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Toward more pragmatic engineering classes: Transformation from traditional to Deweyan classes in technological literacy and competency approaches

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TOWARD MORE PRAGMATIC ENGINEERING CLASSES:
TRANSFORMATION FROM TRADITIONAL TO DEWEYAN CLASSES IN TECHNOLOGICAL LITERACY AND COMPETENCY APPROACHES

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ABSTRACT
This paper looks at what some initial steps that teachers of traditional, lecture-based, one-sided engineering classes can take to transition to Deweyan, inquiry-based classes. The goal of this study is to identify concrete step-by-step actions needed for transitioning towards inquiry-based classes where critical thinking and systems-level approaches to problem solving are prominent elements of the course and where presentation of out-of-context facts is avoided. The paper first examines the basis of traditional classes in order to identify and discuss their main shortcomings and to explain the need for modifications. This explanation will be in part grounded in our findings about teaching technological literacy and competency classes.

INTRODUCTION
Engineering colleges and programs were very successful in producing a technical workforce and a number of effective leaders in technology in the late 19th and 20th Centuries. During that period, the engineering curriculum in higher education has gone through major changes. The historic launch of Sputnik began a new era for science and engineering development. The flourishing of engineering and science in the 1960s and 1970s led to a series of remarkable discoveries and inventions that continue to this day. Since the 1960s, engineering education has changed in many ways, but very few revolutionary concepts have been introduced. Overall, most engineering schools have continued to focus on the same delivery methods with small changes of style. [1, 2]

However, as many engineering programs recognize, there is a need for more changes. Recently, attempts are being made to encourage hands-on learning and to promote creativity and active learning. We believe that engineering education needs fundamental modifications and new approaches to match the needs of the 21st Century.

In previous papers and presentations, we have discussed classes and curricula that are based on the Deweyan pragmatic philosophy and argued that they have tremendous potential for creating critical thinkers and lifelong learners and therefore more adaptable problem solvers than the current crop of engineering-education graduates. Authors have also identified the studio model as the best course structure for accommodating Deweyan philosophy. However, a shift to that model requires a comprehensive review and revision of the standard engineering curricula and practices. The main objectives of the paper will be to explore this practical question: "How can instructors and administrators gradually make the fundamental changes needed to move the courses and curricular structures of engineering programs to match the Deweyan (inquiry-based) educational philosophy?" [1-4]

Engineering-program reform would have a better chance of success if in gradual, progressive steps engineering faculty come to reflect on their underlying educational value systems and belief structures in the context of their specific pedagogic practices. Thus, this paper attempts to identify some of the needs and possible ways of assessing and modifying educational practices in engineering.

Specifically, we introduce ideas for helping a typical engineering class to incorporate more inquiry-based content. Finally, some of the findings based on engineering classes for non-engineering students are presented and discussed.

The Motivation

During the last 100 years, engineering education has gone through major soul searching and philosophical debates. The need for this search and these debates continues, perhaps more so now than in the past. The need for a better approach to engineering education is in part related to the fact that engineering and science are in constant transformation, expansion, and intermixing. This pedagogical debate and philosophical dialog will continue to engage all consciences educators and engineering enthusiasts for the 2nd and 3rd decades of the 21st century. The truly enormous challenge facing engineering education can be formulated in this way: What effective curricular and pedagogic practices can educate and prepare practical engineers with proven ability in critical thinking, in mathematical reasoning and analysis, a firm grounding in scientific and engineering methodologies and knowledge to address the complex, multidisciplinary, and multidimensional problems that humanity faces now and will in the future.

Of course, educators in all fields are actively trying to change and be more effective. However, most engineering schools have not gone through fundamental changes since 1970's. Although engineering is fundamentally pragmatic, hands-on, and project and application driven, engineering *education* has been drifting away from that approach since 1970-80s. By the end of 1980's most major universities started to have more mathematical, physics-based, and abstract conceptual approaches in classes to be able to solve bigger problems, and attract more federal funds for research. Gradually, many programs have lost their pragmatic and design-based approaches that engineers historically have been famous for.

As our knowledge base expands, placing greater demands on programs to provide rigorous training in mathematics as well as expanded coverage of physical sciences, engineering classes have gradually become sites where students are systematically presented with and systematically required to review the vast depository of concepts and facts engineers need to know. Courses are packed with important formulations, problems, drilled exercises, discussions of numerous technical issues, know-hows, important methods, and deep analysis contents. These are all important and necessary but they have gradually crowded out critical thinking in the context of the practical activities of engineering.

