CONTINUOUS IMPROVEMENT OF A CDIO PROGRAM USING MANAGEMENT BY MEANS

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Abstract

The Vehicle Engineering program at KTH was one of the first programs that adopted the CDIO-model for engineering education. The implemented changes was during the first three years subjected to a number of internal and external evaluations, with very positive judgments. Perhaps, the most important task for the program management after such a major overhaul of a program is to motivate faculty for continuous improvement work. Faculty have put a lot of effort into the change process, and they are in general not easily susceptible to further demands from the program management. Thus, there was an appropriate opportunity to try a new management philosophy.

This paper describes how the *management by means* concept is introduced in the continuous improvement work of the Vehicle Engineering program. This concept, that is in contrast with traditional *management by results* concepts, has been used successfully in industrial engineering development work. The main feature of the *management by means* concept is that the development work is driven not by explicit preconceived targets, but by common values and principles.

The paper presents the development of common values and principles for the Vehicle engineering program, and the implementation of them in the practical work, carried out in a change group covering all first year courses. Benefits and difficulties are described and the experiences gained so far are discussed, particularly, the dual loyalties of faculty that arise in the educational system at KTH where a program, in general, is not owned by a department.

Keywords: management by means, kaizen, first year courses, continuous improvements

Introduction

The Vehicle Engineering program was one of the first programs that adopted the CDIO-model [1] for engineering education. The first cohort of students, which follow the reformed program, begun at KTH in August 2003, and they are expected to graduate in 2008.

The changes implemented in the reformed program has been subjected to a number of internal and external reviews, with very positive opinions from the reviewers. The relations between the new learning objectives and the associated teaching activities were also reviewed by a number of students and found to be in very good agreement. The development work of the Vehicle Engineering program was also noticed in a positive way by the Swedish Agency for Higher Education (HSV) in a recent review of all engineering educations in Sweden [2]. Thus, since most indicators are very positive, why bother for additional change?

Motivation for change

First of all there are still a number of issues that need further consideration. Many of these issues are related to the actual process of running the program, implementation of individual courses and student performance, and not the program structure and content. There is also a strong risk for degradation with time of the introduced changes as soon as the initial enthusiasm experienced during the change process has faded. Thus, after a major overhaul of a program, the key question for the program management is how to motivate the continuous improvement work. How do you keep the spirit among faculty that has been deeply involved in the change process for almost five years? They have put a lot of effort into the change process and are in general not easily susceptible to further demands from the program management.

Program management also has a strong believe in that a detailed knowledge of the program content and objectives among faculty is vital for the quality of the program and student learning. Therefore, we wanted to develop methods that advance faculty knowledge.

There was a fear among program management that their major task in the future would be to check that every instructor did what was expected according to the integrated program descriptor [3], and not to put efforts into further improvements. Thus, there was within the Vehicle Engineering program an excellent opportunity to try a new management philosophy. Inspired by the quality work at the Swedish truck manufacturer Scania, the *management by means* (*MBM*) concept was considered [4]. This concept, that is in contrast with the traditional *management by results* (MBR) concept, was originally developed by Toyota, and has also been used with success for example in management of health care.

The main component of the *MBM* concept is that development work is driven not by explicit preconceived targets, such as number of passed exams or number of graduated engineers, but by common values and principles agreed upon by the program management, faculty and other program stakeholders. Thus, improvements in the student's learning and program quality should be the consequence of actions motivated by the values and principles, and not by preconceived targets. The *MBM* concept is described in more detail in the next chapter.

Quality issues

The most important quality problems experienced in the new Vehicle Engineering program are related to the work load of the students, practical problems like scheduling, little time for students to reflect on their learning and the lack of conceptual understanding among the students, primarily in the first and second year. There is also an observation that many students exhibit a lack of independence and have difficulties to adjust to academic studies that requires independent thinking and long-term planning of their learning. Many of these issues originate from details in the actual teaching of the individual courses, and are not easily handled by the program management. Furthermore, for funding reasons, courses at KTH are in general shared between several programs making it difficult for the instructors to introduce individual adjustments for each program. Faculty often experience dual loyalties; toward their department and toward the program, and this creates a problem of lack of freedom for the them to make the necessary changes.

