* [4] the following about faculty's role:

Faculty are asked to be innovators – they are asked to adapt their teaching style to one that is more student-centered and to teach personal and interpersonal skills, and product, process and system skills specified in the syllabus. There must be a process for supporting faculty as they enhance their competence, in teaching, in new forms of evaluations, and in engineering practice and related skills. Enhancement of faculty competence must be accomplished while protecting the academic careers of faculty.

At this point there is already a conflict between the CDIO approach and the faculty that is to adopt it. Boden continues to promote the opportunity for faculty to attend courses, take sabbatical leaves to work in industry and indeed also to hire faculty that has industrial experience. This might work in educational programs where the conflict is of less magnitude because the core subjects are well-represented in industry, but what about the mathematical department? The CDIO-initiative focuses primarily on the student as an individual in a learning process and as a product of an educational program, but in doing so the role of the instructor has become an implicit one. Unless the instructor is already involved and enthusiastic about the CDIO approach, there are only hierarchical incentives for him or her to adapt and in truth there are no real reasons at all to do anything at all in addition to what is required. This is not a favourable way to implement change, and it might even be destructive for the ecosystem of people that constitute an educational program.

The Semantics of Change

Psychology professor Steven Pinker describes semantics in the following way [5]:

Semantics is about the relation of words to thoughts, but it is also about the relation of words to other human concerns. Semantics is about the relation of words to reality – the way that speakers commit themselves to a shared understanding of the truth, and the way their thoughts are anchored to things and situations in the world. It is about the relation of words to a community – how a new word, which arises in an act of creation by a single speaker, comes to evoke the same idea in the rest of the population, so people can understand one another when they use it.

Pinker encompasses clearly why semantics is not just some detail, but perhaps the most important cornerstone in any cooperation. In established groups there is a common set of concepts, which are used to describe the world the group is jointly concerned with, but when several such groups interact, semantic gaps will start to show between them. The same seems bound to happen when instructors from different fields of science and different departments come together to form an educational program.

When adopting at protocol of change, as well as in any team effort, it is necessary construct and work with an intra-group set of concepts which have a universal meaning to the group and are interpreted equally and similarly by each group member. It is also vital to share a common goal, formulated within the concept space of the group. In the same way the group needs a execution plan and a method of evaluation based on the shared values and formulated with the shared concepts.

Even if this can seem to be a trivial task, or maybe even an unnecessary dimension of the problem of change, it has proven to be an element that is all too often left out or taken for granted when working with adopting or implementing change.

In our interview survey, we found that in addition to prioritizing different concepts differently, each instructor's interpretation of the concepts given to him or her also differed widely. It is clear that there is a vast difference between asking a person to prioritize a set of concepts, and finding that same persons true preferences in terms of interpretations of and prioritizing of those same concepts. In fact, there might actually appear to be a conflict between two persons, just because they associate different concepts with different values.

In an academic setting, it is also notable that different terminologies and different concepts create a sense of belonging and an internal hierarchy in each discipline or institution. Hence, when people from different institutions interact there is a possibility of miscommunication simply because different concepts hold different values to each of them, depending on the vocabulary of their own discipline.

When working with an educational program cross-disciplinary communication becomes more evident, since both parties have to adapt to a new, common program concept environment, whereas other academic settings allow for simpler switches in between disciplines when one visits the other. Also, the frequency of interdisciplinary interaction and communication seems to differ prominently between different universities.

In change management, it is often necessary to introduce and work with new concepts in a established group setting, and this will also be reflected in a uncertainty about the new concepts in comparison with those that the group have used previously and converged on a common interpretation of.

Re-Engineering for Creative Change Management

We wish to propose here a overview of the instructor perspective on an educational program, and based on this we wish to reason about how to encompass not only student-centered educational tools in the shape of the CDIO syllabus, but also a toolbox for change management among instructors at an educational program. We have taken our inspiration from philosophical as well as empirical research on creativity, but also from the vast knowledge of change management that has been accumulated in industrial settings for centuries.

We have focused on mapping the current situation with respect to the instructors involved in the Engineering Physics Program at the Royal Institute of Technology, and suggesting proper tools and procedures to continue from, and improve on, this diagnosis. It is important to note that this is not only a question concerning the single instructor's opinions, but also the concept of a program mentality and how each instructor perceives his or her part in an educational program.

Research into innovation procedures and innovation mechanisms have resulted in several models aiming at explaining as well as optimizing innovative processes. One such model has been developed by E. Roland Andersson and Carl Rollenhagen [6]. They have through empirical experience and experimental research created a model they call the *System Group Methodology*, which is designed to work best in environments where **a)** it is hard to see what the possible options are and **b)** attitudes changes might be needed to catalyze real change. We will argue that the premises for this methodology, or at least relevant parts of it, also fits for the adoption process connected with the introduction of the CDIO approach. Furthermore, this methodology simplifies the continual adaptation required in a CDIO-program.

Interview Survey

In order to map an instructor perspective, we have conducted several in-depth interviews with the faculty of the Engineering Physics Program at the Royal Institute of Technology, where we have asked questions and confronted the interviewees with statements in order to get a picture of their perceived structure and perceived values of the program. The questions have been centered around the Engineering Physics Program's goal, structure and methodology, as well as each instructors course as part of this program. In addition to these questions the interviews have focused on letting each interviewee give his or her background on why they hold the values they hold how they interpret certain key factors in program management and what their personal relation to and goal with the program is.