Most schools are still claiming to have programs that are practical, and provide students with very strong foundations in engineering. Many also claim that students seem to be losing their interest and capabilities in their mathematical and problem solving skills and are focusing less on foundational detail. This is definitely in the opposite direction with respect to the expectations of engineering educators. [4-6]

In our experience, engineering students often pursue schooling to guarantee better-paying jobs. To most engineering educators, it is a disappointment that students often do not show enthusiasm for engineering as a profession, which historically has had a strong sense of social awareness and conscience. Nor do students seem to have a strong appreciation for the pragmatic uses of mathematics, science, and technological know-how. The broader goal of engineering as a discipline tasked with changing the world for the better using tools and technologies and the perspective that engineering is a field to design and create new "things" are not in the conceptual repertoire of many of engineering students about their chosen field of study. We believe these gaps emerge from the dominant value systems underpinning undergraduate engineering education. Unfortunately, a packed curriculum emphasizing acquisition of facts at the expense of embodied (grounded in the social and personal lives of students) experiential learning and fundamental systematic critical thinking dominates current engineering education. [4-11]

As educators we know that content is of course important and discipline is needed. However, content and discipline are necessary but insufficient elements of engineering education. And introducing more content and more discipline will not solve the problems engineering education faces, especially as these challenges are greatly magnified by the new, unwelcome trend towards larger engineering classes.

A Note to All Engineering Educators

Authors of course recognize the value of traditional classes. Our friends, colleagues, and associates have been successfully educated through mostly traditional systems of education. The goal of this paper is to identify the modifications needed to improve our education to prepare our students for the complex and non-linear problems that the engineering workforce of the future will be facing. The need for creative, flexible, and critical thinking groups of engineers who are able to understand the larger problems their societies face and to collaborate not only with engineers within sub-disciplines of engineering but with professionals in other disciplines has never been greater. So the broad framing question for this paper is "What kind of engineering education can best move in that direction?" An answer to that question requires the engagement of all engineering educators in a systematic search for answers to that question.

This paper ultimately hopes to offer a possible venue for introducing a self-questioning (critical thinking) element to engineering education. We believe a key first step is to introduce adding an inquiry-based question-and-reflection element to class activities. Our creative colleagues involved in project-based learning, collaborative learning, design-based learning, problem-based learning, and others are already successfully using what we suggest. The introduction and gradual mainstreaming, in traditional engineering classes, of inquiry-based reflections and questioning according to the pragmatic philosophy of John Dewey can greatly complement and improve the creative efforts that is being made by our colleagues [11].

Engineering Classes, Instructor, and Major Issues

In traditional engineering classes, the lecturer leads the class presentation, shows the basics, derivations, and identifies essential and relevant points. These traditional lectures are more or less unidirectional. The lecturer will provide definitions, methodology, examples, and will review the material and important information. The assumption is that the expert (the lecturer) through delivery of information and limited discussion will provide the framework of the material, facts, relationships, and practical applications. Such a traditional approach has been the may of most of mathematics, science, and engineering classes. There are some new developments that are taking place in the last decade, but we need more [12,13]. Within this delivery model, there are some variations, including some new creative styles with more student collaboration. [12] Traditional classes stick to exact and detailed syllabi, which are viewed as more important than allowing student discussions, work sessions, and other reflective activities.

From very early days, educators knew that engaged students will perform better. Starting in late 1990s and early 2000s educators added engaging activities to enhance students' knowledge retention and knowledge base. To introduce more discussions, many programs have introduced recitation sessions, where students would work on applications, solve problems, and review the lecture materials in order to enhance their foundation and knowledge integration. In most major schools, recitation classes have been strictly problem solving/reviewing sessions. The recitation instructor (often a teaching assistant) will review and lead discussions on the main concepts, approaches, and examples. But this approach can have limited discussion-based reflective activities for the students. Thus, although some recitation sessions include elements of interaction and collaboration, the critical inquiry-based reflective activities remain rare [12-13].

Notably, and more recently, few programs also have added different modes of engagements to the traditional approach, for example, cooperative, project-based, hands-on, or design-based learning to help improve students' engagement and activities.