Basic facts about the program

The Vehicle Engineering program at KTH is a five years program leading to a Master of Science in engineering. The program prepares graduating engineers for work in industrial enterprises related to design, manufacture and maintenance of aircraft, automobiles, trucks, trains and marine vessels, but also for work with general engineering problems requiring skills in applied mechanics and system engineering. The strength of the graduates of the Vehicle Engineering program was traditionally on analysis and component design, and less on product and system building skills, and this was the main reason for joining the CDIO Initiative in 2000.

At KTH the programs in general consist of courses from several departments. The required courses in the basic bachelor level (Year 1-3) of the Vehicle Engineering program, and the advanced master programs (Year 4-5) involve eight of the departments at KTH; Aeronautics and Vehicle Engineering; Mechanics; Solid Mechanics; Mathematics; Physics; Machine Design; Signals, Sensors and Systems; and Numerical Analysis and Computer Science, requiring special care in the curriculum design activities in order to fulfill the demands on pre-requisites from these.

Management by means

How to reach excellence and good results is an old and crucial question to most organizations. The more sophisticated our society becomes, the more we must be able to reach excellence. Today any organization will have to focus on the results, being measured and judged on how well they perform. This goes for industry as well as public service organizations. Through scientific work and long experience, Bröms and Johnson [4] found out that letting the focus on the results guide the way an organization works is actually counterproductive when looking at the actual results. Many organizations are run in this way today, where tangible result goals and advanced measuring tools are the main way and the starting point of managing the organization. This way of managing a company could be called *MBR, Management by Results*. Instead Bröms and Johnson found that it is the focus and attention of the persons involved and of how work is being done that creates excellent results. This focus and attention must start with the top executive of the company. Bröms and Johnson [4] found proof in two companies, Scania and Toyota, for this better way of managing the company and called it *MBM, Management by Means*. Both Scania and Toyota stand out by being much more profitable than their competitors and have not had bad figures for decades. Through the scientific work, these companies were found more to be governed by a common way of thinking than of tangible result goals. This common way of thinking enables the organization to improve from a bottom up empowerment, instead of a top down control.

The thinking model in MBM

In *MBM* the excellence and result of an organization is governed by a common way of thinking. Such a common way of thinking could be expressed as values and principles. In *MBM* a typical way of thinking is that the need should be the starting point of everything we do. This need explains why we do something. When it is clear why something should be done, we need to find out how to do it. Thus the way we think guides "how" we do things. Understanding "why" and "how" enables us to find a specific method that hopefully helps us fulfill the need. How well we fulfill the need is expressed as a result. Any deviation from what we think is normal will help us to question and improve our methods and how we think. By continuously questioning the way we work and try to find better ways of working we will improve the result. In *MBM* the result is, however, never the starting point.

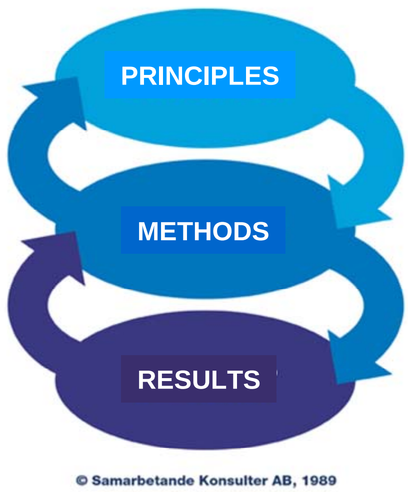

Figure 1: The thinking model in MBM, Management by Means.

Figure 1 shows the thinking model in *MBM*: principle – method – result. The model gives a structure without govern over the details; management needs to raise and explain the principles to the organization. This reduces the managements need to make decisions concerning details (e.g. how to do things…), but on the other hand increases their need to teach involved persons how to think. Everyone in the organization will be involved in the improvement work, in the same time motivation among the involved persons will increase.

A good result is the consequence of a correct way of working, a god "how". The management needs to get everyone to constantly reflect about how to improve the working methods and to act on deviations and what happens. Management needs to promote reflection and taking actions on what happens now. Management needs to empower the will and the possibility to actually implement improvements. The attitude and behavior of the managers must also be influenced by the way we think.