It is important to note that this is an in-depth interview survey, which means that the results have no general statistical significance for programs at the Royal Institute of Technology or any other university. Also, not every instructor has been interviewed, and their identity has been concealed to focus solely on some of their priorities, perceptions and values in relation to each other. The general significance of this survey lies in the methodology and the interpretation of the outcomes rather than the exact results presented below.

Perceived goals

First, the interviewees were asked to state the program's mission and goals, by listing 5 key words relating to what the program's product (the graduating students) should encapsulate. The resulting list has a wide spread, but with certain clusters of more or less synonymous words. The list will be presented in a condensed format, where each word will be commented to reflect its meaning as it was presented to us during the interviews.

Critical consideration

Critical consideration refers to the student's ability to criticize accepted theories, and value information in order to determine the quality of a solution or theory.

Modeling

Modeling is a cluster concept for the ideas of creating, working with and evaluating physical and realistic models. The modeling concept was used to describe basic mathematical problem solving, as well as high level simulation and discipline-specific modeling. It's important to note that when the word was used to describe high level, high details work, it was not considered equally important to the bachelor grade of the program as when it was used to describe basic methodology and terminology.

Problem Formulation
Problem formulation is a cluster of the words problem identification and problem formulation. The difference lies in the fact that problem identification implies that there is a more or less well-posed problem to be found, whereas problem formulation leaves the question open and allows for the conclusion that there is no relevant way of posing or solving a problem given the information at hand.

Problem-solving
This is perhaps the single most well used term when the interviewees describe the program in different contexts. Here, this is a cluster for words like calculation technique, problem analysis, general and specific problem solving.

Group dynamics
Group dynamics is taken to represent teamwork within the program, but also interdisciplinary teamwork in between different educational programs. Different instructors value group assignments differently, based on whether they are explicit and externally controlled or optional so that the students can design their own groups within certain size intervals. Some argue that group dynamics are best taught by simply letting the students work however they want with hand-in assignments, while others promote group assignments with constructed groups and certain rules and conditions.

Employability
Employability refers to the student being well prepared for their first job, not only in terms of subject knowledge but also in terms of personal and interpersonal skills. In short, employability is an accumulated measure of the entire educational process.

Analytical methodology and terminology
Analysis was prioritized quite differently by different interviewees, ranging from implicit definitions of analysis as part of the problem-solving process to explicit definitions pointing to the separate methodology of analysis or the terminology associated with analysis.

Independence
Independence was emphasized in the context of educating students and future engineers who can prepare, perform and evaluate their work independently.

Quality certificate
This category is twofold, on one hand emphasizing the importance of signaling the quality of the graduating students to future employers, but on the other hand focusing instead on signaling the quality of the educational program to presumptive students. These two interpretations are not entirely contradictory, but they must be treated and taken into account in different ways.

Curiosity
Curiosity was brought up during the interviews to emphasize the weight of encouraging the students to do more and learn other things, on their own initiative, than just a predetermined set of course curricula.

General knowledge
The meaning of general technical knowledge encompasses subject knowledge as well as general problem-solving. The concept was brought up in terms of *general technical knowledge* as well as *general knowledge of natural sciences*

Research-preparatory
The idea of making an educational program research-preparatory aims at focusing the educations towards a target group of future researchers with academia and academic careers in mind.

Subject knowledge
Subject knowledge as a concept accentuates the teaching of factual content. It can be argued that this goal can be achieved in different ways, but there was a surprising consensus among the interviewees that subject knowledge is best attained through a subject-oriented curriculum.

Learning abilities
An educational program aimed at promoting learning abilities not only focuses on what students learn, but also how they learn and how they can become more efficient learners. During the interviews this factor was brought up as strength to make the graduating students more versatile in applying their future careers.

Communication
Communication is taken to represent personal and interpersonal skills with fellow students and faculty as well as other target groups, with different background knowledge, in different contexts.

We have mapped the occurrence of each category by its frequency (number of interviewees who made it a top-five priority) and by how well the interviewees assessed it in the current program structure

Using the frequency measure, it becomes clear that different members of faculty perceive the goals of the Engineering Physics program quite differently. Still there are some common concepts and goals that many faculty members seem to share, especially when the meaning of each concept is taken more explicitly into account. In Figure 1 the frequency measure is plotted into a pie chart to show the relative frequency of each category. In Figure 2 the same measure is plotted into a diagram, showing the common intersection between the different interviewees.