The hope and premise of the most traditional approaches is that students who listen, work, and engage with master teachers (in most cases this has been a master apprentice model [19]) they will learn a thinking process. Consequently, the students will take various classes that are thoughts by different masters and try different approaches to become better thinkers.

All engineering educators are familiar – either as students or lecturers -- with successful examples of such classes with dynamic and great presentations that continue to help many students learn and understand the subject matter.

Mathematics, science, and engineering include many important concepts, approaches, and practices. In such fields there is a core knowledge base that all students must have. In engineering, facts, , rules, and established processes for arriving at solutions are prioritized. And rigor in applying these facts, rules, and processes is foregrounded. These priorities along with much variety of disconnected classes, the burden of getting good grades to get a good job complicate the process of learning and in-depth understanding necessary for becoming critical thinkers. Often, the traditional approach even with modifications fails to place sufficient emphasis on systematic and creative approaches to problem solving and perhaps more important, on personal and group reflections on the part of the student and faculty.

Critical Reflection and Inquiry-Based Classes

We would like to frame modifications being suggested in terms of John Dewey's broader concept of inquiry and his definitions of thinking and reflective thinking [13-17]. As Dewey explains in *How We Think*, thinking is "that operation in which present facts suggest other facts (or truths) in such a way as to induce belief in the latter upon the ground or warrant of the former" [16]. The two key elements necessary for reflective thinking are "(a) a state of perplexity, hesitation, doubt; and (b) an act of search or investigation directed toward bringing to light further facts which serve to corroborate or to nullify the suggested belief" [16]. Dewey expands on those key elements in the context of his concept of inquiry, an activity in five steps aimed at restoring an imbalance in the inquirer with the environment. The five steps are "(i) a felt difficulty; (ii) its location and definition; (iii) suggestion of possible solutions; (iv) development by reasoning of the bearings of the suggestion; (v) further observation and experiment leading to its acceptance or rejection; that is, the conclusion of belief or disbelief" [16].

The first step in this process is critical. Without a genuinely "felt difficulty," a genuine "state of perplexity, hesitation, doubt," or a genuine obstacle or problem, there is no possibility of real inquiry. This "felt difficulty" is directly related to the interests and goals of the inquirer. Thus, to promote genuine inquiry, education has to be first and foremost pre-occupied with understanding and harnessing student interest.

Dewey argues that the teachers can rarely "aspire to the office of kindling or increasing" curiosity: "His task is rather to keep alive the sacred spark of wonder and to fan the flame that already glows. His problem is to protect the spirit of inquiry, to keep it from becoming blasé from overexcitement, wooden from routine, fossilized through dogmatic instruction, or dissipated by random exercise upon trivial things" [16].

Thus, given the centrality of student interest, a key problem of education in general becomes "discovering and arranging the forms of activity (a) which are most congenial, best adapted, to the immature stage of development; (b) which have the most ulterior promise as preparation for the social responsibilities of adult life; and (c) which, at the same time, have the maximum of influence informing habits of acute observation and of consecutive inference" [17]. The teacher's problem is twofold. The teacher must be a student of “individual traits and habits; on the other side, he needs to be a student of the conditions in which individual powers habitually express themselves” [17].

DEFINITION OF CRITICAL VERSUS UNCRITICAL THINKING:

Assuming that student’s interests have been engaged and a genuine difficulty emerging from the student’s constellation of interests and concerns has emerged, the stage is set for the possibility of critical reflection. Given this genuinely “felt difficulty,” the inquirer will want “some way out—the formation of some tentative plan or project, the entertaining of some theory which will account for the peculiarities in question, the consideration of some solution for the problem” (12). Where do these “suggestions” come from? Dewey says from “past experience and prior knowledge,” in other words, “analogous” situations and experiences present in the imagination. In terms of pedagogy this suggests that education should strategically aim (A) to tap into as broad a pool of ideas students have with them and (B) to create conditions to broaden and expand the students’ pool of ideas. Dewey also argues the difference between critical and uncritical thinking emerges can be discerned at this stage of inquiry. To accept the first suggestion one encounters indicate uncritical thinking, the minimum of reflection.” Critical thinking means

