Lean Thinking and Quality Control Strategies for Improving Engineering Educational Processes

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Abstract

The quality of a product, in general, depends on the quality of the input materials and the quality of the processes used to realize the product. To improve or control the product quality, continuous monitoring of both the input material and the various processes is essential. The monitoring process itself requires establishing control mechanisms and feedback links to the proper process checkpoints.

Similarly, the quality of the educational process in any field usually follows the same principles. In other words the quality of both the individual and the educational process determines the quality of the educational outcome. The improvement of the engineering education outcome is directly linked to controlling the quality of educational processes. These educational outcomes, however, should be directly linked to the desired attributes and quality standards defined by the end receivers of the education process. To meet the educational objectives based on the desired outcome requires departmental structure with empowered process ownership and continuous communication strategies.

In this paper a quality improvement and control process for engineering education based on lean thinking principles is presented. The three lean thinking areas of development needed to achieve the educational process quality are discussed. The developed quality measures and feedback are linked to the educational process outcomes established based on the receivers input. Through continuous communication and feedback with empowered process ownership, academic program quality improvement and control can be achieved.

Introduction

Engineering education institutions are under tremendous pressure to produce industry ready engineers equipped with the knowledge of the emerging new tools and technologies. At the same time these institutions need to minimize the curriculum total number of hours to stay competitive. The ultimate success of any education institution, However, depends totally on the intrinsic and perceived quality of its graduates.

The quality of a product or a process, in general, depends on the quality of the inputs and the quality of the measures and control used to realize the desired result. To improve or control the quality, continuous monitoring of both the inputs and the various processes is essential. The monitoring process itself requires establishing control mechanisms and feedback links to the proper process checkpoints.

Similarly, the quality of the educational process in any field usually follows the same principles. In other words the quality of both the individual and the educational process determines the quality of the educational outcome. Educational quality, however, is the most difficult attribute to define, measure and properly control. In the following the factors causing the difficulties in defining educational quality in the receivers domain are discussed. By following the lean thinking approach an educational quality measures and control are discussed.

Lean Academics Approach

Under the pressure to stay competitive improve quality and eliminate waste and focus on the end customer several industrial institutions adopted the lean thinking methodology [1]. With increasing pressure to produce high quality industry ready engineers, reduce the curriculum time, and include mastery of new technologies educational institutions are facing similar challenges [2-4]. By identifying the end customer or client and focusing on the desired attributes of the educational process graduates the lean thinking approach can be followed. To focus on the end results and establish a process flow with integrated internal measures and feedbacks to control and improve quality the following development areas are needed:

- Develop educational quality Standards based on input from the receiving end.
- Develop educational process with the quality standard as outcome.
- Develop control mechanisms to continuously measure, feedback and improve the performance relative to the developed quality standards. .

Figure 1, shows the schematic of the proposed educational process with the feedback and quality control links. The main differences between the proposed process and the traditional approach are:

- Quality Standards based on input from the receiving end for student quality controlled by university admission, and classes controlled by the department and faculty.

- Classes quality feedback flows from higher classes to lower class based on the desired output for most traditional programs the flow from lower classes to upper classes is based on faculty desires.
- The structured continuous feedback input from all the receivers at the receiving end.

In the following each of the development areas are discussed.

