AC 2011-2058: EXPERIENTIAL LEARNING TO SUPPORT AN INNOVATION DISPOSITION WITHIN ENGINEERING EDUCATION

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EXPERIENTIAL LEARNING TO SUPPORT AN INNOVATION DISPOSITION WITHIN ENGINEERING EDUCATION

1. OUR MINDSET
Innovation and creativity are essential characteristics of engineering problem solving. Supporting the development of students’ abilities for critical thinking and creative problem solving is recognized as important but is generally lacking as a characteristic in formal engineering educational experiences. As the world becomes increasingly wired and connected, engineers need all the more to engage complex problems with creativity, critical analysis, and innovation. In 2004, the National Academy of Engineering published a report summarizing visions of what the engineering profession might be like in the year 2020 [13 and 14]. The key message gleaned is that engineering education has to adapt to the challenges of the future.

For engineering education to adapt for the challenges of the future, curricular changes are needed – but those must be part of a larger systemic change in the organizational culture of engineering education. Faculty are the critical component in achieving the necessary systemic transformation. Facilitating the development of desired skills, dispositions, and reflective habits of mind within our student populations requires a critical mass of faculty able and eager to embody and enact these desired characteristics. How can we assist faculty to be vital stakeholders in the cultural shift we seek within engineering education, a shift that is imperative for the critical analysis, creativity, and innovation demands that will be placed on the engineering community of the future?

We have begun work to bring about a cultural shift by addressing the needs of current and future faculty to engage instructional strategies for innovation by developing a workshop that supports conceptual and philosophical development, provides instructional strategies and scaffolding, and is based on sound pedagogical theory. Our ongoing experiences with the workshop are providing us with insights regarding unleashing innovation in experiential learning, and those experiences are informing our current and future work toward supporting a culture of innovation in engineering education.

In this paper, we provide the contexts and overview of the workshop, clarify some related issues and foundational constructs and strategies that arise from them, and present a model for scaffolding higher order cognitive engagement and intentional reflection in experiential learning. We also address some specific issues and conflicts we are engaging, including how, and why. We discuss how our experiences and the insights we are gaining from them are informing our current and future work toward supporting a culture of innovation in engineering education. Finally, we pose some questions to promote discussion of these issues in the engineering education community.

2 CONTEXT, OVERVIEW, AND FRAMEWORK OF THE WORKSHOPS
We have conducted the workshop in two locations. The first was in August 2010, in a four-hour conference workshop format at the ASME International Design Technical Conferences, Montreal, Canada. Twelve (self-selected) participants took part. While we were able to predict some of the opportunities and challenges we would face in a four-hour format, the experience also provided several additional insights. Our goals for that workshop were to

A. Demystify Experiential Learning: While all learning involves some experience, not all experience results in learning, nor does all learning experience constitute experiential learning.
B. Practice What We Promote: We demonstrated the themes of the workshop through collaborative effort, forming a learning community, and using a scaffolding model to facilitate experiential learning. A critical premise of our efforts and interactions is sharing-to-gain.

In serving these two goals, the primary activity of the first iteration was presentation and use of a scaffolding model to support faculty development of instructional tasks for an engineering curriculum. Based in the challenges, success, and insights gained from that experience, we expanded the workshop to a full three days and conducted it in January 2011, in Ahmedabad, Gujarat, India. This location is significant because India is poised to serve important roles in the world’s future in terms of economy, engineering, and innovation, and because Ahmedabad, Gujarat in specific is the leading powerhouse of technology and infrastructure-building within India. Ahmedabad is the fastest growing city in India and the third fastest growing city in the world.

For the second iteration of the workshop, thirty participants were carefully chosen from among the senior engineering education faculty of nine universities within the state of Gujarat. This version of the workshop was sponsored by Gujarat Technological University in cooperation with the authors’ home university in the south central United States. For the second version, we retained the two goals from the first version and also added a third goal:

C. Evaluate Experiential Learning and (Meta)Competencies. We explored issues and schemes to help to access and foster continuous improvements for our Experiential Learning environments and curricula to unleash innovations. We interacted in collaboration, all contributing and monitoring our own contributions to create a rich learning experience that utilized expertise from each of the participants as well as the facilitators.

In this paper, we focus primarily on the second version of the workshop and our experiences and perceptions regarding it. In the remainder of this section we present the general outline of the workshop as advertised (see Figure 1), then address some key relevant issues that were highlighted or emerged as the workshop progressed from beginning to end, including some decisions to modify the workshop. In Section 3, we present a scaffolding model (the IRK+B [1]) that integrates both Kolb and Bloom within a matrix of intentional reflection. In Section 4 we share some preliminary insights and we follow this in Section 5 by posing some questions that we think are worthy of discussion.

A list of working concepts and definitions was sent to all participants one week prior to the workshop to help establish a shared language with which to discuss instructional strategies and approaches.

2.1 Ontological Perspectives

To better support the authentic experiential learning component of the three-day workshop, on the first day we focused primarily on establishing the need for supporting innovative thinking and learning within curricula, and on providing theoretical, philosophical, and conceptual background and framing. Interactive components, such as individual and brainstorming and small group discussion, were interspersed throughout all sessions, with a substantial portion of the morning session devoted to establishing the theoretical foundations and philosophical and conceptual basis for the rest of the workshop.
One theoretical and philosophical foundation that was important for us to address in the workshop, even with our tight schedule, is the power of individual ontological perspectives, especially ones that are unexamined and unconscious, and how they can conflict with instructional strategies we select in attempting to accomplish instructional goals. This issue relates directly to the need for a cultural shift in how, generally speaking, engineering education as a discipline views the roles and practices of both teaching and learning.
We all have assumptions regarding how the world works, the nature of reality, what can be known, and how we can know. Some of these assumptions seem obvious to us. Some of them we are not always conscious of. Sometimes we express ourselves in ways that convey ontological assertions that, upon reflection, we don’t necessarily agree with. Ontology refers to beliefs/stances regarding the nature of reality. Epistemology refers to what we can know, and how we can know what can be known. There are several ways to categorize ontological perspectives and stances. One useful categorization uses a spectrum of objectivism and interpretivism.

