STREAMLINING ACADEMIC CHANGE PROCESSES THROUGH ENGINEERING PRINCIPLES

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ABSTRACT

Adaptability, innovation, and efficiency are core engineering skills that students have to acquire to keep pace in a fast-changing world. It is, therefore, important that change processes in engineering education reflect and promote these skills. Further, as stated by, e.g., the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG, 2015) and the CDIO Standard 12 (2010), efficient assurance, enhancement, and evaluation of educational quality is vital. However, change and quality management within universities are often slow and unwieldy (Graham, 2012; Kamp, 2016). Despite being the manifesto of engineering education, systematic problem solving is rarely incorporated into program organization and development. We have applied the CDIO concept to create a new, sustainable line of communication between students and faculty, in the form of a short program-level student questionnaire where the results are used as input to further discussion. Key concepts in the design of our method have been a *collaboration* between students and faculty, *iterative feedback loops*, and *simultaneous bottom-up and top-down* work by student representatives and the program director, respectively. These approaches have minimized the risk of failure and delay as well as actively utilized the creative power of the student body. In the questionnaire, distributed four times per year, students can anonymously share any opinions about the program. The program director and a student representative work *together* to evaluate the responses, immediately forwarding feedback to the correct recipient. Students are informed about key outcomes to ensure a trustful relationship between them and the faculty and promote active participation. With our method, issues are detected and handled at an early stage, allowing the focus within the program to remain on education, innovation, and quality enhancement. In this work, we will detail our methodology for streamlining communication as characterized by the engineering methods taught at universities. We will demonstrate some results obtained so far in improving the time-efficiency of quality management, through active student representation and trustful faculty dialogue. Still being in the early stages of operation, we will also reflect on the future outlook of our strategy. Finally, we will discuss the benefits of utilizing the CDIO concept for implementing change processes in higher engineering education.

KEYWORDS

Programme development, quality enhancement, student involvement, Standards 1, 5, 12

INTRODUCTION

The importance of efficient assurance, enhancement, and evaluation of educational quality is described by, for example, the Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG, 2015) and the CDIO Standard 12 (CDIO, 2010). These frameworks require that students should have the opportunity to make their voices heard and that there are appropriate processes to take care of student complaints. However, the possibility of educational innovation from a bottom-up approach is not explicitly supported by these frameworks. From a system perspective, this is problematic since students and teachers are only minor players in educational quality systems at the same time as they are major players when implementing change in reality. In fact, these arguments call for a complementary process where student input is strategically used for educational quality enhancement (Leander Zaar & Andersson, 2020).

Educational quality enhancement consists of change processes that, in many cases, involve behavioural changes for both teachers and students. However, there are many research reports discussing failures to create real and sustainable change in a higher education setting (Henderson et al., 2011), and it is also established that there are substantial internal barriers for creating change (Henderson & Dancy, 2007). Two keys to creating sustainable change seem instead to come from the active involvement of faculty in the change process (Graham, 2012) and to have quality enhancement processes that are connected with day-to-day work (Kleijnen et al., 2014). These conclusions about faculty involvement are also consistent with the outcomes from a previous pedagogic project at our university, where sustainable change was most easily detected when faculty had been actively involved in the process (Kjellgren et al., 2018).

Kilstrup, Hellgren, and Andersson (2011) have pointed out that "*Difficulties in implementing new ideas and activities in an organisation may be reduced if the development process is taking place within the organization and is performed by the persons that are influenced by the changes*." Since students are also influenced by educational change processes, we wanted to go one step further and try to develop a method to strategically use student input in a bottom-up approach to quality enhancement of a study programme. In addition, actively using student input may also lead to new innovative ideas.

In light of these observations, the overall aims of our work were to create a process for quality enhancement and program development that actively involves students and teachers, makes it easy for all stakeholders to get an overview of the state of the program and allows for sustainable change. A major goal with our project was also to "practice what we preach" as an engineering university, meaning that it was important to us that both our work and our results were characterized by engineering principles. With the help of the CDIO Standards, we have strived to create a method that is simple, logical, and time-efficient.