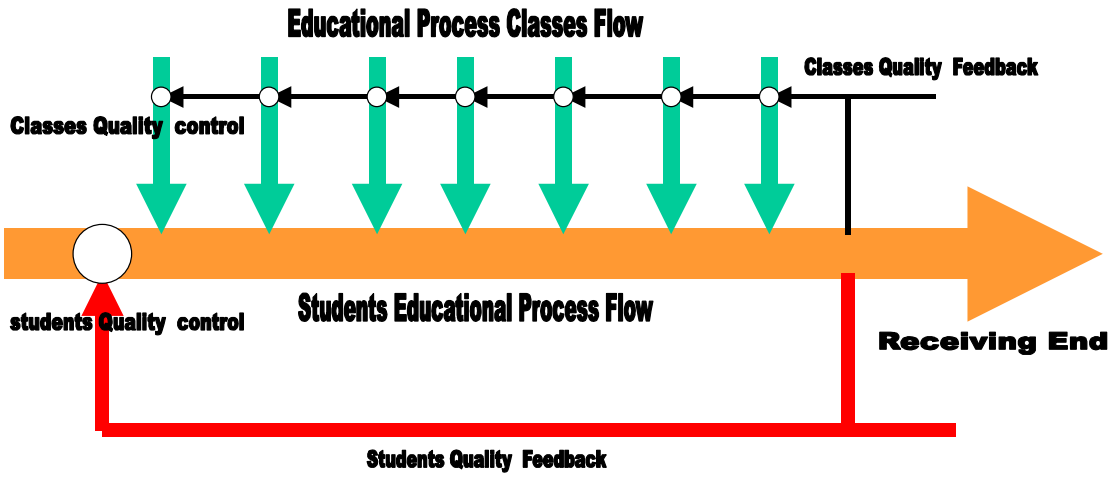

Figure 1. Schematic of the educational process flow and controls

1. Development of educational quality Standards.

For the receiver of any product or service quality is the most difficult and illusive attribute to define. The reason is that quality is in the eyes of the receiver is the sum of all satisfied experiences, the fulfillment of all anticipations, and the matching of all perceptions. In the educational services defining quality is even more difficult and more illusive since the receiver is not the end customer or client, as it may seem. The education process and its results start with the students then their future employers and finally the society at large as shown in Figure 2. These concentric circles of receivers centered by each student get larger and unbounded with time. To satisfy all experiences, fulfill all anticipations and match all perceptions for all the receivers in these circles is a very difficult task. For this reason, focusing on the student as the center of the receiving circles is usually the simplest course of action that is usually taken by many institutions in the traditional approach.

To establish meaningful standards all receiving circles input should be sought continuously. Establishing the link with previous graduates, their employers and their peers is the best approach to define and adjust the educational outcome desired attributes and standards. While, in the traditional approach, most institutions have industrial advisory boards made of employers it is very rare to find statistically viable representation of previous graduates at different stages or their peers on these boards.

For the proposed approach in addition to the formation of statistically viable boards representing all elements of the receiving circles continuous communication and feedbacks are key for monitoring, and improving the educational quality standards. This continuous communication can be established through different means and methods. These methods include periodic meetings, interviews, assessment forms and website surveys.

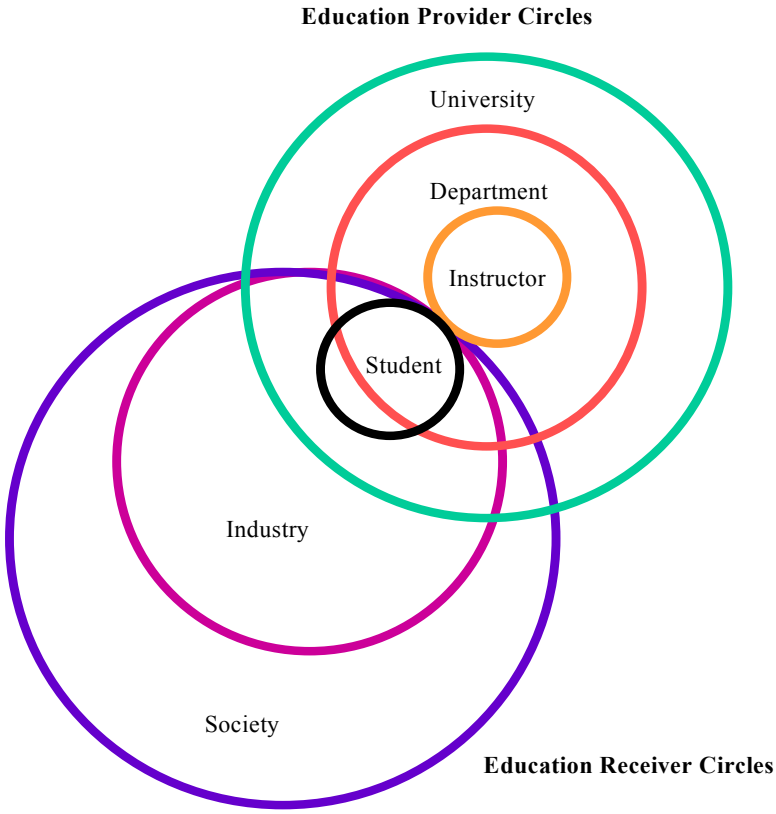

Figure 2. Schematic of the education and receiving circles domains

2. Development of educational process with the quality standard as outcome.

For the educational service provider quality is the toughest attribute to measure, control and achieve. As shown in Figure 2, due to the structure of concentric circles centered by the faculty then the department and finally the institution the measure and control of the education process quality is segmented. While the institution plays the major role in controlling the quality of the admitted students the department controls the curriculum the teaching faculty plays the main role in controlling the course content and outcome. By adding the inability of defining quality at the receiving end to the quality measure and

control problem due to the educational process structure the quality issues become clear in any traditional approach.

To establish an educational process with a set of established quality standards the process development should begin with the end in mind. On the institutional level admission standards should be adjusted and controlled by the quality standards set forth based on the receiving circle. The yearly decision of meeting the business targets or the quality targets in admission will eventually determine the perceived quality of the institution and its graduates. For quality minded institutions quality targets should always be of higher priority. For successful institutions, however, the two targets should not be in conflict.