A strongly Objectivist (or Positivist) position holds that there is an ultimate Truth / Reality, and that it can be known, and that correct understanding of that Truth can be replicated from individual to individual. A soft positivist position might hold that while there is an ultimate Truth and Reality, discovering, understanding, or conveying that reality is challenging, but can be approximated using the right methods. In contrast, a more Interpretivist position holds that, even if an ultimate truth exists, what we can know is, at best, an individual interpretation of that truth or reality. We are conditioned by our individual experiences, cultures, personality preferences and characteristics, physical conditions, and so forth. Even as we try to form an understanding of complex phenomena that is identical to the understanding held by a master teacher, it cannot be identically replicated because the teacher’s experiences, culture, attention, interests, personality characteristics, etc., modify and inform his or her understanding. The same kinds of factors also influence each individual learner’s understanding of the knowledge he or she is trying to acquire. In Table 1, we provide a comparison of four prominent ontological stances along a spectrum of Objectivism to Interpretivism. The workshop is grounded in the perspective in the right-hand column, Constructivism, and also informed and influenced by the column to its immediate left, Critical Theory.

**Table 1. Ontological Perspectives Comparison (Adapted from Denzin & Lincoln [2])**

<table>
<thead>
<tr>
<th>Ontology (Nature of reality)</th>
<th>Positivism</th>
<th>Post Positivism</th>
<th>Critical Theory</th>
<th>Constructivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reality exists separate from and not dependent on the observer, and can be known</td>
<td>There exists a separate reality, but it can only be known imperfectly</td>
<td>Reality is shaped by social, political, cultural, economic, ethnic, &amp; gender values.</td>
<td>Reality is a social construction. Individuals have interpretations of reality.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Epistemology (What can be known)</th>
<th>Positivism</th>
<th>Post Positivism</th>
<th>Critical Theory</th>
<th>Constructivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dualist / Objectivist Findings are True</td>
<td>Modified Dualist / Objectivist; Findings are probably true</td>
<td>Transactional / subjectivist / value mediated findings</td>
<td>Transactional / subjectivist / created findings</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Methodology (How it can be known)</th>
<th>Positivism</th>
<th>Post Positivism</th>
<th>Critical Theory</th>
<th>Constructivism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental / manipulative; Hypotheses verification; Generally Quantitative; Testing</td>
<td>Modified Experimental / manipulative; Hypotheses falsification; May include Qualitative methods</td>
<td>Dialogic / Dialectical</td>
<td>Dialectical Hermeneutical</td>
<td></td>
</tr>
</tbody>
</table>
2.2 Methodologies and Practice Reflect Ontological Perspectives

Instructional choices depend on several factors, including the pedagogical knowledge of the instructor, perceptions of what is acceptable practice in the local setting or within a discipline, the type of knowledge under study, and characteristics of the learners and context. As constructivist perspectives and approaches have gained wider acceptance and support, several teaching strategies and techniques developed from an interpretivist position are being adopted within and across disciplines. One example is cooperative learning. This strategy, and how it is implemented, is critically relevant to the future of engineering education given the increasingly complex social contexts and immediate communications globally. Educational institutions are feeling pressure to serve greater numbers of students with fewer faculty members. For overburdened instructors, cooperative learning can be perceived as reducing a burden. Cooperative learning also was directly relevant to the workshop we were conducting, as we had plans for later in the workshop to engage the students in cooperative learning both students and as faculty. It was important for us to establish clear understanding of what we mean by cooperative learning, both for participants in the workshop and for readers of this paper.

Cooperative learning involves students working together, face-to-face, in small groups (typically two to five members) on a structured project or activity. The students need each other to accomplish their common tasks / learning activities. Students are individually responsible for their work and learning, as well as for supporting their teammates’ progress. Cooperative learning embodies both content learning and social interaction, and for it to take place, instructors need to provide guidance to support both. An instructor with deep background and understanding of constructivist principles carefully prepares the cooperative learning activities to support the development of positive social interactions, and provides students with guidance regarding issues such as establishing roles, supporting each other to be successful, and monitoring themselves and each other for misconceptions and errors. A constructivist teacher might employ cooperative learning as part of broader efforts to support the development of a positive and supportive learning community.

In contrast, adopting cooperative learning without understanding the underlying premises (such as recognizing the need for, and supporting the development of, metacognition, self regulation, schema development, and both shared and individual responsibility) diminishes a rich strategy to
mere group work. Instructors might simply see fewer projects to grade. Students might interpret it as an allowance to disengage and benefit from others’ efforts, or else choose to engage knowing they will have the burden of teammates who do not contribute fairly but get the group grade anyway.

Grouping students is not the same thing as engaging students in cooperative learning. Team projects that are not facilitated by an instructor grounded in the principles of cooperative learning, and the ontological perspective undergirding it, contribute to frustration and cynicism among students rather than empowering them to learn. Poor examples of strategy adoption also lead to misconceptions of constructivist classrooms as being places where anything goes, and misperceptions of teachers as less than the professionals they are.

Understanding the underlying premises and assumptions of constructivism is critical to achieving positive and effective outcomes from the constructivist strategies being adopted. This is not to say that individuals for whom positivism resonates more than interpretivism cannot be successful with constructivist strategies. However, such individuals do need to engage in self reflection and monitoring of their own deeply held assumptions, views, and beliefs, and learn to regulate them, while also working sincerely to understand the pedagogical and ontological assumptions from which the teaching strategies emerged so that they can apply those strategies in ways that support the best outcomes.

2.3 Bloom’s Taxonomy of Cognitive Function
In any discipline, there are some types of knowledge and understanding, such as basic mathematics concepts and procedures, chemical reactions, mechanical principles, laws of physics, and so forth, for which positivist approaches to knowledge and learning are effective. The types of knowledge that are easily taught and learned using positivist approaches are often factual and declarative in nature, such as relates to learning (memorizing) the elements of the periodic table or multiplication tables. Problems and learning activities involving these types of knowledge tend to be “closed ended” – that is, there usually is a limited number of correct solutions, and “right” and “wrong” answers are easily identifiable. Bloom referred to the types of mental activity needed to memorize facts and information (such as those mentioned above) as “lower order cognition” [3], for which he identified three subcategories: Knowledge, Comprehension, and Application (see Table 2). During the 1990’s a new group of cognitive psychologists, led by Lorin Anderson, updated the taxonomy and modified the form of these three categories to Remembering, Understanding, and Applying. Lower order cognition is adequate for memorization and for following simple procedures.

