Systemic Improvement in Engineering Education

Jeffrey Froyd, Karan Watson

Rose-Hulman Institute of Technology/Texas A&M University

Abstract

The paper describes a strategic objective of the Foundation Coalition: systemic improvement. First, a definition for systemic improvement is proposed. Second, a brief overview of change is described to promote the idea that curriculum change is a very complex process. Third, a list of tasks that can lead to systemic improvement is offered.

I. Introduction

To realize its vision for years 6-10, the Foundation Coalition established three strategic objectives: continuous improvement through assessment and evaluation, sharing with the engineering education community and systemic improvement. The purpose of this paper is to describe the third strategic objective: systemic improvement.

During the past decade, several reports that call for systemic change in engineering education have been issued. However, promoters of change in engineering education have expressed concern that systemic change had not occurred. To explore the need for systemic improvement, two questions should be addressed. What is systemic improvement? How you achieve systemic improvement?

Systemic improvement is campus-wide, profound change[1] in how campuses design, implement and evaluate responsive curricula[2] for all engineering majors. Systemic improvement has four characteristics.

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[1] Profound change is "organizational change that combines inner shifts in people's values, aspirations, and behaviors with 'outer shifts' in processes, strategies, practices, and systems. … In profound change there is learning. The organization doesn't just do something new; it builds its capacity for doing things in a new way -- indeed it *builds capacity for ongoing change* [emphasis added]. … It is not enough to change strategies, structures and systems [FC foci in the first 5 years.] unless the thinking that produced those strategies, structures, and systems also changes." [FC foci in the second 5years.] Senge, Peter, et. Al., *The Dance of Change*, New York, Doubleday, 1999, p. 15

1. First and foremost, **systemic improvement increases the capacity of an institution to continuously create responsive curricula.** As campuses create responsive curricula, they cultivate a campus-wide knowledge base for curriculum design and involve faculty members who continuously learn to create effective learning experiences. Responsive curricula require that institutions continuously increase their capacity to anticipate changes in the technological, economic and social environment and respond to these changes by continuously creating innovative educational experiences. Increasing capacity to build responsive curricula requires increasing institutional capacity to initiate, manage, and sustain change.
2. Second, systemic improvement is **sustainable**. Systemic improvement is enduring change that will continue long after funding for the Foundation Coalition ends.
3. Third, systemic improvement is **recognizable**. As a result of systemic improvement, there are fundamental differences in people's behaviors that can be recognized locally. Results of systemic improvement can be recognized nationally and internationally.
4. Fourth, systemic improvement is **replicable**. Systemic improvement is change that is adopted at other institutions.

In summary, systemic improvement has four characteristics: it is replicable; it is recognizable; it is sustainable; and it leads to increased capacity to create the future for the institution and its graduates.

II. Change: Three Perspectives

Now that we have defined what we mean by systemic change, let's examine three perspectives on change processes that could lead to systemic change. The zeroth perspective envisions change as a sequential process. The first perspective envisions two interacting processes: change process and resistance process. The second perspective is more complex; it envisions thirteen interacting processes: three processes are promoting change and ten processes are limiting change. The second perspective is based on a recent book by Senge et. al.[1] All three perspectives may provide helpful insights into avenues that encourage curriculum improvement.

Zeroth Perspective: Sequential Process

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[2] Responsive curricula adapt to changes in the external environment of the educational institution. Examples of specific changes to which curricula should respond are changes in the practice of engineering, changes in the scientific and mathematical foundations of engineering, and changes in our understanding of how people learn and how people facilitate learning. All curricula adapt, but the Foundation Coalition aims to increase the rate at which curricula adapt and reduce the effort required in the adaptation process.

The zeroth perspective envisions change as a sequential process. An institution attempting to implement change implements a sequence of steps. In a curriculum improvement process a possible sequence of steps would be the following.

1. Develop goals for the new curriculum.
2. Develop courses for the new curriculum.
3. Develop syllabi for the new courses.
4. Offer a pilot of the new curriculum. Assess the performance of the new curriculum and revise until ready to implement the new curriculum across the entire student body.
5. Offer the new curriculum for the entire student body.