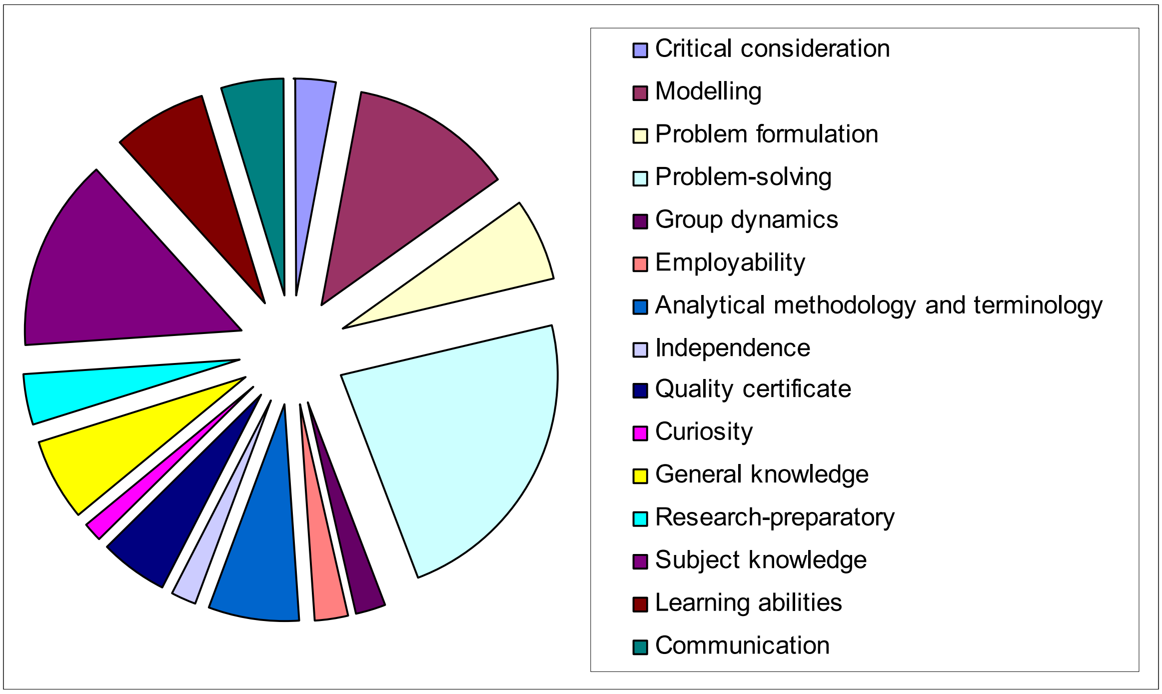

Figure 1. Pie chart of the relative frequency of each category as mentioned by the interwiees concerning perceived goals

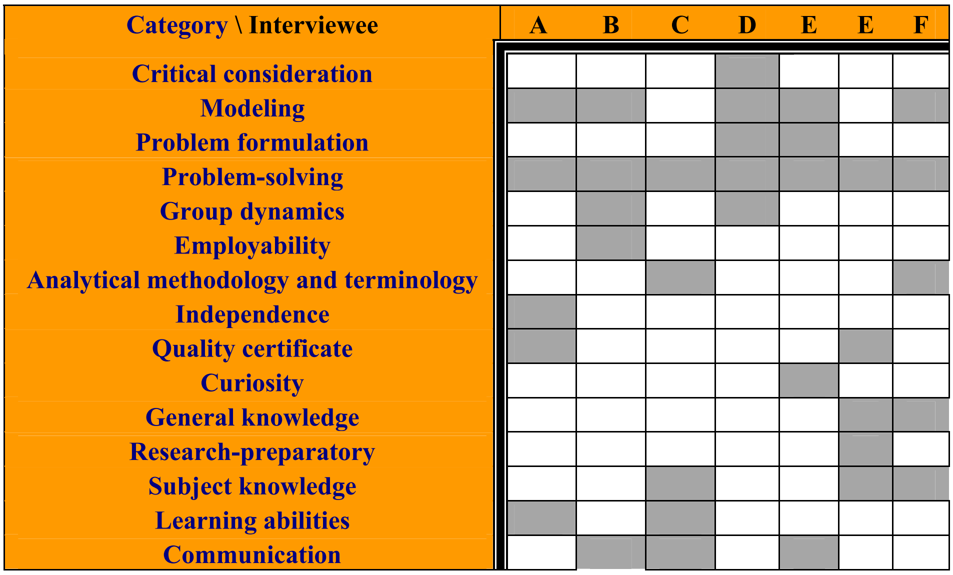

Figure 2. A diagram of the common intersection between the different interviewees

At the end of each interview, the interviewee was asked to formulate the core mission of the Engineering Physics program as they perceive it today, and as they would want it to look in the future. To some extent the same concepts are used there as in the first assignment (above), but given the freedom to formulate a mission statement, and taking into account that they have had the chance to develop their arguments during the other assignments they have taken part in during the interview.

The suggested current mission statements were:

1 - *Wide general knowledge combined with problem formulation, problem-solving and analysis*

2 - *A wide spectrum reflecting currently relevant knowledge in mathematics, physics and mechanical engineering, organized to be as far-reaching and hard as possible*

3 - *A wide knowledge of natural sciences and technology*

4 - *Traditional education in physics*

5 - *An extensive education in physics*

6 - *To understand physical problems and handle them with the help of an extensive knowledge of mathematical and numerical methods*

7 - *Education in applied natural sciences with focus on how to solve concrete problems*

Almost all the interviewees were satisfied with the mission statement the perceived today, and did not want to change it in the future. Number 4 and 5, on the other hand, wanted to change the mission statement to the following:

4 - *To learn, to work with and to communicate problem-solving and physical modeling*

5 - To *solve problems with and communicate information about physical models*

Summarizing these statements with respect to certain concepts, namely Width, Problem formulation and Modeling, Problem Solving, Subject Knowledge and Communication, we have plotted these statements into a diagram in Figure 3 to portrait the collective perception of the programs current and future mission statement.