Some types of learning and understanding require more than rote memorization of facts or simply following directions. Cognitive activities such as analysis, synthesis, and evaluation are more complex, and open ended. There can be many “correct” solutions (as well as many wrong ones). Whether or not a solution is “right” might depend on the specific context. Bloom referred to these functions as “higher order cognition.” In the updated version of the taxonomy, the higher order cognitive functions are Analyzing, Evaluating, and Creating. Although Synthesis from the original version of the taxonomy may be viewed as implicit in the current classification system, it is wise to make that function, and its practice by students, explicit. In Table 2, two basic types of cognitive function are identified in the first column, the second and third columns list the with
six levels of cognition and a key question for each being listed in the second and third columns, and examples of action verbs that can indicate activity at a particular cognitive level being summarized in the fourth column.

**Table 2. Bloom’s Taxonomy, with key questions and demonstration verbs.**

<table>
<thead>
<tr>
<th>Cognitive Level</th>
<th>Key Question</th>
<th>Demonstration Verbs (examples)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lower Order</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remembering</td>
<td>Can the student recall or remember the information?</td>
<td>Define, Duplicate, List, Memorize, Recall, Repeat, Reproduce, State</td>
</tr>
<tr>
<td>Understanding</td>
<td>Can the student explain ideas or concepts?</td>
<td>Classify, Describe, Discuss, Explain, Identify, Locate, Report, Recognize, Select, Translate, Paraphrase</td>
</tr>
<tr>
<td>Applying</td>
<td>Can the student use the information in a new way?</td>
<td>Choose, Demonstrate, Dramatize, Employ, Illustrate, Interpret, Operate, Schedule, Sketch, Solve, Use, Write</td>
</tr>
<tr>
<td><strong>Higher Order</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analyzing</td>
<td>Can the student distinguish between the different parts?</td>
<td>Appraise, Compare, Contrast, Criticize, Differentiate, Question, Discriminate, Distinguish, Test, Examine, Experiment</td>
</tr>
<tr>
<td>Evaluating</td>
<td>Can the student justify a stand or decision?</td>
<td>Appraise, Argue, Defend, Judge, Select, Support, Value, Evaluate</td>
</tr>
<tr>
<td>Creating</td>
<td>Can the student create new product or point of view?</td>
<td>Assemble, Construct, Create, Design, Develop, Formulate, Write</td>
</tr>
</tbody>
</table>

Although higher order thinking has always been important for engineering, increasingly diverse and complex social contexts are becoming not just more frequently encountered, but a necessary part of the practice of engineering. Social interaction in service of engineering ingenuity, then, is an increasingly important skill to be developed. Increasingly connected and immediate communications globally also contributes to the need for higher order thinking. Nevertheless, most undergraduate engineering courses focus on Level 3 skills (Applying). An analysis of one four-year engineering program showed that 2,345 out of 2,952 problems assigned (79%) were Level 3 or lower [4]. On the other hand, probable demands on engineering graduates in the coming decades involve skills at Levels 4–6. For the most part, engineering curricula have not been expressly designed to meet these goals.

In most engineering courses the students have been engaged in terms of lower order cognition. The courses are generally taught with traditional teaching methods, and with assessment methods that also reinforce learning at the lower levels of the Bloom’s Taxonomy. During the senior year,
project-based design courses are used with the expectation that they encourage students to engage in creativity and develop metacompetencies that are needed to support creativity. Although the desired outcome in the design courses is creativity, higher order engagement is not explicitly required and, in most instances, the students do not tend to engage in higher order cognition. Evaluation in these courses usually is based on the product (artifact, report, etc.), not on learning or development of competencies in the students.

Supporting a shift to increased higher order engagement requires moving beyond standard practice lecture and teaching methods, to include multiple complex ways of teaching and facilitating learning. Some of the approaches to facilitate learning may feel uncomfortable to both the learners and instructors at first with learners and instructors being challenged to adapt to methods that support and require higher order cognition, after decades of experience within formal education settings that tend to favor lower order cognition. We suggest that both faculty and student focus needs to shift towards increased concern for learning, and reduced emphasis on final grades. Instructors might find themselves uncomfortable at first as they transition to more open, and open-ended, approaches. For example, when an instructor initially shifts strategies to intentionally allow students more power and self control, a few students might test the limits in order to determine whether or not to trust the teacher. Instructors should be prepared for this temporary phase and resist the urge to revert to more authoritarian dynamics.

Higher order cognition requires different kinds of feedback and support, and involves a greater need for flexibility, adaptation, and, often, negotiation. Higher order tasks and higher order cognitive engagement are necessary for facilitating the development of creativity and innovation. Thus, if we want to support our students to be creative and innovative, we need to provide them with learning experiences that both require and support those higher order functions. As faculty and curriculum developers, we also need to challenge and support ourselves and each other to function and engage in higher order ways. We modeled this for and with the participants in our workshop, in terms of questioning and prompting each other during the workshop, and in terms of our willingness to make changes to the outline and order of the workshop itself as we went along.

Today’s engineering students are tomorrow’s engineers. Future challenges will require engineers to take on open engineering problems and unforeseen issues, understand system level challenges, and respond with strategies that result in innovation. To be successful on creative tasks, learners also must succeed at the two preceding, analyzing the relevant issues, requisite resources and demands of the task to be achieved, then evaluating the potential responses and choosing among available options to produce the most effective and efficient solution/response. To be prepared to innovate, engineering students must be able to perform at Bloom’s the top levels (Evaluating and Creating). Developing the desired skill and expertise in analysis, evaluation, and creative thinking and production for unforeseen needs requires authentic experience in tasks that require students to exercise these skills. If they have not experienced creative challenges that require innovative responses in their engineering classes, they will not be prepared to do so in their professional careers. How can we address this gap?

One way that not only provides the experience, but also leverages a number of other advantages for developing these skills, is experiential learning. If designed well, experiential learning not only provides authentic opportunity, but also supports self-determined motivation and regulation.
It can be structured to enable adaptive interaction among those with various types of expertise, sharing in a professional community, and building both competence and community.