Improvement work

With core values and the thinking model as a background, the next step is to have a coordinated dialog concerning the principles. The aim is to create a common platform and give the involved persons in the organization the possibility to reflect about their work situation and why and how to improve. This training will create the environment for continuous improvements. When why and how is decided, the involved persons in the organization must be given the power and the time to actually do the improvements.

Different parts of an organization need to define its own culture and its own way of thinking. This requires continuous development and training of every part of an organization. The knowledge of the individual cultures could be gathered in a collective reflection. Through all this a forum is created for reflection and dialogue, and the possibility to discuss the own work situation. The dialogue will of course differ a lot between the different training teams, but this will only strengthen the power of the improvement work.

In *MBM* and when discussing principles, it is important to be patient and give clear and persistent messages. The core values and the principles create a framework and by this clearness creativity is let loose. Order and structure in this form generates creativity and not the opposite.

Implementation of management by means in the Vehicle Engineering program

The continuous improvement work according to *MBM* was implemented in the Vehicle Engineering program as a joint-project funded by the Faculty Board and the School of Engineering Sciences, which administer the Vehicle Engineering program.

Common values and principles

The first step in the process of implementing *MBM* is to establish the common values and principles that will guide the improvement work. As a starting point some of the values and principles used by companies that successfully have implemented *MBM* were reviewed in terms of applicability for university engineering education. These values and principles then lay the foundation for an exercise carried out at a faculty, student and staff meeting involving all Year 1-3 instructors, the faculty responsible for the master programs in Year 4-5 and students. At this meeting the *MBM* concept was first introduced in some detail. This was followed by a method of discussing, where all participants were given the opportunity to discuss all subjects with all other participants, but in smaller groups. Everyone therefore discussed the proposed values and principles as well as they were able to suggest modification of these or completely new ones. After some iterations, the process converged to a final set of values and principles. These are schematically illustrated in the form of an “Educational House” in Figure 2. Here, it should be stated that the values and principles illustrated in Figure 2 by no means alter the learning objectives and standards [1] imposed by the CDIO-model for engineering education.

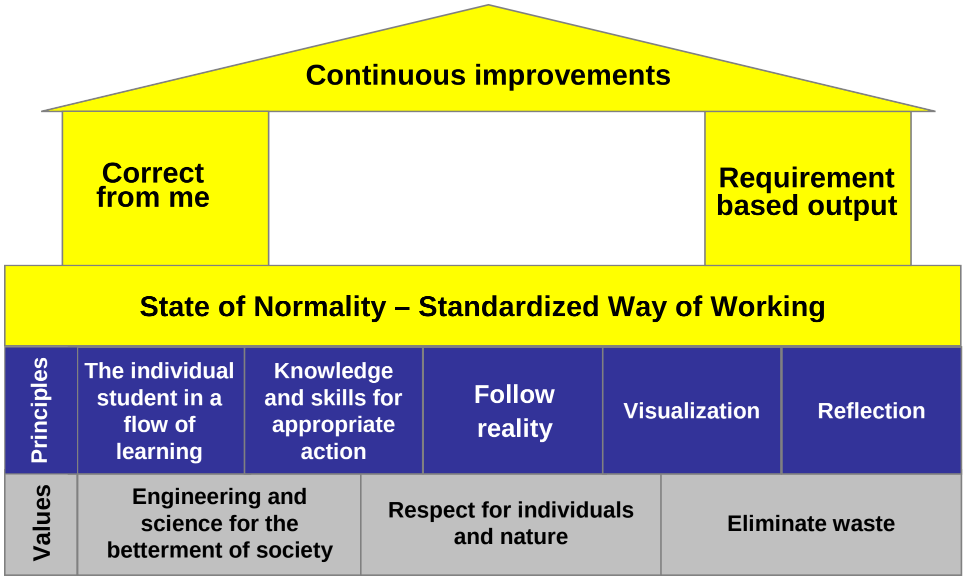

Figure 2. Schematic illustration, known as the "Educational House", of values and principles used in the quality work of the Vehicle Engineering program at KTH.