The CDIO Standards are based on the fundamental principle that products, processes, and system lifecycle development and deployment can be understood through the CDIO model (Conceiving--Designing--Implementing--Operating) and that this model also is the appropriate

context for engineering education (CDIO, 2010, Bennedsen et al., 2016). Hence, it should be natural to use the CDIO model for developing and creating educational change at an engineering university. In our work, we show an example of how the CDIO process is combined with appropriate feedback loops to develop an internal process for using student input as a strategic input to programme development.

Similarities between internal faculty change and the CDIO approach have been reported before (Berglund et al., 2015). The benefits of using CDIO to *drive* internal change is demonstrated by, e.g., Papadopoulou et al. (2019), who utilized CDIO principles in both the development and implementation of a faculty course and by Pham et al. (2012), who used the CDIO approach to design active learning exercises and interactive teaching methods. These examples imply that a CDIO-based work process can be used to improve faculty competence and student learning. Here, we extend this idea by showing how the CDIO approach can be used for general development processes at an engineering university. We will describe our strategy and show how the different stages of development relate to the CDIO model. Finally, we will also shortly discuss how our methodology can complement standard quality assurance processes and how it can be used to support an efficient change culture in higher education.

METHODOLOGY DEVELOPMENT THROUGH A CDIO PERSPECTIVE

We have (more or less) used the CDIO model during the development of a programme quality enhancement process. In this concrete example, we show how the different steps in the CDIO model match our steps in the process development. We also reflect upon the importance of feedback loops during the development process and how to strategically work to use student input for actual quality enhancement.

Conceive

In a usual course development cycle, an end-of-course questionnaire is followed up by a summarizing course analysis written by the teacher. This then serves as input to further course development before the next course offering. However, such a development cycle has some major disadvantages from a programme perspective. Firstly, it does not help a programme director to obtain runtime information about the programme. Secondly, important programme level issues may not reach the programme director until it is too late. Hence, an efficient channel for free and open student input directly to the programme level should be a useful tool for facilitating programme management and for using creative student input for further programme development. In addition, these ideas are also in line with demands for taking care of student views in evaluations of educational quality as, e.g., expressed by Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG, 2015) and by the CDIO Standard 12 (CDIO, 2010).

Naturally, a more direct line for collecting student opinions is also beneficial for the students themselves. In a traditional development cycle, students are rarely given feedback about their input: course analyses and suggested changes are usually not discussed with students, and solutions to problems they bring up may not become available during their time in the course or the programme. As a result, students may not be motivated to give input at all or feel like they are not being listened to. In other words, these factors limit both the opportunities and incentives for students to actively participate in improving their education. With our work, we wanted to develop a methodology that would increase the ability to provide real-time solutions,

allow students to easily raise both complaints and ideas, and ensure that students know they are included in the change processes.

An important part of our methodology and the formulation of our idea has been to lead by example and utilize the problem-solving abilities and the engineering principles that are taught at our university. Formulating the problem in an engineering language is also expected to make it easier to accept for both teachers and students. Our process thus had to be structured, have a logical flow of information, and be easily manageable for both students and teachers.

Design

From a discussion between the master responsible student and the programme director about the basic concepts of the problem, the development work was divided into two parts.

i) Develop an open student questionnaire - lead by the master responsible student (FLZ) - through an innovation process that also included other students at the programme.

ii) Develop a process to take care of the student input - lead by the programme director (MA) - which should be compatible with efficient management of quality enhancement.

Meetings between the master responsible student and the programme director took place during the development process in order to be able to identify other important design concepts and avoid conflicting interests in the solution.

The questionnaire was developed through an iterative feedback loop, where students were actively involved. The inclusion of stakeholder feedback in educational change processes is an explicit scale 5 criteria in several CDIO standard rubrics (e.g., in standard 3, 4, and 5). Standard 12 also makes clear that feedback about program development should, in turn, be provided to stakeholders. In a CDIO programme, it should be natural to think of engineering principles not only as a learning outcome but as a means to produce an agile environment for quality management, leading us to add stakeholder feedback iteration as a tool in the design of our methodology.

An initial version of the questionnaire was put forth by the master's responsible student and distributed digitally to the students in the programme. The invitation to answer the questionnaire also included an explanation of the basic ideas behind it, and students were also asked (as the last question) to give their opinions about the trial questionnaire itself. The questionnaire was then updated according to student needs and suggestions through an iterative process. Finally, the methodology was more deeply discussed in a student meeting, and the following issues were considered as particularly important for students:

- The questionnaire should be short.
- The questionnaire should be distributed *during* the study period so that issues can be resolved before the exam period.
- Student should be informed about how brought up problems will be solved or given an explanation if no solution is possible.