The zeroth perspective ignores competing interests and it seems that no one would view change from this naïve vantage point. However naïve this perspective may appear, it appears that champions of curriculum improvement efforts often adopt this perspective and are surprised, and often become defensive, when resistance appears. Success is determined by whether an institutionalized program emerges from the effort. From the zeroth perspective failure is ascribed to an inadequate curriculum innovation or negative assessment data.

First Perspective: Change Initiative and Resistance Processes

The first perspective envisions two interactive processes: change process and resistance to the change process.

Resistance to change arises naturally in any organizations and may be caused by two phenomena. First, resistance occurs because individuals in any organization enter the change process at different times, they interpret and respond to the same stimuli differently, and change at different rates. Resistance to change is as natural as turbulence in fluid flow. Second, resistance may occur because proposed changes conflict with the culture of the organization[2]. The first phenomenon is always present while the presence or absence of the second phenomenon depends on the nature of the proposed change. Therefore, resistance to change should be anticipated and welcomed instead of producing surprised, defensive reactions.

People who resist change may be viewed by people who are initiating change as detrimental to the change effort. Instead, the perspective of the people that are resisting the change should be welcomed and brought into the open. These people have not had time to learn about and ponder the proposed change and they may need time to assimilate the reasons for the change and an understanding of the proposals. Further, if their opinions are invited, these people often bring helpful insights and productive suggestions that may be ignored to the detriment of the change project.

Second Perspective: Thirteen Interacting Processes

In second perspective, change is envisioned as interaction among thirteen different processes. The complete model will not be discussed in detail and the interested reader is referred to Senge et. al.[1] The crucial node in which most of the thirteen processes is a node labeled willingness to commit and participate. Processes that increase the

willingness of individuals in the organization to commit and participate promote the change. Processes that decrease the willingness of individuals in the organization to commit and participate limit the change. Three of the thirteen processes tend to promote change. In the first, the willingness of each individual to participate and commit grows as he/she learns more through participation. In the second, the willingness of each individual grows as members of his/her formal or informal network indicate their support of the change. In the third, the willingness of the each individual grows as it becomes apparent that the change is creating improvement in the summary evaluations that an organization uses to measure its progress. In for-profit companies, summary evaluations almost always include the bottom line. In educational institutions, summary evaluations are more obscure and, as a result, the value of the third process becomes less obvious.

In the ten processes that limit change, the crucial node is again the willingness to participate and commit. In the first process, individuals in the organization perceive a lack of time to participate. In the second, individuals perceive a lack of help and support from the organization. In the third, individuals perceive a lack of relevance of the change effort to the mission of the organization. In the fourth, individuals perceive a lack of support from upper management. For educational institutions, upper management may include senior faculty, opinion leaders as well as department heads, deans, and provosts. In the fifth process, fear of trying a new approach limits the willingness to commit. In the sixth, apparently negative assessment data reduces the willingness to commit. For new curriculum projects, negative anecdotes about isolated students or faculty tend to propagate rapidly and impact the willingness of individuals to participate to a degree that that far exceeds the value of the actual event. Heuristically, it takes twelve positive stories to equal the impact of one negative story. In the seventh process, isolation and arrogance of the original curriculum innovators can negatively impact the willingness of others to participate. In the eighth processes, the difficulty of communicating to others about the success of the innovation decreases the willingness of everyone to participate. In the ninth processes, questions raised about who is in charge decreases willingness. The ninth process is often observed in interdisciplinary curriculum projects that grow beyond a single pilot. This is because traditional governance in academic institutions is not designed to support interdisciplinary activities. In the tenth processes, questions raised by the innovation about the long-term direction of the institution decrease the willingness to participate. The relative importance of these ten processes in limiting change depends on the particular innovation.

The brief description of the second perspective is provided to promote the idea that curriculum change is a complex process. Considerable effort is required to initiate and sustain curriculum improvement in any educational institution, much less the entire community of engineering education. The next section outlines a set of tasks that, if executed on a regular basis, could help promote systemic improvement across the entire engineering education community.