The three common values are stated at the bottom of the "Educational House". The first, "Engineering and science for the betterment of society", is to some degree a condensed form of the underlying critical need of engineering education according to the CDIO-model, i.e. "to educate students who are able to Conceive-Design-Implement-Operate complex, value-added engineering systems in a modern, team-based environment". The second value, "Respect for individuals and nature", expresses the need for every individual to be seen and respected. These engineers should learn to respect others through the respect they will get from the university. By learning that, these engineers will be able to look at the things they design not only as a profit tool for a company, but as means to improve for other humans, the environment and the society. Such engineers will engineer for a sustainable development. Finally, the third value, "Eliminate waste", is saying that we should not primarily strive to work faster. Instead we should focus on taking away waste in the system. Focusing on waste and only to do what is needed, is also laying the ground for sustainable development.

The second row of the "Educational House" lists the principles that guide the teaching and management activities in the Vehicle Engineering program. The first and most important is "The individual student in a flow of learning". This principle, that puts focus on the student's learning, may sound as an obvious statement, but we are convinced that many faculty (not only in the Vehicle Engineering program at KTH) still follow the reverse principle, i.e. they put their focus on the content of the course they teach. This can be illustrated by instructors adding more and more topics to their courses without considering whether these new topics will contribute to the program objectives or really support the learning objectives of the course.

The second principle "Knowledge and skills for appropriate action" is the CDIO concept as a principle. The students need to learn to have the right knowledge and skills for appropriate action, Conceive-Design-Implement-Operate. The learning is not aimed at passing exams.

The third principle, "Follow reality", states that what a student should learn should be appropriate for today's and tomorrow's engineering, and not reflect the importance when learned by the instructor

The fourth principle, "Visualization", should guide the improvement work and the methods developed. It is clear to any engineer that things need to be visualized to be understood. We make drawings to be able to communicate how something we designed looks like or we visualize the DNA-string through balls in a spiral, attached to each other by sticks. It is just as important to visualize the daily work. This could range from visualizing the work load for the students, the work load in each course or what basic skills that could be taught in several different courses. To visualize is not only to make the document, it is also to make it in such a way that it easily found and easily seen, through boards etc.

Finally the principle "Reflection", tells us that if we are to be able to improve we need to reflect. The students need to reflect to be able to learn and to improve and the same goes for the educational system if we are to improve that. We need to take the time to sit down together and reflect, trying to figure out things to do to improve. If we are to improve continuously, we need to reflect continuously.

The cells at the top of the "Educational House" illustrate four important working principles that also are used by Toyota and Scania. First one has to realize that the educational process typically takes place in a state of normality, i.e. the teaching and assessment activities takes place without any particular disturbances. Thus, one should be aware of that there is seldom any need for panic actions. But it is not always so that we know and have agreed on what is normal. To know what is normal is the ability to detect when something is abnormal. Deviation from the normal is the best way of knowing what to improve.

The vertical yellow cells state "Correct from me" and "Requirement based output", respectively. "Correct from me" says that everyone must focus on what they do. If everyone focuses on that, the system will work. It is much easier to figure out what others have done wrong, than too figure out what I can do better myself. "Correct from me" does not imply that we are not allowed to do anything wrong, that things must be right from the beginning. Instead it says that we need to correct things that we find is wrong and then we should try to improve. We must not be afraid of trying something that might go wrong; instead we should love correcting anything we find is not normal. "Requirement based output", means that we should work towards a need. By doing what is needed we avoid waste and thereby work for a sustainable development. It is very easy to try to do things as efficient as possible. But if the output of that efficiency does not meet a need it is waste. Extra support for the students should for example be supplied when the students need it, not when it suites the instructors. For an engineer it means that bringing down the cost in a process by having low costs in mass production is no good if what is produced is not needed. Such a waste is actually environmentally bad, since what is produced might need to be scrapped.

Finally, everyone involved in the program should always strive for continuous improvements, and which is highly important to stress, no improvement is too small to be neglected. Rather, improvements should be frequent and small in order not to move away too far from the state of normality.

Having established the common values and principles, the framework of the *MBM* concept was defined. Now, we were ready to present the project to the dean and department heads in order to guarantee their support. This is a very important step in the process because a requirement in the quality work is that the instructors should be given the freedom to carry out the required changes immediately without going through the process of having their actions approved at their own department. Here, this turned out to be a potential source of irritation in the quality work as will be discussed later. The program does not own all aspects of the implementation of the program, which is partly a consequence of the educational organization at KTH.