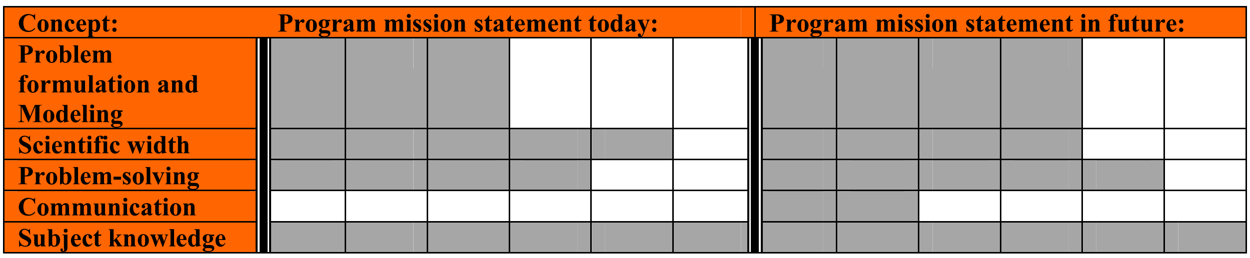

Figure 3. A diagram of the collective perception of the programs current and future mission statement.

Perceived Values

In another part of the interviews, the interviewee received a list of pre-defined concepts concerning the program development. The interviewee was then asked to prioritise these concepts according to their relative value in comparison to each other, and after having done so they were also asked if there were any concepts in the list they wanted to cut out of the priority all together. It is emphasized during each interview that the priority supposed to reflect the approach taken to teaching in the program, and not the set of courses that constitute the program.

The list of concepts presented to the interviewees contained the following words:

- Engineering skills
- Subject knowledge
- Research Methodology
- Problem-solving
- Problem formulation
- Leadership
- Communication
- Group dynamics

The results were divided into three groups of concepts and plotted into spider-web graphs, with each dimension representing one interviewee. The groups were organized to reflect some common similarities between the concepts in each group and some common differences between the concepts of different groups. Since the assignment required the interviewee only to prioritize the list of concepts, their answers are converted to a point system, stretching from 8 points for the highest, and 1 point for the lowest priority. If the interviewee chose to cut words out of the priority, these received 0 point.

The interviewees' interpretations of these concepts are not as explicitly taken into account as in the previous part, but some consideration was taken to make connections between previous interpretations and priorities. At the same time as this assignment requires the meaning of each word to be fairly similar in between interviewees, and so the interviewer gave some rough domains for each concept.

First, *Engineering Skills, Subject Knowledge* and *Research Methodology* were categorized into one concept group in Figure 4. These concepts were according to the interviewees connected by their relation to common disciplinary knowledge and fundamental skills.

In some cases it was clear that Engineering Skills and Research Methodology receive opposite interpretations from the faculty of the Physics Department in comparison with the faculty of the Mathematics- and Engineering Mechanics Departments. The members of the Physics Department generally gave the concept of Research Methodology a positive interpretation, while giving Engineering Skills a quite low rating and a negative interpretation. The opposite was true for members of the Mathematics- and Engineering Mechanics Departments. Although not in agreement about the actual words, it turns out that the values each interviewee charges word they perceive as positive with are surprisingly similar. The positive interpretations both refer to the respective concept as a measurement of system perspective, the ability to make approximations and find relevant terms and measures in which to present an answer and to estimate the degree to which that solution is relevant. The negative interpretations on the other hand are connected to the notion of unstructured and unscientific methods, oversimplified calculations and silly make-pretend assignments.