2.4 Need for / Value of Reflection, Self Interrogation, Self Regulation
Building on ontological positions, the expression of those positions through strategy selection and practice, and understanding of Bloom’s Taxonomy, we discussed with the participants some key contrasts between Transmissive and Transformative approaches to learning and instruction. (see Table 3).

**Table 3.** Contrasts between transmissive and transformative approaches.

<table>
<thead>
<tr>
<th>Transmissive</th>
<th>Transformative</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Uses / reinforces <strong>Lower</strong> Order Cognition</td>
<td>• Uses / reinforces <strong>Higher</strong> Order Cognition</td>
</tr>
<tr>
<td>• <strong>Directive</strong>, seeks Compliance and conformity</td>
<td>• <strong>Explorative</strong>, seeks Questioning and Discovery</td>
</tr>
<tr>
<td>• More <strong>facts</strong> based</td>
<td>• More <strong>meaning</strong> based</td>
</tr>
<tr>
<td>• Supports maintenance of <strong>External</strong> locus of control</td>
<td>• Supports development of <strong>Internal</strong> locus of control (self regulation)</td>
</tr>
<tr>
<td>• Task and <strong>content</strong> centered</td>
<td>• <strong>Learner</strong> centered</td>
</tr>
<tr>
<td>• <strong>Closed</strong> ended, well defined</td>
<td>• <strong>Open</strong> ended, loosely defined</td>
</tr>
<tr>
<td>• Metacognition is <strong>helpful</strong></td>
<td>• Metacognition is <strong>necessary</strong></td>
</tr>
<tr>
<td>• <strong>Banking</strong> model of Education</td>
<td>• <strong>Problem-posing</strong> model of Education</td>
</tr>
<tr>
<td>• <strong>Replicates</strong> the Status Quo</td>
<td>• <strong>Empowers</strong> individuals and society</td>
</tr>
<tr>
<td>• Needed for <strong>variant design</strong></td>
<td>• Needed for <strong>original design</strong></td>
</tr>
</tbody>
</table>

We provided dynamic examples of these two approaches during the workshop. Immediately prior to the start of the workshop, our hosts conducted an opening ceremony to welcome us and provide a context for the collaborations we were forming together. As a large group, we were physically seated as a group of presenters and hosts, facing a group of audience members and attendees, all sitting in precisely arranged rows. This physical arrangement was appropriate for the purpose of the opening ceremony. It also provided a visible and tangible contrast to our later modes of engagement during the majority of the workshop. After the opening ceremony, we moved to the other end of the large room, where we had set up seven tables in a roughly U-shaped arrangement with spaces between them to walk and interact. During whole group interactions, the facilitators presented at the opening of the U shape and moved around in the space within it. This was one of the intentional strategies we used to reduce the perception of distance and hierarchy, toward a larger goal of establishing a trusting and mutually supportive community of learners.
We asked participants to consider the charge: “think outside the box.” This expression is commonly used to encourage people to think creatively. But what is the box? How can a person think outside of the box if he or she does not know what or where the box is?

“The box” is the collective set of assumptions, premises, and beliefs about the nature of reality, what can be known, and how it can be known. The ontological perspectives presented in Table 1 provide four good examples of “the box.” Thinking outside the box – that is, getting to a place where creativity and new approaches are possible – means breaking through cognitive boundaries imposed by ourselves, the dominant paradigm, discipline-sanctioned practice, or cultural norms regarding how we should think, how teachers should teach, and how students should learn.

“Thinking outside the box” requires awareness of one’s deeply held beliefs and assumptions, and willingness to temporarily suspend or modify one or more of them in order to explore how doing so might change one’s perception of, or approach toward, a problem under consideration.

**Self awareness** is a critical component of being able to “Think outside the box” and is necessary for both metacognition and self regulation. **Metacognition** is thinking about one’s own thinking process. For example, “I am engaging in metacognition if I notice that I am having more trouble learning A than B; if it strikes me that I should double check C before accepting it as fact” [5].

Experts become more expert through intentional, metacognitive reflection, self-monitoring, and self-regulation of their knowledge, strategies, and ways of engaging. **Self regulation** involves monitoring, regulating, and adapting one’s own thinking processes, assumptions, effort, and actions. Intentional reflection, self interrogation, and self regulation are important for students, and also for instructors.

Imagine a student being repeatedly being told to “think outside the box.” Being told to keep trying, without being given assistance to figure out what that expression even means, what is being done well and what is not, is like asking someone to keep repeating and practicing a procedure, even if it is wrong or detrimental, without being provided any feedback or support. It does not produce the desired result. Both ontology (Table 1) and Bloom’s taxonomy are useful and valuable constructs to foster such reflection. Examples of questions one might reflect on in terms of Bloom’s taxonomy include, “At what cognitive level am I engaging?” “My instructor labeled this task analyze. Am I really engaged in analyzing?” “What does it mean to analyze?” “How will I know whether or not my students are actually analyzing the problems I give them?”

The next three sections we expand on various elements of self reflection that we covered in the workshop (see Figure 1).

**2.4.1 Performance orientation versus learning orientation**

People approach learning tasks with either a performance orientation, or a learning orientation [6]. People with a performance orientation (and performance goals) tend to think intelligence is static and unchangeable from birth. Performance goals are focused on making the learner appear competent and/or intelligent to others. This is easier to do in areas in which a learner already has competence and confidence. It is not surprising that when learners have a performance orientation, they tend not to take risks or try new things, because to do so might make them look stupid or incompetent. People with a performance orientation tend to be much more concerned with grades than with whether or not they learned anything. They may avoid seeking assistance or working with a tutor, even if help is needed. Performance orientation can affect faculty as well as students. Faculty might be overly concerned that they not appear stupid or incompetent around
other faculty or administrators, and even their own students. There appears to be a connection between performance orientation and lower order cognition (such as rehearsing, recognizing, paraphrasing).