Forming of a Kaizen-group

An important building block in the quality work was the forming of an “improvement” group, in the sequel called a Kaizen-group. The word Kaizen is a merger of the Japanese words Kai (way) and Zen (good) and the word Kaizen, in Japanese, means “change for the better” or “improvement”. The English translation is “continuous improvement”. This group involved primarily all first year instructors, program management and consultants with expertise in *MBM*. The decision not to include students in the Kaizen-group was a matter of some discussion before it was finalized. There is a strong Swedish tradition to involve students in all stages of the program development and improvement process, and they are already participating in a number of different working groups. The experience of this is in general very positive, and the decision not to include students in the Kaizen-group should not be interpreted as any criticism against this system. However, in order for faculty to be able to speak out freely on student related matters it was initially decided not to include students in the Kaizen-group. It should, however, be noted that during the course of the work it was anyway found necessary to involve the students in the activities as will be described below. We are now at the stage of expanding the Kaizen-group concept to cover also faculty teaching the second and third year courses, but this paper will only consider the first year courses. In the next chapter, we will present some of the ideas, concepts and results that have emerged from the meetings of the Kaizen-group during its first year.

Results

The agenda for the Kaizen-meetings was very informal, and was in principle based on what was discussed at previous meetings, and instructor reflections on the ongoing teaching activities. Of course these also included faculty and program management reflections on the student’s learning, but not any direct student opinions. Such opinions were instead, as practiced for many years now, communicated at another type of meetings where instructors in parallel courses and student representatives meet with program management twice every semester.

A vital part of Kaizen-meetings are also to review the “Educational House” in order to strengthen the understanding of the values and principles. However, the main objective of the Kaizen-meetings was of course to detect deviations from the ”state of normality”, and, in such cases, then immediately take the necessary actions. This, however, turned out to be more difficult than initially expected, and it took several months before this really began to happen spontaneously. Instead, faculty as well as program management were stuck in the traditional way of solving problems, i.e. ”we need to take this into consideration in the course next year”.

Identifying the most important conceptual knowledge of the Vehicle Engineering program

Probably the most critical principle of the “Educational House” is “the individual student in a flow of learning”. For this reason it is important that the order by which subjects as well as key-conceptual program knowledge is properly designed. Of course, formal pre-requisites are taken in consideration in the integrated curriculum design [1]. This design implicitly assumes student conceptual understanding as soon as a student has been exposed to the topic once. However, in reality many students do not get conceptual understanding until working through a topic several times. Therefore, it is important that instructors are well acquainted with the implicit flow of learning of program key concepts. For this reason several Kaizen-meetings as well as two program staff and student meetings were dedicated to this issue. Despite the fact that instructors, program management and the students of the Vehicle Engineering program have been through this process previously as reported in the integrated program descriptor [3] also this process needs to be repeated and furthermore there has been some changes of instructors.

A consequence of this was that the above activities emerged into discussions of how to design continuous assessment of program objectives. This visualization of the program objectives and key-concepts interestingly raised the focus of the instructors beyond their own course, which was something that program management had hoped would happen, but still was somewhat of a surprise.

Example of visualization

There was among faculty and program management a feeling that the student work load was not well distributed among the different first year subjects. The major source for this concern was the assessment method practiced in the first year mathematics courses. However, we could not easily take in the whole picture and we did not capture the consequences of this. It was then decided that all types of assessment activities during the first and second semester of the Vehicle Engineering program should be visualized in an understandable way. The result of such visualization activity is shown in Figure 3, which shows an excerpt of all assessment activities during four weeks of the first semester.

This figure clearly illustrates the waste amount of assessment activities in the mathematics course, and although everybody was aware of the problem from the start, nobody thought it was that bad. The mathematics course, which basically occupies the students every day of the week leaves none or very little time for self-reflections, and perhaps even more important; very little time for the parallel courses.

Another problem identified was that since the overall work load during the initial part of the first semester is low (perhaps too low), the students get accustomed to the fact the mathematics course should occupy all available time. In general, the students are not aware of this problem until they begin to prepare for other exams, and realize that they have spent too little time on these subjects and are not as prepared as they should be for the exams.