> “To turn the thing over in mind, to reflect, means to hunt for additional evidence, for new data, that will develop the suggestion, and will either, as we say, bear it out or else make obvious its absurdity and irrelevance. . . . The easiest way is to accept any suggestion that seems plausible and thereby bring to an end the condition of mental uneasiness. **Reflective thinking is always more or less troublesome because it involves overcoming the inertia that inclines one to accept suggestions at their face value; it involves willingness to endure a condition of mental unrest and disturbance. Reflective thinking, in short, means judgment suspended during further inquiry; and suspense is likely to be somewhat painful . . . . [T]**he most important factor in the training of good mental habits consists in acquiring the attitude of suspended conclusion, and in mastering the various methods of searching for new materials to corroborate or to refute the first suggestions that occur. To maintain the state of doubt and to carry on systematic and protracted inquiry — these are the essentials of thinking.” (16)

Suggestions and inferences depend on “(a) a certain fund or store of experiences and facts from which suggestions proceed (b) promptness, flexibility, and fertility of suggestions; and (c) orderliness, consecutiveness, appropriateness in what is suggested.” The teacher’s role has to be framed in terms of a clear understanding that it is the student who needs to experience and enact inquiry.

DEWEY ON RHETORIC AND LECTURE

These key Deweyan observations suggest pedagogic environments like studios, a topic the authors have explored elsewhere. But they also suggest modifications to existing pedagogic environments. Since Dewey also devotes a chapter to discussing communication of information, we will summarize this material before getting to specific suggestions. Although Dewey argues that students must do their own research by identifying problems and centering their studies of subject matter on solving those problems, he acknowledges that not everything can be studied that way. “The field of fact open to any one observer by himself,” he writes, “is narrow” [16] we need to renumber these. He writes, “No educational question is of greater import than how to get the most logical good out of learning through transmission from others” [17]. He notes, “the material supplied from the experience of others is *testimony*: that is to say, *evidence* submitted by others to be employed by one's own judgment in reaching a conclusion" [17]. He sets three conditions for pedagogically sound communication of this kind of evidence:

1. The communication of material should be *needed*. "For teacher or book," he writes, "to cram pupils with facts which, with little more trouble, they could discover by direct inquiry is to violate their intellectual integrity by cultivating mental servility" [17].
2. "Material should be supplied by way of stimulus, not with dogmatic finality and rigidity. When pupils get the notion that any field of study has been definitely surveyed, that knowledge about it is exhaustive and final, they may continue docile pupils, but they cease to be students" (198).
3. "[M]aterial . . . should be relevant to a question that is vital in the students own experience. . . . Instruction in subject-matter that does not fit into any problem already stirring in the student's own experience, or that is not presented in such a way as to arouse a problem, is worse than useless for intellectual purposes" [16].

Link to Reflection Activities

The premise of inquiry based classes requires a proactive role by the lecturer and the lecturer team to periodically seed the students reflective activities with probing, engaging, and open-ended questions to allow students to reflect on the material, cooperate with each other and share perspectives on the material. As a result the students will re-examine and re-express the concepts in terms of their personal perspectives and experiences. This is what concept maps, memory maps, and similar tools do in most cases. Students should also work on verbal, written, drawing, and other communications venues to express their thoughts. The essential part is that their work needs to be reviewed and critiqued by an experienced instructor or instructional team. In inquiry-based classes the instructor or instructional team will need to provide very frequent feedback to students in their journeys of discovery.

The Role of Reflection and Feedback

Problem of over packed curriculum

All of the engineering educators know that it is not practical to teach all that we want to the students to know within the 4 years of college life. Many institutions have been trying to change their curricula to address this issue. In all cases, the solutions have been to reduce the required material, knowing that these may be occasional shortcoming, and allow students to focus on their interests and future aspirations [12]. But much more needs to be done to infuse the classroom with practical inquiries.

Developing a Sense of Pride and <u>Ownership</u> *in Students, need to transform student belief structure*

Perhaps the most important challenge for all educators is to help students have a sense of ownership of the material that is needed to be experts in a field. As long as students do not feel connected and emotionally committed to the material and the subject this goal is not really achieved. So, the challenge for most of us is to transform some of our students' basic assumptions about the field. For many, students are in engineering to end up with "good," stable, and well-paying jobs. However, we can make a stronger case that these goals are not in opposition to the key mission of engineering as a profession: To change the world for the betterment of humanity. We need to encourage students to take discrete actions to be proud of their work, understand professionalism, be lifelong learners, and passionately pursue their interest and desires.