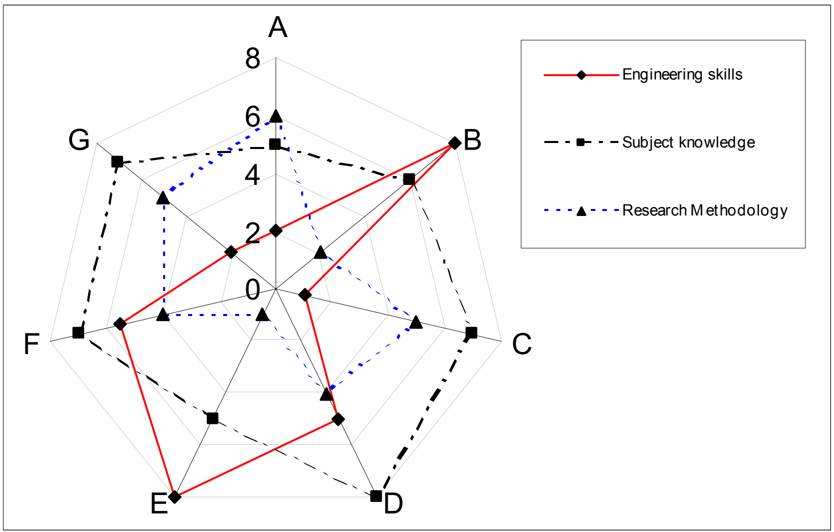

Figure 4 Spider-web graph of the first categorized group

The resulting priority of these concepts clearly shows that Subject Knowledge is a high priority across the group of interviewees. It is never given a lower rating than five, and it is never cut out of the priority order. This is perhaps not surprising for an engineering education with such a strong focus on mathematical and physical sciences, but it is never the less important to note that there is in fact a consensus rating of this concept to a mean level of 6.4 points and a total score of 45 out of 56. The priorities of Engineering skills and Research methodology reflect the interchanged interpretations of the two concepts by different interviewees (strongly correlated to witch department they belong to). Still, taking into account that the concept are to some degree interchangeable pointers for the same values, it is possible to make a read of their joint mean value, which amounts to 4.2 and a mean total of 29.3 out of 64. If these measures are taken to represent the values rather than the explicit words, it is clear that system perspective and methods for estimation and determination of solution relevance hold a priority across the interviewees, since the two concepts are never cut out of priority order and are never simultaneously rated low.

Next, Problem-solving and Problem formulation were grouped together in Figure 5 to compare the relevance of posing and solving problems as perceived by the instructors. It is clear that Problem-solving is the highest priority across the group of interviewees, and it receives the highest mean, 7.3, as well as the highest total score, 51 out of 56. Problem formulation is ranked third most important in mean, 5.6 points, as well as in total core, 39.5 points. Only in one case is Problem formulation prioritized to Problem-solving, and in this case Problem formulation is given the second highest priority, while Problem-solving is the third highest. Overall Problem-solving is never given a lower priority than third highest, while Problem-solving has a dip at third lowest in one case.

It is obvious that Problem-solving, along with Subject Knowledge, is jointly perceived are some of the most important aspects of the Engineering Physics program according to the instructors.

This is also reflected by how the interviewees express their opinions about the program, which is strongly biased towards a subject-oriented fundament, complemented with problem-oriented aspects the further on the educational process goes. This stand is not contradictory to the CDIO approach, although the discovery of conceptual differences partly explains why CDIO can be perceived as hostile to those core values that each instructor holds.

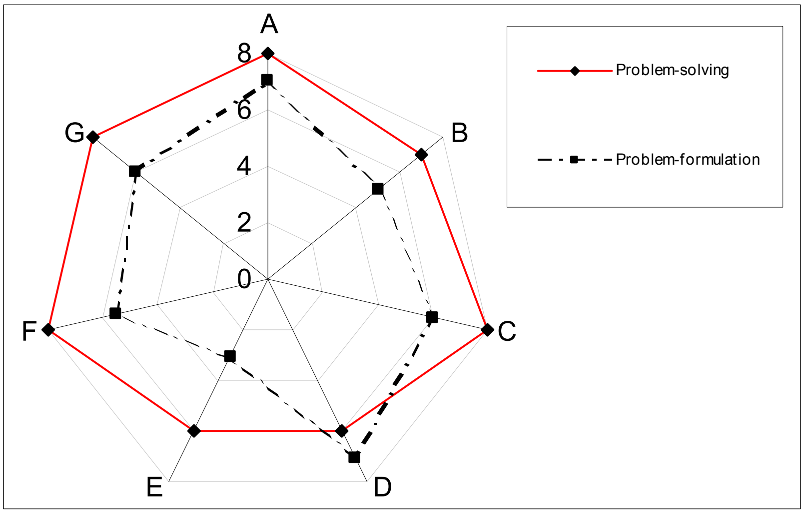

Figure 5. Spider-web graph of the second categorized group

Last, *Leadership, Communication and Group Dynamics* are grouped together in Figure 6, mainly since all these concepts represent personal and interpersonal skills.

It is immediately noticeable that these concepts receive lower priority overall, and none of them have a mean score higher than 4, although Communication was given 4 points by one interviewee.

Among these concepts, Communication receives the highest ranking, and from the interviews it is obvious that many instructors prioritize the inter-disciplinary as well as intra-disciplinary communication. Communication is mainly referred to as oral communication, but written communication receives equal priority when the interviewees are confronted with such a comparison. Even if none of the concepts in this group received any substantial ranking, it stands clear that the interviewed instructors favor the implementation of Communication, rather than Leadership or Group Dynamics, as a measure to increase personal and interpersonal skills.

Group Dynamics, as a concept, is met with skepticism from most interviewees, and when asked about this reaction most respond that they do not believe in forcing group dynamics on the students by teaching it explicitly or intervening in group formations. The idea of group assignments or cooperation with hand-in assignments is not met with the same negative reaction, and some interviewees are open to increasing the amount of hand-in assignments and making these more complex by adding numerical modeling and simulation problems. So, it seems that the low ranking of Group Dynamics mainly reflects unwillingness towards any explicit action reaching further than to allow groups on hand-in assignments.