Another problem identified, that was believed to stem from the intense continuous assessment system practiced by the mathematics courses, was that the students' conceptual understanding of important topics of the program was weak. The students were basically occupied by managing the recommended daily assignment, preparation for the weekly short examinations and home assignments in the mathematics course, rather than reflecting over the concepts, because they were considered necessary, and in principle also required, in order to pass the final examination at the end of the semester.

At this stage it is plausible to state that we in general support continuous assessment because we are fully aware of the advantages, but when the continuous assessment process is stretched to the limit it loses some of the advantages and promotes student activity rather than student learning. This was also reflected in the outcome of the diagnostic tests described below.

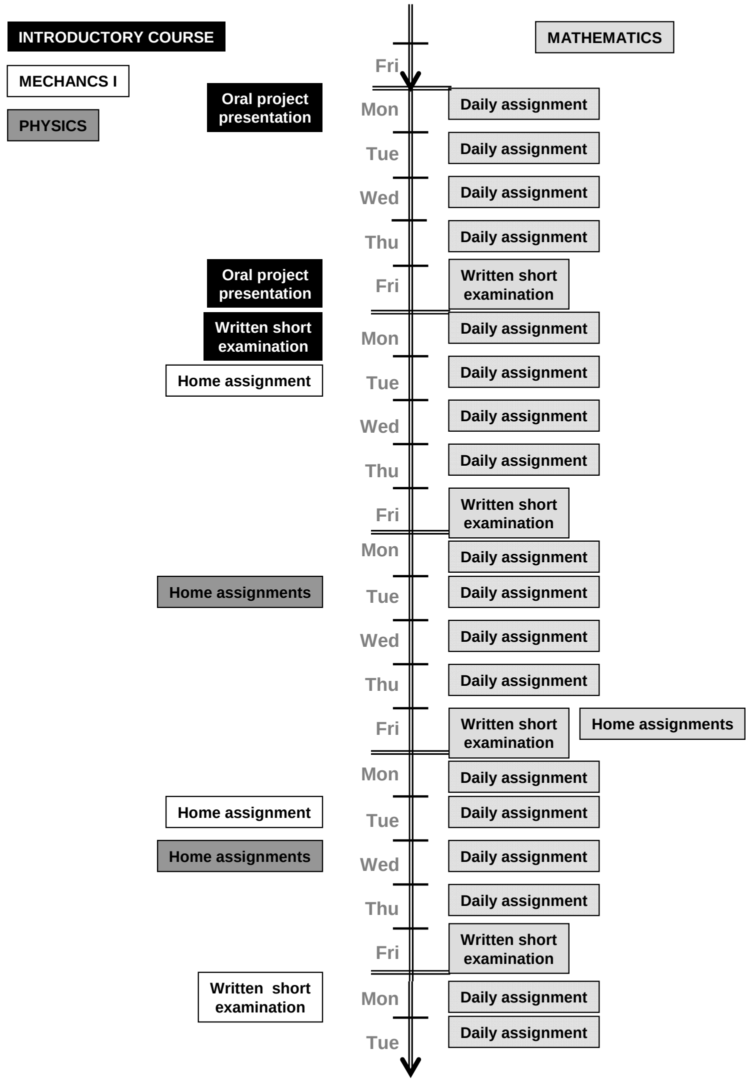

Figure 3. Excerpt from visualization of student work load (assessment) for first year students in the Vehicle Engineering program at KTH. The figure shows four weeks of the first semester.

Attempts have also been made to visualize the flow of important program concepts and learning objectives with some success. However, it has also been to some degree been troublesome. Firstly, it is not straightforward to practically design this flow based on the principle of a “flow of learning for the student”. Secondly, there are problems in communicating the visualization to instructors, but more seriously to students. A obvious solution would be to use the web, but the web is no guarantee that all involved will observe the visualization. A common work space where they can be posted would be preferable.

Knowledge transfer between courses

The first educational principle, “The individual student in a flow of learning”, visualizes the student learning as a flow where the individual courses are important building blocks in this flow. Obviously, the knowledge transfer from one course to another is a possible source of disturbance in this flow. This is further illustrated by instructors frequently complaining that students do not have the knowledge and skills stated by the course pre-requisites, and equally frequent by students telling us that the instructors require knowledge and skills that they do not recognize.