People with a learning orientation (and learning goals) tend to think intelligence can be developed. Learning goals are focused on increasing the learner’s knowledge and understanding. When engaged in learning goals, the student might make mistakes (which can be learned from) and is willing to ask for help when it is needed. Students with a learning orientation generally are not concerned with whether or not they appear smart or stupid, or what their final grade in the class will be. They are driven by their desire to understand and increase their competence, and they do not let their egos get in the way of their learning. Students and faculty with a learning orientation tend to be more comfortable with uncertainty and more willing to try new things, even if they may fail, because they know they are likely to learn in the process. There appears to be a connection between learning orientation and higher order cognition (analyzing, evaluating, creating).

Many learning goals include actual performance tasks, such as music or athletics. However, even for performance-involving disciplines, actual performances are preceded by the needs to learn and to practice. A student who experiences performance anxiety while learning a new piece of music, for example, has an inhibited ability to learn the piece.

A learner’s orientation toward performance or learning is not necessarily static. It might be situational. Students may feel safer to focus on learning in some courses, or with some instructors, than with others. Instructors may unintentionally reinforce a performance orientation in their students through their interaction styles, grading practices, refusal to re-teach material students didn’t master, and unwillingness to be flexible or negotiate.

Instructors can encourage a learning orientation by working to develop a safe and trusting learning environment, reiterating the importance of incremental improvements both in projects / coursework and in intelligence generally, providing low stakes practice opportunities and processes for revision, and practicing forms of cognitive apprenticeship with their students.

2.4.2 Personality awareness
Two of the many dimensions of personality that are relevant to the ideas and strategies explored during this workshop are the dichotomies of Introversion / Extroversion and Closure / Openness.

Preference toward Introversion or Extroversion. People with a preference for introversion tend to expend energy when they interact with large groups of people and tend to get their energy recharged through time spent alone. They may have many thoughts and opinions about matters being discussed in a group but might not offer their input if not directly asked, or unless it is very important to them. They may be frustrated with others who dominate a conversation or who do not allow brief periods of silence within a conversation.

People with a preference for extroversion tend to expend energy when they spend time alone and tend to get their energy recharged by interacting with others. They may inaccurately assume that others who do not speak up do not have anything important to say and they may be less patient with (and therefore actively fill) periods of silence within a conversation.
Preference toward *Closure or Openness*. People have a preference toward either early closure or prolonged openness. Both preferences are valid and each has advantages and disadvantages. People who prefer early closure feel more comfortable making decisions quickly and finishing tasks on or ahead of schedule. People who prefer earlier closure tend to be very productive, but in their rush to closure might make errors or fail to consider some important information or processes. They may sacrifice deeper inquiry for efficiency. People with a preference for early closure can use self regulation and support from colleagues to prolong openness.

People who prefer later closure feel more comfortable when they have a longer time to think about decisions and tend to use all the time available to complete projects and tasks. They may start a project right away and yet delay completion until just before (or right at) the deadline. This often is because they want to consider many different approaches, perspectives, or possibilities, reduce avoidable errors, and be sure they don’t overlook important information or processes that they are more likely to find prior to submission if they use all the time available. People who prefer prolonged openness may make fewer errors or omissions, but may have difficulty finishing tasks on time. They may sacrifice efficiency for deeper inquiry. People with a preference for openness can use self regulation and support from colleagues to monitor and pace themselves so that they stick to a schedule and finish projects on time.

There appears to be a relationship between closure preference and the form of questions posed. People who prefer earlier closure tend to ask more closed-ended questions and people who prefer prolonged openness tend to ask more open-ended questions. These tendencies can be modified. Expert teachers with a preference for earlier closure self regulate to intentionally ask open-ended questions, since open-ended questions are usually better at eliciting higher order responses. Likewise, expert teachers with a preference for openness self regulate during large group discussions or collaborative activities to intentionally summarize and restate, achieve consensus (as appropriate), and bring meaningful closure.

Self awareness and reflection are important for regulating communication, expectations, and support of students and colleagues. Recognizing one’s own preference is especially important when working as part of team. People with opposite preferences regarding closure can easily become frustrated or anxious with each other if they don’t understand the advantages each preference has to offer, or if they are coerced by others in the team to operate according to their non preference. People with opposite preferences can make powerful teams when they understand and make use of the strengths each has to offer. Members with preference for early closure can help others stay focused and keep to a timeline and members with a preference for openness can prompt for other possibilities or more thorough inquiry.

2.4.3 *Facilitating a supportive environment (Trust, Sharing, Support)*

Without an intentional disruption, people tend to teach in the same manner as they were taught. Therefore, it is imperative that in our roles as faculty we intentionally regulate ourselves to model the behaviors, attitudes, and dispositions we want to see develop in our students, from whom will emerge the next generation of engineering faculty. A trusting environment is more conducive to innovation and creativity (as well as other higher order cognitive functions and tasks) than is an environment wherein students feel they must be guarded or constantly in performance mode. Instructors can do several things to help facilitate the development of a trusting and supportive environment. At the beginning of the course, we can explain to students...
what kind of environment we wish to create with them and ask them to help create and support it. We can model our own willingness to be supportive, reflective, adaptive, open, and so forth. We can (and must) monitor and, if necessary, adapt our use of language to include more open-ended questions ("What would you change about the system?" rather than "Should the system be changed?"). We can (and must) model a learning orientation and willingness to take some risks. Other habits we can cultivate include acknowledging contributions. Ask learners to elaborate on their own or others’ comments for specifics and examples. Paraphrase, summarize, and check for understanding ("So what you're saying is that you are concerned about who defines the requirements and parameters for the project. Is that correct?"). Acknowledge when you don’t know the answer to a question and briefly discuss how you can learn the answer. Give encouragement, but don’t give empty or false praise. False praise is recognized by students and reduces trust. It also might increase an inclination to performance orientation. Encourage and support participation by all members but don’t put people in the awkward position of being forced to speak without warning. Along with these suggestions, we provide participants with some specific guidelines for positive teamwork. Thoughtful grounding in and support for ongoing development of interpersonal skills leads to more positive and effective team and cooperative learning activities.

2.5 Experiential Learning
During the workshop, we provided an overview of the benefits, roots, and premises of Experiential Learning. Referring to Kolb’s Four-phase model of Experiential Learning as the prime example, we discussed underpinnings, assumptions, and limitations. The workshop itself provided substantial opportunity for participants to experience authentic experiential learning. We present some preliminary insights gained from the experience in section 4.