Thinking, critical thinking, and progressing to be lifelong learning begin with reflective thinking. All experts remember the teacher(s) who initiated and seeded their transformation. They can also remember going through steps of trial and errors on they found their way to their current state.

And we believe that a first, best step towards transforming engineering classes to become more inquiry-based is to incorporate many systematic, well planned, and connected series of reflective and collaborative activities in traditional classes (mostly in class, followed by out of class assignments). Many educators have included collaborative learning [12] in classes and lectures, but there are few systematic approaches to inquiry-based reflective thinking.

Start from Basics of Engineering

Reflective thinking activities should continue to be focused on basic concepts covered in engineering lectures. The criteria that help the instructor decide the reflective activities should begin with the class, the discipline, and fundamental concepts that are shared and necessary within each field of study. Each instructor needs to identify the major concepts, ideas, formulations, and definitions that are used in all subjects in the area. Reflective and inquiry-based thinking need to be seeded by in-class activities that are initiated from basic definitions and progress toward more advanced conceptualization and applications.

However, the instructor needs to establish and become engaged in a learning culture that will appreciate and value all personal and group activities that take place in and out of class. Reflective activates need to be defined, described, discussed and practiced on a regular basis.

Example of Electromagnetism

Let us focus on one of the most difficult subjects of electrical engineering, Electromagnetism (EM). The basics of EM are the practical foundations of electrical engineering. The definitions of electric field, electric potential, magnetic field, Faraday's law of induction, Ampere's Law, eddy current and losses, and basics of waves and field-material-interactions are infused in all areas of electrical engineering. This is also true in multidisciplinary areas such as bioengineering and related areas. However, due to the emphasis of the rigorous mathematics in the traditional EM classes, the basic ideas are not in the conceptual repertoire and the foundational knowledge base and skill-sets of most of the graduating students.

1. In order to make students have a better retention of any material they need to be engaged with it, value it, play, fail, redo, and have fun doing it. The reflective activities, and collaborative exercises that are based on emphasizing the main concepts would to other classes
2. How better understanding of the definitions can help in practical experimental, design, and critique activities.
3. Identify some examples/possibilities where lack of deep understanding (of the definitions) can lead to major design flaws and failures
4. Others…. Each faculty and student groups can add to and enrich this list by their research, experience, and projects.

These activities need to be frequently presented in the class. Students need to reflect on them personally as well as write and talk about them. It is also important that they reflect in collaboration with other students.

It is critical that the instructor or the instructional team review the writings and reflections of each student individually, to monitor the progress and engagement, and to plan the next set of activities based on the findings of the previous ones. help immensely to rectify this shortcoming.

The instructor needs to have the following progression in mind:

1. Basic concept and definition
2. Rewording and connecting definitions
3. Applications that would help us use and understand the definition
4. Myths about the concept and definition
5. The general mathematics that are used together with the definition
6. How better definition can help synthesize the subject in the class

We should remember that the longest walks have to be achieved one step at the time. This is true for all reflective processes added to each class, the instructional team needs to be patient and wise as it provides feedback.

Conditions for inquiry are created when we ask students to identify the difficulty with the material at hand, try to solve it in more than one way by tapping into their pool of knowledge and experiences, examine their solutions, critique their work and others' solutions, and throughout not be afraid of making mistakes. These are essential values for this process.

In order to encourage our students to reflect, we need to promote an appreciation for the value of doubt and some disorientation. Inquiry requires an appreciation for failure as one of the most important tools for understanding and that real failure comes from not trying ideas. In this process, instructors cannot help students if students do not openly communicate what their thoughts, their questions, and their understanding of the concepts. It should be noted that this is the major promise of reflected thinking and inquiry based learning and cannot be neglected by the educators nor the students. Getting students to openly communicate has to also be linked to a nonthreatening environment and class culture that is set and maintained by the instruction team.

Having an open mind, patience, multiple available perspectives, and repeated processing as we enhance the content are key points of success. We propose that every class at all levels needs to include in most lectures (if not all of them) student reflective activities to engage in the above-described critical examination of student knowledge. The authors together with many different colleagues all over the world are utilizing different versions of this process.

Experience with Technological Literacy and Competency Classes

Let us focus again on the major concepts of electromagnetism (EM). As we explained, the traditional engineering approach to EM that engages with necessary rigorous mathematical manipulation does not help students retain the basics of the field far beyond the class. When reflective approaches and inquiry-based seeding of ideas have been added to such classes the results have been much more successful and students have been much more satisfied.