This is particularly important from a program quality point of view since these pre-requisites in general represent conceptual knowledge that will be of importance in many courses. Therefore, it was found critical, for the student flow of learning, to develop methods that could help both students and faculty to overcome these problems, or at least improve the knowledge transfer from one course to another. The aims of these methods were to detect problems in the knowledge transfer and to diminish the consequences before any formal assessment of student learning was made. Note that the formal pre-requisites in all courses are fulfilled so there is no need to make adjustments to the curriculum. What we are considering here is differences in student and instructor opinions about the fulfillment of the pre-requisites. Instructors tend to believe that students have a complete conceptual understanding of all previous concepts, while the students are, in general, only in the middle of the process of achieving this conceptual understanding. Remember also, that according the "Educational House" we strive for frequent small improvements and not necessarily for major changes with uncertain outcome, thus the method should be simple and immediately implantable.

One method that has been tried out during this first year is the concept of diagnostic tests. At the first lecture in a course, sometimes twice during the course, the students were asked to take an unprepared diagnostic test covering the major pre-requisites and other conceptual knowledge that is of importance for the present course. Typical such questions that were used in the diagnostic test in the physics course are shown in Figure 4.

Evaluate the integral $\int_{-a}^{a} \frac{x dx}{\left(a^2 + x^2\right)^{\frac{3}{2}}}$	During certain circumstances is the solar radiation to the earth E (power per unit area) given by $E = 1\,\text{kW/m}^2 \cdot \cos\left(\frac{t-12}{12/\pi}\right)$ where, t is time [h] (24 hours per day system). For which times is the equation reasonably applicable. How large is the total solar radiation to the earth (energy per unit area) during a day?

Figure 4. Example of problems given at the diagnostic test in the physics course. Typically students had considerably less difficulties solving the left, more calculus oriented problem, than the problem to the right.

Immediately after the diagnostic test, the instructor solved the problems on the black board and discussed the type of required knowledge or skill that the problem was supposed to illustrate. The students marked their own tests, and were able to obtain immediate feed-back on what is expected from them. This was appreciated by some of the students, because it made them understand their shortcomings and change their way of study in order to meet the demands at the formal assessments. Finally, the instructor collected the tests, and reviewed the result. This review made it possible for the instructor to learn about the prior knowledge of the students, and to consider this in the following teaching activities.

Program management also wanted to support the knowledge transfer between courses, particularly for those student that did not do well in the diagnostic tests. Since we have previous experience of using SI (Supplementary Instruction) [5], we based our support on group activities lead by more experienced students. Initially, this system worked out well, but quite soon the number of students that attended the meetings of the groups activities dropped dramatically, despite the fact that most student did not do well on the diagnostic tests. This was very unexpected, and we did not really know why. Thus, we immediately run into a reason for involving the students more directly in the *MBM*-activities. Obviously, we did not meet the student requirements, or alternatively the students did not realize the consequences that a lack of conceptual knowledge can lead to. The problem is really how to motivate students to focus on conceptual learning instead of “spoon feeding”. The student solution to this problem is often to suggest a change of instructor, while the instructors suggest a change of students, i.e. the complain about the quality of the students.

Student participation

In accordance with the principle “The individual student in a flow of learning”, we wanted to know the opinions of all first year students, and not only those of the student representatives. This has been met by meeting where all first year students as well as instructors and program management were invited. Typically between 25 and 50% of the students attended these meetings. The student were encouraged to freely speak about good and bad things in the program and their present problems (if any). Here, the major problem turned out to be the mathematics course, which were considered to be very theoretical and abstract. The students request was better knowledge on where to apply the mathematics, particularly in vehicle engineering.

At the first meeting it was decided that engineering faculty should contribute to this by giving short lectures continuously on the application of the mathematics in their specific subject. Note, that this was needed despite the fact that the Vehicle Engineering program, in accordance with the CDIO-model, has a well-developed introductory course. Of course part of the problem is that the mathematics instructors in general are not graduated engineers and are lacking knowledge on the details of the program. However, this is something that we cannot require from the mathematics department, and we believe that the initiative need to come from those that have the engineering knowledge.