III. Systemic Improvement Tasks

In this section, the paper will describe seven tasks that could lead to systemic improvement. These seven tasks must be performed regularly on at a cost that allows them to be sustained indefinitely. The question of who performs the tasks depends on the system to be improved. If the system is a single institution, then the institution should perform the tasks. If the system is the engineering education community, then the community should perform the tasks.

Task No. 1 - Understand and Document Substantial Change in Engineering Practice

Decisions about undergraduate education should be informed by the knowledge of the current practice of engineering education. Therefore, each education institution should have explicit, efficient, well-developed processes for obtaining and refining information about changes in engineering practice. The Foundation Coalition thinks that significant improvements in these processes are required to facilitate systemic change. Therefore, the Foundation Coalition will fund efforts to develop processes with the characteristics described in the following paragraphs.

Develop a process that acquires, distills, and assimilates knowledge about the ongoing changes in the environment in which engineering graduates work. It should be understood that the environment is much broader than the environment in which graduates practice for the first few years after graduation. This process will produce data and reasoning that will help faculty grasp the nature and rate of changes in the environment. Faculty have been educated to validate information that is presented to them via one of three mechanisms: 1) reasoned argument from accepted hypotheses, 2) data that substantiates a proposed hypothesis, or 3) consensus within a peer group. Currently, faculty peer groups do not agree that the environment for engineering graduates has changed substantially over the last twenty years. Therefore, the Foundation Coalition needs to present either reasoned arguments or compelling data to document substantial change or projected change in the work environment.

For example, reasoned arguments or compelling data can be presented to document changes in the work environment such as:

- increasing rate of growth in information/data/knowledge,
- increasing emphasis on interdisciplinary activities,
- increasing emphasis on interdisciplinary teams,
- increasing emphasis on adaptive work, and
- increasing emphasis on accepting responsibility for leadership.

It may be possible to collect and organize information on change in the work environment via joint search conferences with employers and academia. With a convincing case that the environment in which engineering graduates practice has changed and is changing rapidly, it is easier for faculty to accept that changes in engineering education are necessary. Further, the costs associated with the process must low enough that institutions can perform the process on a sustained, regular basis.

Task No. 2 - Benchmark Best Practices in Undergraduate Engineering Education

Decisions about undergraduate education should be informed by current best practices in undergraduate engineering education. Therefore, each education institution should have

explicit, efficient, well-developed processes for obtaining and refining information about best practices in undergraduate engineering education. The Foundation Coalition thinks that significant improvements in these processes are required to facilitate systemic change. Therefore, the Foundation Coalition will fund efforts to develop processes with the characteristics described in the following paragraph.

Develop a process that acquires, distills, and acts on best practices in undergraduate engineering education. The process must be implemented by an institution on an annual or biannual basis. The process must be maintained by a sustainable annual resource investment. It will be informed by current best practices in organizational change. The process must produce recommendations that are acted upon by the institution within twelve months. It will produce reports that could be used by other institutions.

Task No. 3 - Transform Understanding about Changes in Engineering Practice into Changes in Student Outcomes

Once information about the environment in which graduates will practice and information about current best practices are available, an institution translates the information into student outcomes and how it measures these student outcomes. Therefore, each education institution should have explicit, efficient, well-developed processes for translating its knowledge about the environment and best practices into student outcomes engineering education. The Foundation Coalition thinks that significant improvements in these processes are required to facilitate systemic change. Therefore, the Foundation Coalition will fund efforts to develop processes with the characteristics described in the following paragraph.

Develop a process through which a systemic-wide, interdisciplinary team starts with documented changes in engineering practice and develop outcomes for engineering graduates that will be necessary to succeed in the changing environment documented in Task No. 1. Once changes in the work environment have been documented, the next task is to describe changes in student outcomes that will enable graduates to excel in this environment. Descriptions of student outcomes should include instruments and processes through which achievement of student outcomes can be documented.