Furthermore, Leadership is cut out of the priority order by all but 2 interviewees, who gave it the lowest or next to lowest priority. Many of the interviewees expressed concerns that Leadership is something inherent in personal growth, or to some degree in Group Dynamics, but that it should not be given explicit priority in an educational process. In explaining why, a common answer was either that leadership can not be taught, that the faculty has no expertise in teaching leadership or that leadership comes with other abilities such as Subject Knowledge. These opinions can of course be contested, but more relevant here is the fact that there is a similar consensus among instructors across departments about how these concepts should be ranked. This means that suggested changes presented only with respect to the introduction of personal or interpersonal skills will (presuming that these words were used) be perceived as an attack on the collective set of values, or at least something incompatible with the program goals.

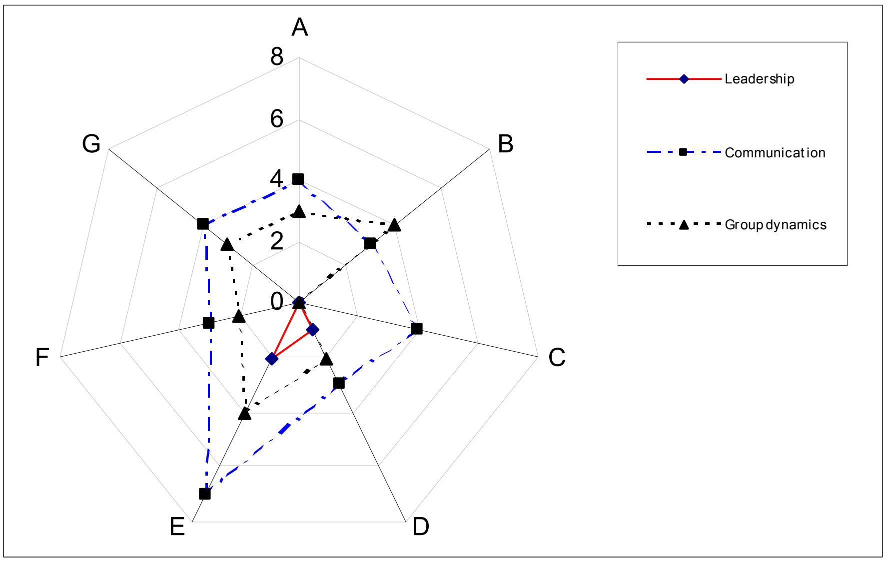

Figure 6. Spider-web graph of the third categorized group

In conclusion, there is clearly a set of values held collectively and in similar priority order among the interviewed instructors. Comparing the three groups of results, it is obvious that the perceived values of the Engineering Physics program are mainly directed towards teaching subject knowledge, problem-solving and problem formulation from a system perspective, with a secondary focus on communicating the learned skills to other within the same discipline as well as to other, such as employers or colleagues from other engineering branches or other disciplines as together. Some interviewees also stretch the importance of communicating scientific content to a nonscientific audience.

To summarize, the total results were plotted in a spider-web graph in figure 7, with each dimension representing one of the eight concepts, and the total scores are rescaled to a graded scale of 0-8. This gives a fairly good view of how the interviewed instructors perceive the Engineering Physics program, and also what program development-and change plans should take into account in order to preserve quality and make improvements without introducing unnecessary conflicts.

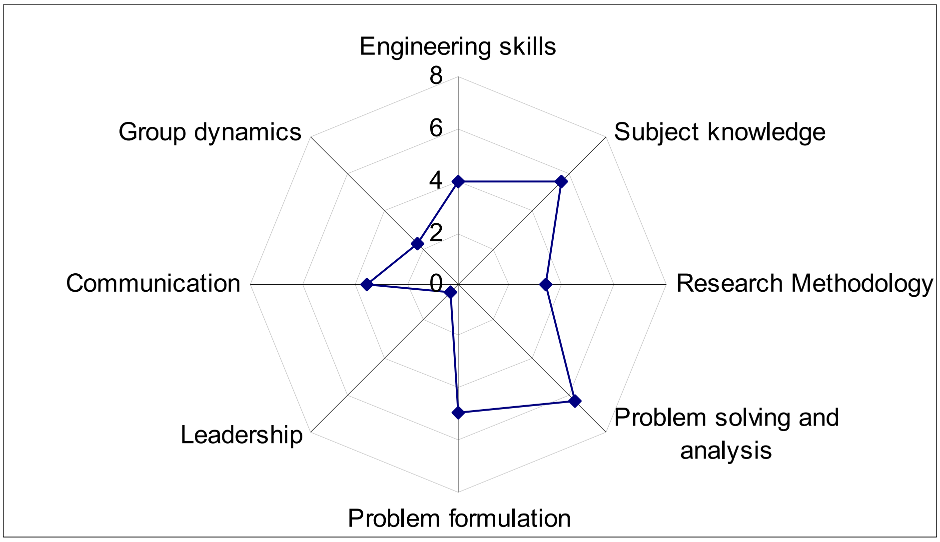

Figure 7. The spider-web graph of all categories

It is of course necessary to take other stakeholders, like students and potential employers, into account when planning program development and running change management, but faculty represent an all too often underrated opinion in program management, not least in the CDIO approach.

Perceived Structure

During each interview, the interviewee was asked to map their own course into the program structure as they perceived it by motivating its place in the educational process and connect it to previous and succeeding courses. To begin with, the idea was to map the entire program in accordance with the interviewees' perceptions, but it turned out that the results given were quite a lot more general, and as for naming the order of the program curriculum most instructors knew essentially what courses the students had taken before their course and would take after finishing it. More interesting, as it turned out, was the program mentality as it was perceived from the perspective of each instructor.