The difference in way of thinking when using *MBM* compared to previous thinking is that we immediately try to solve the problem by whatever means that are available in short notice, rather than making a major effort in the next year. An immediate small improvement today will be noticed also by the present student group, which will increase their propensity to suggest similar actions whenever needed.

Faculty participation

The engineering faculty contributing to the understanding of the use of mathematics is an example of actions driven by student participation. There are also examples of actions motivated by instructor observations. One such example is the instructor that two week before the written examination made the observation that the students, due to commitments in parallel courses, really were not at a level of knowledge that is reasonable for them in order to be able to pass the examination. In the spirit of *MBM*, the Kaizen-group then discussed if there was anything the program could do to improve the situation. The solution this time was to offer the students a practice examination with immediate feed-back taking place prior to the formal written examination, with the only purpose to help all students to some improvement.

Another example is a suggestion by the mathematics instructor to improve the students' reading ability in mathematics, but immediately change the way of teaching of parts of the mathematics course.

Discussion

Role of the consultants

The role of the two *MBM* experts that participated in the Kaizen-group meetings was to summarize the discussions and together with the program management compile the ideas for actions. They also frequently needed to help instructors and program management to change the way of thinking and how to implement changes. It should be emphasized that it is very simple to forget about the new management philosophy and to do things the usual way, which not seldom means a thinking along the line "we should remember to implement this change next year" rather than "what can we do now".

Resources

Quality work according to the *management by means* concept as implemented in the Vehicle Engineering program required initially considerable more resources than traditional academic improvement work. This was to a large extent due to lack of experience. Both program management and instructors frequently fell into traditional management by results concepts and needed to reconsider their way of thinking as well as their actions. However, after running the Kaizen group for approximately six months all involved are slowly beginning to learn the *MBM* concept, and if the conflict related to teaching of similar courses in other programs is elucidated, it is believed that the *MBM* concept should not require more time and efforts than other types of quality work.

Support from dean and department heads

As discussed above, the program management vigilantly secured the support from the dean and the department heads for the *MBM* activities, and the dean also participated in some of the Kaizen-meetings. Despite this, the Kaizen-group activities did not seldom run into conflicts associated with the fact that the instructors are not only liable to how their course is run in the Vehicle Engineering program, but also to how their colleagues are running similar course in other programs. Thus, even though the Kaizen-group could identify required actions, the instructors did not consider themselves as having the mandate do it because it would create a conflict with the way the course was taught in another programs by their department colleagues. To avoid this, support should not only be secured from deans and department heads positioned far from the real teaching activities, but also from directors of undergraduate studies and person coordinating teaching activities in a department. It is of utmost importance for the success of the *MBM* quality work that *all* involved instructors have the commission to participate fully in all activities.

Visualization

Visualization has turned out to be more difficult than initially expected. It is hard to illustrate in pictures what faculty and program management are used to present in writings. It is, nevertheless, a very important part of the *MBM* activities. If carried out carefully it gives a very clear picture of the situation for all involved in the development work. However, in order to be useful, the visualization should be easily available for all program stakeholders. A problem encountered in the quality work at the Vehicle Engineering program is the lack of an appropriate meeting point, where the illustrations are visible for all involved in the development work.

Conclusions

The management-by-means concept for continuous improvement work has been tried in the Vehicle Engineering program at KTH, The Royal Institute of Technology. During the first year this was implemented in a "improvement" group covering primarily the first year courses. Based on the results from the first year, it can be concluded that

- Implementing management-by-means can as a consequence increase the number of students that pass examinations and graduate or other pre-conceived targets. However, it should be emphasized that within *MBM* every small improvement is worth striving for, and that could also be for example increased conceptual understanding.
- Visualization has proved to be an important tool in the quality work. However, it is essential that the visualization is made visible for all involved, including students. This, is sometimes a problem in a university environment where students, instructors and program management not necessarily share work spaces.
- Management-by-means is a concept that has a lot of potential for radical changes in the way of thinking of continuous improvement work in academia. It is an excellent tool for increasing the instructors awareness of the student learning, contribution to program objectives from other courses and it creates cooperation among faculty. The concept is not straightforward to implement, and it takes some time for all involved to adopt the new way of thinking. However, as soon as this is achieved the management-by-means concept will contribute substantially to the continuous improvement of a CDIO-program.

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