Kolb’s work [7, 8] provides an often-referenced model of experiential learning. Kolb understood that people approach learning in different ways and his model recognizes four distinct personality types with different approaches to learning. The two personality dimensions acknowledged in Kolb’s model are Concrete Experience / Abstract Conceptualization and Active Experimentation / Reflective Observation. Four distinct personality types can be based on these dimensions. Kolb proposed a cyclical model (see Figure 2) for experiential learning with four stages:

- **Concrete Experience**: the learner must be willing and be actively involved in the experience;
- **Reflective Observation**: the learner must be able to reflect on the experience;
- **Abstract Conceptualization**: the learner must possess and use analytical skills to conceptualize the experience; and
- **Active Experimentation**: the learner must possess decision making and problem solving skills in order to use the new ideas gained from the experience.

Highlighted in this model are two complementary dimensions: grasping information and then transforming that information. From an epistemological perspective, experiential learning aligns with constructivism, which posits that learners construct meaning from their experiences. However, the theory behind the practice of experiential learning has had limited attention in engineering education literature. A thorough understanding of experiential learning, as it
operates within engineering tasks and in supporting engineering knowledge, is needed to properly utilize the experiential learning mechanism in the engineering curricula to develop competencies.

![Kolb's experiential learning model](image)

Figure 2. Kolb’s experiential learning model

There are many unanswered questions about the efficacy of “hands-on” activities for fostering learning. Are they merely popular intellectual events, or do they actually promote innovation? Do they merely showcase existing skills and prowess of a select few stellar students – led by professors who know how to design the device – or do they hold potential to develop the skills of all engineering students in ways important to their future success?

Most “creative problem-solving” or “experiential learning” in educational settings is too structured to develop these ways of thinking. Most instructors use tidy problems with correct solutions, not tasks requiring innovation. Solving neat, well-defined problems only gives learners practice in solving those, not in creativity and innovation. To learn to respond to open problems or tasks without existing solutions, learners need practice with exactly those types of tasks. Redesigning tasks and models for classroom use and re-educating faculty to support authentic experiential learning is challenging. Curricula and instructors need to balance structure and autonomy, support both team and individual effort, and value error that leads to deeper learning and skill refinement. Course or curriculum redesign must address “what” is to be learned, and “why” those target outcomes are needed. It should present clearly the “how” (or strategies) we will use to achieve them.

### 2.6 Core Competencies and Metacompetencies

There are two levels of competencies in any professional field: Task-specific competencies (technical/core competencies) are benchmarks for graduates in a given field, that define them as well-prepared to meet job demands and excel in the future. Technical competencies, in many instances, need to be updated continuously. The second type, General (meta) competencies are skill sets that enable learners to function globally, such as working with others, functioning in systems and meeting organizational demands, and transferring task-specific skills to novel
problems or tasks they have not encountered before. Engineering educators need to rise to the challenge of going beyond equipping students with foundational math and science skills, and ensuring that they are able to use them to address novel and complex problems and challenges. *How can they best prepare to do that?*

One answer is to focus on strategies that help them learn to innovate. We are not the first to call for a curriculum that supports development of conceptual understanding and skills that can be transferred from one context to another. Jones, Scanland, and Gunderson [9], recognized this need, calling for a change to current, typical engineering education. “Rather than focusing on specific technologies or specific problems, we need to equip students with those concepts that are common to all problems, all technologies, all skills, ranging from workplace engineering to ethics to entrepreneurship.”

We suggest that the emerging engineering education curriculum will be anchored in mathematics and sciences, while also emphasizing the professional role of the engineer and demanding new competencies suited for newly emerging world contexts, with innovation, interdisciplinary and complex problems being a central theme. This curriculum can be moved forward by specifically focusing on the research and development of instructional activities that address the engineering metacompetencies related to innovation. The development of competencies to support engineering and innovation, more globally, is spiral in nature, with students building on some and adding new ones as they progress through the curriculum.

The problems we are facing today are global and complex in nature, where engineers need to manage dilemmas among Economical capital, Social Capital, Ecological/Natural Capital, and Intellectual Capital. Innovations in the future will increasingly come from teams of collaborators who can bring together multiple skills and perspectives. The competencies required by engineers will have to support innovations that go beyond the current models of only economic capital.

### 2.7 Integrating Instructional Design with Experiential Learning

In the workshop we showed the relationship between Instructional Design and Experiential Learning. Brief presentations, practice activities, and reflection opportunities regarding key principles and practices of instructional design (such as Gagne’s Conditions of Learning, Well-written performance objectives, psychomotor and affective Learning domains (in addition to the cognitive domain represented earlier by Bloom’s Taxonomy) were engaged during the workshop. Consistent with principles of schema theory and constructivist perspectives, overt connections were repeatedly made between information and experiences likely to be new to participants and those that were likely familiar to them. As one example, the facilitators pointed out the similarities between engineering process and instructional design process (see Table 4 and Figure 3).

### 3. The IRK+B Model for Scaffolding Higher Order Thinking in Experiential Learning

The Intentionally Reflective Kolb + Bloom model (IRK+B) developed by Bradshaw [1] is shown in Figure 4. IRK+B supports faculty and learners to develop higher order thinking skills in planning and conducting experiential learning. This scaffolding model provides a framework for the design of learning tasks and also for learning community to develop a culture and practice of intentional reflection, wherein members (students and faculty) develop dispositions of metacognition and self regulation.
IRK+B blends the process of Kolb with an intentional scaffolding of Bloom, within a culture and practice of Intentional Reflection, which is the matrix by which the four phases of experiential learning are engaged. A primary outcome as a result of implementation is the development of learning community cultures in which members become habitually and dispositionally analytical and creative. The model requires learning community members to constantly ask themselves (and each other) questions that more fully utilize higher levels of cognition (analyzing, evaluating, and creating), which are critical components of both innovation and scholarship.

Table 4. Similarities between engineering process and instructional design process.