It turns out that many of the instructors experience a inertia in communication within the program and between different instructors from different departments. Many relate to the ease with which they communicate within their own department, but express the need to be able to feel comfortable with "just picking up the phone and call one of the other instructors involved with the program". This negative experience was, according to the same instructors, partly mended with the program conferences that have been arranged during the past year. Mostly, faculty members only meet to discuss economical issues and externally planned changes that affect the program.

Apart from this, a few interviewees express a demand for central management concerning more extensive changes and program development questions, while others emphasize their independence. It stands clear that none of the interviewees wish for total independence or total regulation of program development, but the desirable structure seems to be unclear even to the instructors themselves. This signals that although the faculty members perceive the physical topological structure of the program, they are at least to some extent unclear as to how the organizational topology looks. This is to some degree connected to the organizational changes taking place at the Royal Institute of Technology as a whole due to the Bologna Process among other things. Even so, it is imperative to the program mentality that there is a collectively coherent perception of the organization. This will be dealt with more extensively later.

Tools for Crafting Change and Creativity

The problems brought up and defined in this paper are mainly that of encouraging creativity among instructors and creating a commonly perceived structure and organization for change management and communication within the program. In order to confront these challenges we will need a toolbox of different methods and models, and suggestions will be made here about how certain tools can be used to create certain effects in program development.

The System Group Approach

The System Group Model was developed by professors E. Roland Andersson and Carl Rollenhagen as they worked with and did research on innovation processes. The model is designed to fit a certain type of systems:

a) Systems in which it is hard to see what the possible options are
b) Where attitude changes might be needed to catalyze real change

The System Group is in essence a smaller model of the entire system in which the innovation or organisation is supposed to work. This means that all stakeholders are represented, and not only by managers from each department, but from a mixture of those who will have to deal with the changes or who belong to the target audience for a certain innovation. The idea of creating a smaller replica of the system and to make sure each stakeholder or department is not only represented by its manager mainly aims at creating a common structure within which a common domain of concepts, and later ideas and procedures, can be devised. It is Imperative to the System Group that the goals are not strictly predefined, since this disables the creative element of the model. Andersson and Rollenhagen write:

To begin with, the 'Problem Space' (borrowing an expression from Newell & Simon, 1972), which is given by the conditions of the problem, is 'open' and weakly defined (simply because one does not know that much about the conditions). But through the dialectic process (through which the successive confrontations of ideas with reality in each 'loop') the Problem Space closes up and becomes more well defined.

The loops Andersson and Rollenhagen refers to are iterative repetitions of the working scheme defined within the System Group Model, as described below:

1 *Problem Seminar*
2 *Idea Seminar*
3 *Idea-choosing Seminar*
4 *Idea-development Seminar*

For each phase of the project at hand this scheme is used to move on to the next iteration. For example, the first iteration represents the conceptualization, while the following might handle the development of the design and the final might be about the execution.

From the perspective of managing an educational program, the System Group approach is advantageous in its ability to accumulate a common domain of shared concepts by iteration, and then, based on this domain, construct common orders and perceptions from which new, joint, ideas can be encouraged and developed.

The System Group model differs from other organizational models in the aspect that it fractal in its applicability. A system group can be constructed around the entire program, around a semester or perhaps even around a single course. In the latter case it would strongly resemble the Kaizen Group that Sören Östlund *et al.* promote after successful implementation in the Vehicle Engineering Program at the Royal Institute of Technology. The System Group differs from Östlunds Kaizen model only in that it works proactively with an artificial system reacting to the development instead of targeting and reacting to the signals of the entire actual system. In the case of a single course model, the Kaizen model might be advantageous, while the System Group model gives the appearance of encapsulating greater structures better. Together, these two models could help keeping a continuous communication during a change process as well as preserving and securing quality of the resulting program structure.

Other Tools

The Power of What We Do Not Know

The semantic issues raised in the interview survey clearly show that words are more than just details in the machinery of interdisciplinary cooperation, such as that of an educational program that employs courses from several institutions.

By working with a common domain of concepts, one does not only make sure that any decision made on the basis of that domain is in fact collective and coherent. It is also valuable to note during the process by which this domain is established, how interpretations of concepts differ and what this actually means. In fact, this is equivalent to research conducted through comparison studies in between different sciences, by which new connections and thereby new details about, the concepts are revealed. This process is in many aspects similar to the one each student goes through when learning the different subjects, although of course each such process is unique with respect to the individual who perceives it.

So, by working with concepts we can also map what we, both as individuals and as a group, do not know, and we can learn something from it. This also raises the question of how common concepts can be put to better use in the educational process, for example by encouraging instructors to step outside their subject domain to analyze or criticize their own models and methods. This could also be achieved by inviting guest lecturers with the mission to study the same, or some similar phenomena, from the perspective of another science or methodology.

A Common Identity

During the interview process, it became radiantly clear that there is a need for a sense of belonging within the frames of an educational program. This is partly covered by the idea of creating and maintaining a common domain of concepts, but this is mainly a structural and not an executive measure.