These comments emphasize the importance of inclusion and time-efficiency in change and quality management; the *collection* of these comments illustrate how these concepts can be used in a development process. By including the stakeholders of our methodology in the

design phase, their needs could efficiently be taken into account, and their ideas put to use. This approach allowed us to implement our strategy within a year of conceiving the idea, receive runtime feedback on its reception among everyone involved, and avoid misunderstandings and mistakes.

The process for handling outcomes of the questionnaire was developed by the programme director, simultaneously with the development of the questionnaire itself by the master responsible student. The original plan included forwarding relevant parts of the obtained student input to one of the following recipients:

- Course responsible teacher - if it only concerns one course.
- Programme director - if it can be solved directly by the programme director.
- Programme board - if strategic discussions are required.
- Track responsible faculty member - if it only concerns one track in the programme.
- Student meeting - if more student input is needed to start a change process.

During the development work, it became clear that it was also necessary to include the educational administration and the students themselves in this scheme. When the final version of the questionnaire was ready together with an initial process to forward the input to the right recipient, the methodology was presented and discussed within the programme board, which immediately accepted it as a good idea.

Implement

The questionnaire has two standard questions, which are always posed:

Q1: So far, what has worked well during this period?
Feel free to discuss your courses, your schedule, your teachers, program administration, or the program in general.

Q2: What improvements would you suggest?
Feel free to discuss your courses, your schedule, your teachers, program administration, or the program in general.

However, it is also possible to add one or two other questions. The aim of such questions could, e.g., be to follow up on answers to previous student questionnaires, to obtain a broader perspective of issues brought up by individual students, or to initiate a constructive dialogue between students and faculty (Leander Zaar & Andersson, 2020). The questionnaire is distributed to students four times per year (two weeks into each study period), and students can anonymously share any opinions about the programme. In our case, we used a university-specific web service for forms that provides a link to the questionnaire, and the link was then forwarded to the students by E-mail (this is similar to how Google Forms works).

The programme director and a student representative then work together to evaluate the responses, immediately forwarding feedback to the correct recipient. This ensures that the recipients only receive information that concerns them and that course-specific information (handled on course level) is separated from programme relevant information (handled at a programme level). The programme director now also becomes aware of course-specific issues that need to be handled quickly, can talk to the teacher before the course ends, and can also,

in collaboration with the department, discuss support to the teacher if needed. Some types of course-specific issues can then be solved before the course ends (e.g., missing course information or unclear information) without affecting the students too much. Strategic issues are handled by the programme director in the appropriate forum, which could be a programme board meeting, a track meeting, or a student meeting. Students are informed about key outcomes from these discussions on the programme's website, which helps to ensure a trustful relationship between them and the faculty and to promote active participation.

Operate

The methodology described above has now been in operation for two years, and we have gathered some practical experiences about how it works. A few general observations are:

- Essentially all student input has been good and constructive. However, in a few cases, it was not possible from the responses to connect a course-specific comment with a course.
- About 15% of the students answer the questionnaire.
- Feedback to students has been written for about 4-5 issues per questionnaire.
- Nearly all suggested improvements are either under consideration or have already been provided.
- The methodology seems to have been generally accepted by the teachers.
- It is possible to use student input to create change processes that are finalized.

A few practical examples of successful change processes that have been initiated by our methodology – including improved processes for providing information to students, changes in tracks, and better use of the official learning management system – are reported elsewhere (Leander Zaar & Andersson, 2020). In addition, collegial discussions seem to become less polarized when student input is provided as one of the starting points. Although the work to also streamline faculty and administrative discussions is still in progress, the indications we have so far pointed to that the CDIO principles are an appropriate foundation when developing quality enhancement processes in this context as well.