<table>
<thead>
<tr>
<th>Engineering Process</th>
<th>“ADDIE” Instructional Design Model</th>
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<tbody>
<tr>
<td><strong>Plan</strong> – know what you are trying to achieve in the design. What are the design requirements?</td>
<td><strong>Analyze</strong> – know what you are trying to achieve in the design. What are the design requirements – based on need, content, context, learners and tasks?</td>
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<tr>
<td><strong>Design</strong> – map out information about the design with sketches or computer drawings. What does the design look like and how does it behave?</td>
<td><strong>Design</strong> – map out the general strategies for the instruction and the demands of the learning environment. What does the course look like and how does it facilitate learning?</td>
</tr>
<tr>
<td><strong>Assemble</strong> – build a working prototype of the design. How is the design manufactured?</td>
<td><strong>Develop</strong> – gather and create materials to be used by the teachers and learners. Are all materials ready to go?</td>
</tr>
<tr>
<td><strong>Test</strong> – check to see if the design behaves as expected. Does the design meet all design requirements?</td>
<td><strong>Implement</strong> – test the course with learners in class. How does the course function with the learners in practice?</td>
</tr>
<tr>
<td><strong>Articulate</strong> – discuss/report the outcome What did you learn by undertaking this activity?</td>
<td><strong>Evaluate</strong> – measuring if the course was effective. How did it work?</td>
</tr>
</tbody>
</table>

Applicable to both planning by faculty and implementation with learners, the model and its supporting material prompts for reflection and higher order thinking along at least three dimensions:

- Desired Instructional Task Level
- Realistic Lowest Cognitive Level
- Scaffolding Needs/Prompts.
In the workshop, the scaffolding model was presented in the context of a mechanical engineering course project [10, 11, 12], to demonstrate its use for participants. The model was then implemented by them in two modes. First, on Day 2 of the workshop, participants used the model to design instructional activities for an engineering education project intended to require and support higher order thinking and interactions. In teams of four, participants were responsible for identifying the learning goal(s), specific tasks and the level of cognitive engagement desired from the students for each task, and the likely lowest level of cognitive engagement students would realistically bring to the tasks, and to provide multiple specific forms of scaffolding to help push them to higher levels of cognition. In addition, each team was responsible for composing appropriate and well-written performance objectives, meeting specific criteria they had practiced with previously. This phase also included formative evaluation components and opportunities to revise based on feedback received.
Second, on Day 3 of the workshop, participants implemented the instructional plans using role playing to carry out the instructional tasks as both students and instructors, with roles changing part way through the activity. Following this phase, teams were asked to prepare brief reports regarding their experiences including what was useful and noteworthy regarding the experiences.

The process of the workshop itself was intentionally designed to be consistent with

1. the ADDIE model of instructional design,
2. Gagne’s Condition’ of Learning,
3. the phases of Kolb’s experiential learning model, and
4. the reflection and scaffolding to higher order thinking prompted in and supported by the IRK+B scaffolding tool.

Moreover, the workshop was intentionally designed to progress in a spiraling way around the workshops themes – from abstract to concrete, connecting familiar and unfamiliar, eliciting and integrating core competencies and metacompetencies, and requiring and supporting higher order engagement.

4. PRELIMINARY INSIGHTS, ISSUES, AND CONFLICTING NEEDS FROM THE SECOND ITERATION

In preparing for the three-day workshop in Gujarat, which included reasoned needs assessment of our learners, and insights gained from the first version of the workshop [12], we had several concerns:

a. There was potential for resistance by participants to us as the workshop facilitators, because as we all live and work in the U.S. and, despite good motives and intentions, we are outsiders. This could be exacerbated by the fact that half of our team are faculty from a college of education, rather than from a college or school of engineering. (We viewed this combination of expertise as an asset overall, but recognized that our different identity and experience could present different credibility for our learners.) To address this issue we would need to emphasize the appropriateness of these strategies for all of learning (not just in Western cultural contexts) and for engineering in particular.

b. We would need to clearly and precisely demonstrate and scaffold the meanings and benefits of the concepts, themes, and practices we were introducing to participants. (For example, we needed to do more than conceptually discuss the idea of a “community of learners” – we would need to actually create with them a lively, dynamic, trusting, and supportive learning community; we needed to do more than inform them of the concept of an “affective domain,” we would need to appeal to and engage them affectively, as well as cognitively.)

c. Some participants might not sincerely engage the ideas, and might see the workshop as a hoop they needed to jump through to please upper administrators. To gain and sustain their interest, we would have to address the value-added that these strategies could contribute to their teaching, specifically for engineering education.

d. Some participants might find the ideas and approaches conveyed as too foreign, or too “out there” because they are drawn from the social sciences and a predominantly interpretivist (in contrast to an objectivist) ontological stance. To address this issue we
would need to provide a bridge to support understanding of: 1. how familiar these ideas were in practical terms rather than in abstract terms; and 2. how the ontological shift could complement the goals these instructors had for their students (to align with what they already wanted for their learners).

Regarding Concern a., potential for resistance to us as outsiders, participants’ comments to us (the facilitators), as well as later reports forwarded to us from insiders not participating directly in the workshop, some participants did feel an initial resistance prior to and during the opening hours of the workshop, but that that resistance was reduced or eliminated by the end of the first day.

Regarding Concern b., the need to demonstrate the concepts through our actions and provide scaffolding and support along multiple dimensions, we were overt in our attempts to honor what the participants might already know or practice intuitively but for which they didn’t have official language. We tried to balance the need to provide necessary information without being perceived as insulting their intelligence or professionalism.

Regarding Concern c., potential for lack of sincere interactions, this might have been the case initially for some participants, but we have no evidence that is so, and we do have observational indicators that they were sincerely engaged (such as level of enthusiastic team discussions, quality and complexity of the teams’ applied projects, quality and quantity of feedback they provided each other during peer evaluation process, level of engagement during group discussions – to our delight, we repeatedly had to extend the time we allocated for discussion after reflection questions because of participants’ relevant elaborations, questions, and applications to their own contexts).

Regarding Concern d., we got no indication that the interpretivist and constructivist ideas we presented were perceived as too “out there.” To the contrary, we were unanimously thrilled with the extent to which the participants considered, applied to their local settings (both professionally and personally), and later referred to the concepts and approaches in serious and thoughtful ways. These responses may have been partly a result of our pro-active approach to presenting these least familiar ideas in clear and practical terms.