Many of the instructors expressed a wish to find easier ways to communicate. At the Engineering Physics program we have started arranging program conferences, at which we only plan parts of the schedule, to allow for larger as well as smaller discussions among instructors and program management.

Apart from this, it is worth to investigate how the university's information infrastructure can be used to create simpler forums or mail-lists between faculty or fractions of faculty to simplify group communication in between conferences.

A Clear and Transparent Structure

In order to promote communication and individual initiatives there must be a clear and easily perceived structure for the organization. Each participant of the organization should know what their domain of action is, as well as what others domains are. Most importantly, there must be a clear division of responsibility and authority between instructors and program management.

To achieve a functioning structure built on a common domain of concepts, it is important that the organisation I transparent and easily accessible so that each member can see his or her own position as well as that of any other member. This allows for easier cooperation between members ad well as easier communication and conflict management.

A Question of Time

As has been pointed out time and time again, one major obstacle towards promoting creativity and change in program and course management is the time at each instructor's disposal. There are mainly two types of time issues: The time span of each course, limiting what can be covered and what type of assignments can be handled, and the working time of the instructor, who also has to be able to tend to his or her research and not be set back in his or her academic career because of external demands on teaching methods and course content.

The CDIO model partly deals with the first type of time issue by integrating new concepts into the current course structure, thus making better use of the lecturing time without cutting out classical values such as subject knowledge. The other type of issue on the other hand, is not dealt with as easily. Although there is a growing opinion forming in favor of giving more credit to teaching experience and teaching-related activities, this is not yet an accepted value for academic advancement and it is far from an equilibrium opinion among academia globally. This can be handled in two ways. One is to minimize the time it takes the instructor to keep a continuous communication with the rest of the program faculty members and the work related to program- and course development (which is of course attractive in any case since it makes for a more efficient process), and the other is to work actively with branding and marketing of faculty involved with CDIO-related projects and work. CDIO is internationally established, and could easily work to market not only students related to the process, but also instructors, and this would make for a initially risky but from the long-term perspective promising investment for engaged instructors.

Creating Creativity

The main issue for this paper, the goal in some sense, was to establish how to promote faculty members active participation in program-and course development, mainly by encouraging creativity. As was stated initially, we believe that creativity can not be explicitly controlled by external forces, neither is it possible to instruct individuals to be creative. Creativity demands a lot from the individual, and it is required that she or he sees a gain in the process of creativity. In some sense the prior suggested measures to create a common domain for and a sense of belonging within the program environment are aimed at solving this problem as well. Within a common space where dialog between instructors is promoted, creativity is more easily triggered, but it might not be enough. Since we deem it impossible by definition to command creativity, we will settle for making the various thresholds for creative processes as low as possible.

First out, any economical system for division of means within the program should be given a dynamical fraction which can be used to promote change projects on a shorter time spam. This way, there is actually an incentive for the individual instructor to consider revising his or her course in cooperation with program management to better fulfill some joint goal.

Furthermore, students should be invited to help with course development. This is an efficient way for students to get an extra-curricular activity while learning more about the subject at hand. For example students can be used to do research for project assignments aimed at the following.

Also, instructors should be encouraged to present their own research when they teach, but they should never be forced to present research that they do not feel familiar with. This would only cause extra work for them to prepare such activities. Here, it would be more strategically sound to encourage that other instructors from neighboring program courses visit and do guest lectures on a quid pro quo basis. To get in touch with external guest lecturers, program management can compile a list of potential lecturers which could be easily accessible for the faculty. Also, of course each instructor would be free to facilitate contacts from his or her own network.

Conclusions

The system of higher education, however it may be organized, is machinery with several stakeholders on each side and current students and faculty in the actual process. Each part of this machinery is equally important, although current trends tend to favor one in front of the others, mostly because this was previously the least favored one. In an attempt to balance this system in the search of an efficient engineering education, we believe that the instructor plays a key part in facilitating the interests of other stakeholders. Instructors are all too often treated as part of the establishment, when they indeed play a much greater part in encouraging the learning process as well as other characteristics such as imagination and creativity. The latter of these is the center of our attention in this paper, and we aim to categorize what makes for a more creative faculty.

It is our assumption and conclusion, as portrayed by survey results, that creativity is something indefinable and unique to each individual. Creativity is in some sense the individual reaction to a set of problems given the certain domain to which these problems are applied and require solution. Since each instructor holds his own perception of his environment, varying with department, program, course and even personal experience and values, it follows that in order to promote creativity we must work with secondary indicators. By jointly among faculty defining a common domain of concepts to describe the work at hand and a order of procedure in which this work is to be completed, we believe that each instructor is given more freedom to form and create the content of his or her course according to his or her own preferences.

We believe that the research and suggested methods derived from innovation technology and innovation management can be of great importance to the CDIO-initiative in order to further implement and revive the CDIO approach in engineering education internationally. In accordance with the System group Methodology describes earlier, it would also be interesting to investigate how the exchange of knowledge during international conferences can be enhanced in similar ways.

At the Engineering Physics program at the Royal Institute of Technology we will implement a System group structure among the instructors of the compulsory course syllabus, in order to revive old ideas as well as encourage new ones and foster an internal creativity among faculty members.

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