DISCUSSION

The main idea of our methodology is to build up a bottom-up quality enhancement process that is complementary to the top-down quality assurance process. While the latter is based on the concepts of accountability towards society and the use of external reviews, our methodology is based on the concepts of active participation of students and teachers, internal problem-solving, and the support of educational innovation initiatives. External quality assurance processes are not able to go into details without creating too much administration and high administrative costs. Hence, their main role is to help the organisation to identify potential strategic areas for further development, whereas they are much less useful for helping individual teachers to improve student learning and to support innovation. Our methodology has the opposite characteristics – its main role is to identify issues that improve student learning within a specific programme, support innovative ideas, and create actual change based on this knowledge. It is less useful for identifying overall strategy changes at the university level, although it can initiate faculty discussions on such issues. Besides being designed as a programme quality enhancement cycle, our methodology is also complementary to the standard course development cycle at our university (Naimi-Akbar et al., 2018, Kjellgren

et al., 2018). While the course development cycle focuses on changes for next year's course offering, our methodology can be used for creating changes already during an ongoing course offering.

It was recognized early on that time-efficiency for both students and teachers is a key design parameter for bottom-up quality management. Without implementing time-efficiency in the information flow, time, and available resources will not be spent optimally, and the internal motivation to participate in the change process will drastically decrease. Inefficient information flow will also decrease the available time for creating actual change. Although efficient information flow is a necessary condition for an efficient change culture, it is not a sufficient condition. Teachers must also feel an inner motivation to actually create change. Hence, there must also be a low barrier for teachers to create change and some reasonable economic support and appreciation to those who execute the work. From our experience, it seems as if teachers are delayed by the barriers that have to be overcome if problem-solving is done on an individual basis. Hence, an efficient collegial change dialogue is also required to support the change process. This is provided in our process by having a strategy to find the best forum for further discussions of different issues that are raised in the questionnaire. The work to fully set this up is ongoing, but what has been done so far looks promising.

One barrier towards creating change that teachers face may consist of insufficient constructive and useful student input. In our experience, teachers take student opinions very seriously, perhaps more so than rules dictated by policymakers. However, educational change processes that concern students and their role in the change process are often managed in a top-down fashion involving external reviewers, programme directors, faculty members, and pedagogic developers. Although quality assurance systems (ESG, 2015) and CDIO standard 12 both require that student opinions are collected and included in programme and course analysis, students – despite being the very epicentre of education – seldom *actively* participate in change processes. This arguably makes it more difficult for teachers to update their courses to suit student needs. For this reason, and because there is an innovative power within the student body that is now often overlooked, continuous student-faculty dialogue should be a natural way to swiftly improve engineering education at a CDIO university. Furthermore, by clarifying the student needs from the student input, it also becomes easier for teachers to use their own innovative ability to come up with new ideas that suit their own students both from a learning and a programme perspective.

From a change management perspective, it is quite well understood that change processes controlled from above have a large tendency to fail, while change processes involving faculty have a larger probability of leading to actual change (Henderson, 2011, Graham, 2012, Kleijnen, 2014). Georgsson and Holmgren (2012) have even shown that there are advantages of going one step further in quality management by including student-faculty communication through student representation in a programme board that advises the programme director. However, this board works in traditional development cycles, by, e.g., following up on end-of-course analyses. This *after-the-fact* mindset delays quality enhancement restricts the ability to handle urgent issues and stifles innovation. In our work, we have strived to resolve this by creating a method for collecting students' opinions *during* courses, as well as welcome their creativity in change processes.

The rubrics for the highest level of CDIO Standards 12 Programme evaluation, version 2.1 (Bennedsen et al., 2016), states that "There is documented evidence that systematic and continuous improvement is based on continuous program evaluation results." Our methodology clearly meets this goal for one of the key stakeholders (students), and in addition,

it attempts to take care of their innovative power to initiate further programme development. A similar process could possibly also be envisaged for other stakeholders provided that there is a mechanism for gathering information from them in an efficient way. An interesting observation is that since we have developed our process using CDIO-like ideas, the development process is by itself a design-implement experience for us and for the development of new processes at a university. This couples to CDIO Standard 5 - Design-Implement Experiences, where the standards for such experiences are described for students' experiences. A question that naturally arises in connection to our work is if a similar standard for developing internal processes at a CDIO university should also be part of the CDIO Standards?