On the departmental level to begin with the end in mind requires the development of an educational curriculum with outcome meeting the set of quality standards established based the receiving circles input. The curriculum development should start with the senior classes and move backward in developing the out come of the lower level classes. After developing and balancing the outcome of all classes the course objectives and contents for each class can be developed. This is different than the traditional approach in which classes are pieced together based on mere experience and perceptions.

At the teaching faculty level understanding the global outcome is as important as the understanding of the individual class outcome and objectives. The delivery of the course contents to meet its objectives with any addition or deletion should not affect the course outcome or the global curriculum outcome. This provides guidelines that balance faculty's freedom and the educational process outcome. This is different than the traditional approach in which faculty academic freedom, experience, and perceptions control the educational process outcome.

3. Development of quality control mechanisms

The most important elements in developing a quality based educational process are the process measures and feedback mechanisms. On the institutional level the measures of achieving the quality standards is proportional to all satisfied experiences, fulfillment of all anticipations, and matching of all perceptions for all the receiving circles all the times. This is sometimes impossible to measure but establishing indicators and measuring links with subsets of these circles at specified time intervals can provide adequate measures. Using these measures to set the admission quality targets, the hiring and promotion of faculty and administration is the quality feed back link necessary for the global success of the process. These links include established board meetings, interviews, and surveys for viable representation of all circles at the receiving end.

On the departmental and faculty levels while the development of quality control measures and feedback mechanisms is easier it requires the establishment of empowered process owners. This empowered ownership can take different forms depending on the size and structure of the department. One form of the empowered process ownership can be the establishment of course coordinators. The responsibility of these course coordinators is

to satisfy the internal customers for each succeeding course, or course sequence. By integrating with the preceding and succeeding course coordinators a course coordinator establishes the following:

1. Course learning objectives to meet departmental established outcome
2. Course syllabus
3. Course textbook
4. Course exams and projects.
5. Course feedback and assessment
6. Course continuous improvement

At the teaching faculty level adhering to the established course syllabus and continuous feedback to the course coordinator is essential for the local and global success of the process.

Implementation of the Lean Academics Approach

Traditional educational approaches lack educational output uniformity due to un-enforced common course standards. For example, in nearly every multi-section core course very few exams are common and even fewer finals are common. As such, it's uncertain to what level students are achieving stated course learning objectives collectively, or even if objectives are entirely covered by each multi-section faculty. As a result faculty complaints have steadily risen relative to the expected student knowledge set upon course entry. Basically, it's not clear what student should know, when students should be expected to know the material, why student should be expected to know the material, and how to assess the educational process product relative to a specified standard.

To improve quality and to overcome such problems the Mechanical Engineering Department at Kettering University is implementing the proposed process. Being a large multi-discipline, the department established empowered facilitators for integrating vertical and horizontal educational flows. The vertical flows represents the Thirds such as Design and Energy systems while the horizontal flows represents the Disciplines such as Automotive and Biomechanics. The facilitators work with course coordinators to establish the following work standards:

1. Common Course Learning Objectives
2. Common Syllabus
3. Common Final Exam & Course grading Percentage allocation.
    a. Course coordinator with faculty teaching course to ensure final is established each term.
    b. Course coordinators arrange for common exam time/room and administer the final exam.

c. Exam questions must be linked to course learning objectives.

d. Exam format should allows for easy tracking and historical recording of student performance, as well as, provides a built-in mechanism for ABET and North Central assessment. Assessment becomes painless, simple, and easy.

e. Final exam must be approved by internal customer receiving work product, i.e. course coordinator, must approve previous course final exam.

4. Common Textbook
5. Final exam assessment metrics to evaluate work performance, i.e. expected student performance.

Course coordinators are empowered and have the responsibility of working within their respective core discipline curriculum groups to develop a common final that must be linked to course learning objectives. The student performance results should be tabulated providing for each learning objective. Course coordinators should receive the approval of their group facilitator for course learning objectives as well as final exam content and assessment metrics.

To administer the developed educational process the department and faculty started to:

1. Establish website for every Mechanical Engineering course.
2. Establish database for every Mechanical Engineering course to record and store final exam assessment data.
3. Support course coordinators and take whatever steps necessary to support the department's decision to embrace "Lean" processes.
4. Establish appropriate incentives for facilitators and course coordinators.

Conclusion

The developed lean thinking based educational process is at early phases of implementation by the Mechanical Engineering Department at Kettering University. The full implementation and preliminary evaluation is in progress. It is expected, however, that the full implementation of the process can bring the following benefits:

1. Streamline the "flow" of learning process (i.e. what students is expected to know and when), by evaluating outcomes according to a stated quality standards.
2. Enhanced decision making through empowerment.
3. Enhanced quality control and receivers' satisfaction.
4. Enhanced team environment and communications.

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