Example from the class of one author

One of the authors teaches a class on practical and application-based electromagnetism for non-electrical engineering students. During the same term he instructs the traditional EM class for electrical engineers. In addition, in a class that is taught for non-engineering students (the class is called "How Things Work" and most students are from the Department of Industrial Design in the College of Design) there is a section about EM and practical aspects of the field in order to prepare students for explanations of observed phenomena in everyday gadgets.

The above three classes cover the spectrum from deep technological competency (electrical engineering EM) to deep technological literacy (the class for the design college), and the class for non-electrical engineers fits in between, with more tendency to the engineering side (most students are from different fields in engineering or related areas). Repeated observation indicate that the **students in the non-electrical engineering class do remember more concepts, get excited about their final projects (about applications of EM), and are much more active in learning, challenging, and engaging with the class**. The technological literacy students were also more interested and engaged with the subject. The majority of them appreciated the ideas and got engaged much more with the material than did electrical engineering students.

The key-differentiating factor between these sets of courses was that the non-electrical-engineering classes included many reflective activities. It is interesting that the idea of including reflective thinking to promote technological literacy was first introduced to the non-engineering students. The results based on the students' engagement, excitement, and projects that they did were eye opening. The first trial of this process was added to the EM class for non-electrical engineering students. The addition not only helped student engagement in the class, but also engaged students beyond the class. The class became one of the most interesting and impactful classes that more than a few students would remember in their exit interview. Consequently, the instructor added more reflective activities into the electrical engineering class, and the result was much more effective retention of knowledge and excitement. And according to anecdotal evidence from accounts of students and other faculty in the program, students also showed more continuous appreciation for the use of the concepts in other classes that they took in their programs.

Approaches in the Laboratory and Homework Assignments

Laboratory activities, which often complement lectures, can easily include open-ended questions. Many of our current engineering labs do that. However, in this approach it is important to see students' reflections while they are in the lab. It is vital to ask them to write (reflect) about some of the issues or concepts that were covered in the lecture and the previous lab. The goal is to examine students reflections regarding the material and concepts. This information should be used to *improve* the lectures and labs. It is also important to have regular and frequent feedback to help each student advance their knowledge base and their visions. The final goal is to have students develop their own processes of thinking and their own perspectives of the material.

The laboratory report is an important part of the student reflection and growth. The assignments should include questions with open-ended answers, and a few questions that would force the student to provide the way they think about the subject. Feedback on such questions would be essential to help them develop their conceptual and practical framework of the subject. Encouraging the students to relate their learning in the laboratory and assignments to the material and discussions in the lecture, in other classes, as well as some of the technological applications that they have seen would also be a beneficial reflection and integration.

The assignments need to balance the practice and rigor with research, knowledge integration and student development. A part of the assignments need to help students probe deeper into some of the major items that personal and group reflections in the class shed lights on.

The Fear and the Heart of the Issues

Many instructors may be reluctant to move toward inquiry-based learning and approaches in the engineering classes. There would be many issues that could hunt the early adaptors. With careful implementation all of the following issues can be addressed and resolved.

a) What if we cannot really cover all the material that needs to be covered?
b) What if the students do not really learn?

c) What if the people in the industry (or our colleagues) would not approve of the method?
d) What about ABET? Can we really do well with ABET if we follow in this?

All of the above questions are important. It would take time for each instructor to implement this process into his or her teaching activities. This should be done with open communications with the students, with other faculty, and with the industrial partners. The feedback from all of the constituents is valuable in this process and must be systematically reviewed to make appropriate modification.
Finally, an effective assessment process needs to be created. The subject of creative assessment is beyond the scope of this paper and needs to be addressed in depth in other publications.

CONCLUSIONS

This paper proposes a systematic methodology to transform traditional engineering classes to more inquiry-based systems-level classes that are according to Deweyan pragmatic methodology. By nature, engineering education is a fertile land for pragmatic philosophical approaches. The challenge is to make practical transformation in meaningful ways and preserve the essence of engineering education. This paper reviewed the traditional engineering classes and some of the challenges that are facing engineering education for the early decades of the 21st century. A need for changes in our approach was identified and discussed. Such changes include well-planned, systematic activities in engineering classes that would encourage open-ended questions, and student personal and group reflective thinking is proposed as a viable solution.

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