CONCLUSIONS

We have developed a time-efficient methodology for strategically using student input for programme development, which is consistent with the rubrics for the highest level of CDIO Standard 12 Programme evaluation. In addition, our methodology promotes innovative power in the interactions between students and teachers. The process which we used during the development of the methodology followed the CDIO model, which we suggest to be a workable model for handling internal change processes at an engineering university. Through our work, we have demonstrated the value of not only teaching engineering principles but also actively utilizing them in educational change and quality management.

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REFERENCES

Bennedsen, J., Georgsson, F., & Kontio, J. (2016). Updated Rubric for Self-Evaluation (v.2.1). *Proceedings of the 12th International CDIO Conference* (pp. 140-153). Turku, Finland: Turku University of Applied Sciences.

Berglund, A., Havtun, H., Johansson, H.B., Jerbrant, A., Andersson, M., Hedin, B., Soulard, J., & Kjellgren, B. (2015). The Pedagogical Developers Initiative - Changing Educational Practices and Strengthening CDIO Skills. *Proceedings of the 11th International CDIO Conference*. Chengdu, China: Chengdu University of Information Technology.

CDIO (2010). *The CDIO Standards v 2.0 (with customized rubrics)*. Retrieved from the CDIO initiative: http://www.cdio.org/knowledgelibrary/documents/cdio-standards-v-20-customized-rubrics.

ESG (2015). Standards and Guidelines for Quality Assurance in the European Higher Education Area (ESG). Brussels, Belgium.

Georgson, F., & Holmgren, H. (2012). A Quality System for Engineering Education. *Proceedings of the 8th International CDIO Conference*. Brisbane, Australia: Queensland University of Technology.

Graham, R. (2012). *Achieving Excellence in Engineering Education: The Ingredients of Successful Change.* London, UK: The Royal Academy of Engineering.

Henderson, C., & Dancy, M. H. (2007). Barriers to the Use of Research-Based Instructional Strategies: The Influence of Both Individual and Situational Characteristics. *Physical Review Special Topics - Physics Education Research*, 3 (2), 020102-1-020102-14.

Henderson, C., Beach, A., & Finkelstein, N. (2011). Facilitating Change in Undergraduate STEM Instructional Practices: An Analytical Review of Literature. *Journal of Research in Science Teaching*, *48*(8), 952-984.

Kamp, A. (2016). *Engineering Education in a Rapidly Changing World: Rethinking the Vision for Higher Engineering Education.* Delft, The Netherlands.

Kilstrup, M., Hellgren, L. I., & Andersson, P. (2011). "Good Teaching Practice" at DTU Systems Biology - Sustaining Quality in Teaching and Learning. *Proceedings of the 7th International CDIO Conference*. Copenhagen, Denmark: Technical University of Denmark.

Kjellgren, B., Havtun, H., Wingård, L., Andersson, M., Hedin, B., Hjelm, N., & Berglund, A. (2018). The Pedagogical Developers Initiative – Sustainable Impact or Falling Into Oblivion?, *Proceedings of the 14th International CDIO Conference* (pp. 738-747). Kanazawa, Japan: Kanazawa Institute of Technology.

Kleijnen, J., Dolmans, D., Willems, J., & van Hout, H. (2014). Effective Quality Management Requires a Systematic Approach and a Flexible Organisational Culture: a Quality Study Among Academic Staff. *Quality in Higher Education*, *20*(1), 103-126.

Leander Zaar, F., & Andersson, M. (2020). Quality Enhancement Through Trustful Interaction Between Students and Teachers. *Proceedings of the 14th Annual International Technology, Education and Development Conference (INTED 2020)*, 1117-1123.

Naimi-Akbar, I., Havtun, H., & Nyberg, S. (2018). Systematic Course Analysis - How Infrastructure and Research Findings Collaborate to Support Course Development. *Proceedings of the 2018 IEEE Frontiers in Education Conference* (article No. 1570433377). San Jose, California, USA.

Papadopoulou, P., Bhadani, K., Hulthén, E., & Malmqvist, J. (2019). CDIO Faculty Development Course - Built-In Implementation. *Proceedings of the 15th International CDIO Conference* (pp. 489-500). Aarhus, Denmark: Aarhus University.

Pham, C. B., Goss, J. S. & Nguyen H. L. (2012). CDIO in Engaging Students for Engineering Courses. *Proceedings of the 8th International CDIO Conference.* Brisbane, Australia: Queensland University of Technology.

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