During the workshop, we frequently asked participants to reflect on the information being exchanged and how it relates to current and future practices within engineering education. One of the vehicles for reflection we used during the workshop is a SWOT (Strengths, Weaknesses, Opportunities, Threats) Analysis. In applying SWOT to our own experiences conducting the workshop itself (both in the design process and reflectively following implementation), we have identified the following:

**Strengths**
- Experiential Learning, when designed properly, can help develop engineering competencies at higher levels of cognition.
- Our workshop raised awareness and enthusiasm among the engineering faculty participants for using instructional design to support learning.
- The IRK+B model provides a map to explicitly consider scaffolding needs of students.
• Participants engaged in Experiential Learning based development of an instructional plan during the workshop.
• Our workshop provided participants with terminology and support for strategies, approaches, and practices that many engineering faculty had experienced or intuited on their own, but didn’t have language for, or conceptual or theoretical support to validate.
• Knowing the information would likely be unfamiliar, we took a proactive design strategy of making the ideas and their benefits practical and clear, while respecting participants’ perspectives.

Weaknesses
• We need, in the future, to provide more planned instructions and pre-workshop reading material regarding unfamiliar or challenging concepts and theories to increase participants’ understanding prior to the sessions and to reduce the cognitive load during the sessions.
• We need to develop more example(s) of how to translate the experiential learning that occurs in extracurricular activities into the formal curricula, and make these easily available.
• We need to increase time and methods for discussions regarding facilitating the development of dispositions conducive to innovation in engineering education.
• We need to better link specific concepts, activities, and other components to the development of innovation competencies.
• We need to divide some of the information sections into even smaller chunks, and supplement application development with more incremental activities.

Opportunities
• We see clear opportunities for the use of instructional design in engineering education.
• We perceive that some faculty members are receptive to changes that better facilitate and support the development of innovation within engineering education.
• We see benefits in bridging perceived gaps between engineering and education expertise, so that neither seems so “foreign” to the other, and the complementary integration of assets of both is more apparently feasible.
• We see much more possibility in negotiating integrative understanding through our active and ongoing collaboration as education and engineering scholar-practitioners.

Threats
• The adoption of Experiential Learning in a course requires a change in culture of both the faculty and the student. This may not be forthcoming.
• There is a potential for resistance from different components / constituencies of the system (beyond faculty across disciplines, such as administrators and policymakers).
• There is a potential for poorly designed Experiential Learning activities using IRK+B (not considering all the elements), if not trained appropriately.
• There is a potential to focus on the activity only and not acknowledge and honor the theoretical and philosophical concepts and underpinnings.
• The adoption of Experiential Learning constructs and approaches to teaching may be threatened by the culture and lack of resources.

A key challenge involves balancing the often-conflicting needs for time, efficiency, dialogue, modeling, reflection, practice, conceptual and philosophical scaffolding, procedural learning, and affective development. In addition, we see potential to engage dialectics and practices that
• Balance the need to allow extra time for discussion / clarification, while being mindful of our time constraints and the experiences for which we want to be sure to preserve adequate time.
• Balance generalizable ideas and strategies (meta-competencies of instruction) with discipline-specific ideas and strategies that explicitly address and promote the objectives of engineering education and expertise (engineering competency development).
• Balance philosophically unfamiliar, abstract, or intuitive content and experiences with those that are more concrete, sensory, and procedural.
• Invite questioning and reflection, leading to action taken to modify current systems and instructional practices that may be sanctioned and seem proper in local social and cultural contexts, yet be pedagogically problematic.

5. MOVING FORWARD
Based on the success of our initial workshop implementation in Canada [12], we revised and designed the fuller and more effective version delivered in India. That implementation was very successful, generating positive feedback and eagerness for repeated workshops and ongoing support for instructors’ implementation and integration in their classrooms. These messages were conveyed to both the workshop facilitators and (more importantly) to the leadership and policymakers at the Gujarat Technological University (GTU) and throughout Gujarat. These messages prompted the leadership to initiate specific conversation about plans to: a. return and expand our delivery to more of the engineering faculty, and b. continue support of the faculty already trained, through follow-up visits and through technology-based, asynchronous communication systems. These activities also are supported by the existence of a Memorandum Of Understanding that was set up in advance of the workshop delivery and officially signed following completion of the workshop.

The experiences and insights we are gaining from the workshop and our continuing interactions with workshop participants and the growing community of interest are informing our current and future efforts to support a culture of increased innovation in engineering education. We wish to support the growth of this emerging movement. Hence, we ask ourselves (and request additional responses and questions from readers):

1. What are the preliminary steps in this endeavor?
   • Inform a greater portion of the community of needs for and methods of modifying existing cultures and curricula. We perceive the majority of engineering educators are willing to support change, if they understand the benefits through their own direct experience.
   • Target and train a set of faculty from different institutions to provide workshops to their own institution.
   • Investigate Experiential Learning via a variety of different competition groups and analyze learning in these groups.
   • Investigate and provide extracurricular events that will attract members of the community who are not drawn to overtly competitive events.

2. How can we engage and interest our professional colleagues to be interested and willing to undertake the challenges inherent in program and curriculum redesigns that will support innovations across our wider engineering community?
• Develop sample courses / curricula that use experiential learning to develop engineering competencies, with example drawn from a broad range of engineering specializations.
• Evaluate development of competencies in engineering students to demonstrate the benefits.
• Provide more workshops / seminars / discussion forums, at conferences, and in other formats.
• Develop a web portal / community hub where interested faculty can go for ideas, inspiration, materials, support, and networking.

3. What conceptual and philosophical support is needed, and what are the best ways to provide this support?
• Disseminate information through a variety of channels – publications, conferences and colloquia, workshops, and so forth.
• Develop and disseminate tools that will help engineering faculty members adopt sound pedagogical practices, such as using instructional design models and processes and the IRK+B scaffolding tool.
• Develop a workshop and related materials specifically for administrators.

4. In what formats can meaningful engagement be facilitated?
• Workshops and discussions in conferences.
• Web-Portal / Communication Hub.
• Brown bag discussion lunches.
• Local and regional colloquia.

We invite you to join our growing and expanding learning community as we continue to explore and learn how we can support the widespread development of innovation dispositions within engineering education contexts.

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