Task No. 4 - Transform Changes in Student Outcomes into Changes in Engineering Curricula

Once an institution has formulated its student outcomes and decided how it will measure its student outcomes, then it must design its curricula or educational experiences through which students will be able to gain the background required to achieve the outcomes. Therefore, each education institution should have explicit, efficient, well-developed processes for designing curricula to achieve its student outcomes. The Foundation Coalition thinks that significant improvements in these processes are required to facilitate systemic change. Therefore, the Foundation Coalition will fund efforts to develop processes with the characteristics described in the following paragraph.

Develop a process through which an interdisciplinary team starts with documented changes in student outcomes and creates sets of learning activities to achieve the student outcomes. Describe and document changes in the preparations of engineering graduates that will be necessary to meet the student outcomes documented in Task No. 2. In other

words, describe and document learning activities that will help achieve the student outcomes documented in Task No. 2. For example, based on our current knowledge we can assert that learning activities should emphasize active learning, cooperative learning, inclusive learning communities, technology-enabled learning, and curriculum integration.

Task No. 5 - Document Changes in the Processes of Engineering Curriculum Change

The fifth process in systemic change is to create a curriculum change process that facilitates Task No. 3. The first step is to describe desired processes for curriculum change engineering education. Next, describe existing processes for curriculum change at current Foundation Coalition partners. Once desired processes for curriculum change have been described, and an accurate picture of existing processes has been portrayed, the foundation has been laid for change. Develop actions that will close the gap.

Task No. 6 - Implementing Culture Change in Engineering Education

Proponents of change in engineering education often suggest the need for changes in the criteria and processes for tenure, promotion and reward. However, the faculty at an Institution ultimately set criteria and processes for tenure, promotion, and reward. So proponents of change in engineering education are in the position of crying "Physician, heal thyself!" In other words, we have met the enemy and s/he is us. Criteria and processes for tenure, promotion and reward are visible artifacts of the culture of engineering education. They are not the deeper assumptions. Instead of continuing to advocate changes in the criteria and processes for tenure, promotion and reward, the Foundation Coalition proposes to examine and raise to visibility the unquestioned assumptions that form the culture of engineering education.

Therefore, the sixth process in systemic change moves the current culture towards one that nurtures learning and growth in the practice of teaching. The first step is to describe cultures in engineering education that emphasize learning and growth in the practice of teaching. Next, describe cultures present at current Foundation Coalition partners. Once desired cultures for engineering education have been described, and an accurate picture of present cultures has been portrayed, the foundation for culture change has been laid. The third step is to develop actions that will close the gap.

Task No. 7 - Develop Management Teams as Models of Change Leadership

Develop management teams that model response to adaptive change in their environment through dialog, leadership, personal change, and team change.

IV. Conclusion

Systemic improvement across the engineering education community is a goal of number of reform efforts that have been supported by the National Science Foundation and other organizations. The paper has offered a definition of systemic improvement, perspectives on the process of change, and a set of tasks focused on achieving systemic improvement. Hopefully, the paper initiates substantial, energetic discussion that will realize the goal of systemic improvement.

Bibliography

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JEFFREY FROYD

Jeffrey Froyd is a Professor of Electrical and Computer Engineering at Rose-Hulman Institute of Technology and currently serves at the Strategy Director for Systemic Improvement for the NSF Foundation Coalition. His academic pedigree lists a B.S. in Mathematics from Rose-Hulman Institute of Technology and the M.S. and Ph.D. degrees in Electrical Engineering from the University of Minnesota. He has taught for seventeen years at Rose-Hulman. His interests include control systems design, VLSI design, and systemic improvement of engineering education. On a one-year leave from Rose-Hulman, he is working on systemic improvement in engineering education as a visiting professor in Electrical Engineering at Texas A&M University.

KARAN WATSON

Dr. Watson received the B.S., M.S., and Ph.D. degrees from Texas Tech University, all in electrical engineering. She joined the faculty of Texas A&M University in 1983, where she is currently Professor of Electrical Engineering and Associate Dean. She has received numerous awards, including the 1996 IEEE Undergraduate Teaching Award, the 1996 Harriett Rigas Award, the Tenneco Meritorious Teaching Award, the Women's Week Administrator of the Year Award, and was recently named a Regents' Professor at Texas A&M University.