Constructivism in Colorado:
Applications of Recent Trends in Cognitive Science

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Abstract

Partnerships between scholars from engineering and education can result in teaching innovations based on systematic instructional design and theoretical foundations. Cognitive teaching models are discussed that reflect current trends toward constructivist learning environments and provide research-based frameworks for the intellectual development of engineering students. Experience with undergraduate curriculum restructuring, educational technology, and assessment strategies is shared, including design of laboratory modules, multimedia simulations, and cognitive apprenticeships.

Introduction

We do not need people from Education coming over here, telling us how to teach. We’re doing OK—just look at what engineers have accomplished.

Engineering focuses on the real world—understanding it, analyzing it, and shaping it. Yet today, our undergraduates are principally educated through traditional classroom instruction in theory-dominated courses. Consequently, they fail to gain hands-on understanding of the links between theory and practice. Also, we are faced with declining enrollments, high national attrition rates, ineffective and pernicious gatekeeper courses, continuing efficacy complaints from industry, diversity issues, and decisions that need to be made regarding expensive teaching and learning technologies. The Quality of Engineering Education Project (QEEP) Task Force on the Use of Educational Technology reported that the latter item, those decisions about instructional technologies may prove to be an integral part of the solution to many of our problems. We would like to add this sentiment to the Task Force recommendations: The potential for a renaissance in engineering education is enhanced if our teaching innovations are based preeminently on theoretical foundations that address student learning.

Perhaps it is time to span the gap created by traditions and territories in higher education exemplified by the dictum at the beginning of this section. Our goal is to model interdisciplinary collaboration by sharing our collective experience in the areas of curriculum planning, instructional design, and the implementation of new learning environments. The School of Education at the University of Colorado at Denver is actively involved in learning environment and instructional technology research. The College of Engineering and Applied Science at the University of Colorado at Boulder is taking a bold step toward teaching with technology through significant capital investment. The engineering community at Colorado School of Mines has long been recognized as a leader in innovative education, and has applied many of the modern learning theories discussed in this article for over ten years. In the following section we take a look at a logical foundation for change—new ways of thinking about human learning.

Recent Trends in Cognitive Science

Some changes in engineering education today are based on the admission that it is often the didactic orientation of courses that is limiting their effectiveness. How do we change this? What is missing in our approach? Many scholars would suggest that what is missing is the negotiatational, social aspects of human learning, authentic contexts, and acknowledgment of the unpredictable nature of personal interpretations. Addressing this situation does not require adding something, such as more humanities subjects, to the already crowded engineering curriculum. Rather, it entails a shift in our thinking about our students, our academic and industry colleagues, and our own beliefs about teaching. This sort of paradigm shift is currently taking place in social science as a philosophy called constructivism gains in popularity. We feel that this movement is also pertinent to the enrichment of engineering education. What is different about constructivism? The best way to answer this question is to contrast it with its polar opposite, objectivism. Table 1 provides a summary of these epistemological views.
**Table 1. Comparison of Objectivism and Constructivism.**

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<thead>
<tr>
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<th>Objectivism</th>
<th>Constructivism</th>
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<tr>
<td>Mind</td>
<td>Processor of symbols that mirror the world's structure</td>
<td>inner representation of outer reality</td>
</tr>
<tr>
<td>Knowledge</td>
<td>External reality mapped onto learners</td>
<td>Residing in the mind</td>
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<tr>
<td>Meaning</td>
<td>The structure of the real world independent of understanding</td>
<td>Internally constructed</td>
</tr>
<tr>
<td>Thought</td>
<td>Governed by external reality</td>
<td>Grounded in perception and bodily experience</td>
</tr>
<tr>
<td>Learning and Teaching</td>
<td>Prescribed knowledge is transmitted to learners</td>
<td>Negotiated construction of meaning</td>
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**Objectivism.** The concept of instruction as the great setting forth of knowledge that others do not have, and the passive receiving of information by students has dominated all levels of education since it was first put forward in the mid-1600's by Johann Comenius. Traditional teaching at all academic levels relies on the view that knowledge is some entity or object that exists independent of the mind and is transferred into the student-as-empty-vessel. This interpretation of the nature of knowledge has given rise to two theoretical frameworks that have been especially influential for all academic levels, including engineering education.

- Behaviorism—a philosophy entirely concerned with external, observable, measurable behavior that does not try to analyze the workings of the mind. The behaviorist educator will focus on an instruction-learning outcome (stimulus-response) paradigm. Objective-based training, standardized objective testing, desirability of error-free student response, and reinforcement through grades are classroom artifacts associated with behaviorism.

- Information processing—a philosophy that relies on the metaphor of the mind-as-computer, suggesting that people store concepts and rules in a place called memory through a vast network of interrelated symbols, propositions, and knowledge components. Emphasis on problem solving processes and strategies, use of algorithms, show-your-work requirements, and the general view of engineering as a set of rules are evidence of this model’s influence.

**Constructivism.** Old-style constructivists follow Jean Piaget in emphasizing individual thinking and creation of meaning. Modern constructivism has broadened to incorporate ideas about cultural and social learning. The philosophy holds that knowledge is constructed from experience. Meaning is indexed by experience and imposed on the world by us, rather than existing in the world independent of us. Radical constructivism calls for minimalist instructional strategies and significant student invention.

More appropriate to engineering education are less dogmatic, more moderate positions taken by many theorists. They feel that knowledge construction can be stimulated by high-quality explanation, modeling, and practice—as long as the learner is provided with an active social and physical learning environment where interpretive activity and some control over one's own learning is fostered. The theoretical frameworks and teaching models we discuss in this article provide several perspectives on how to accomplish this. They represent recent research areas in cognitive science and instructional technology that are informed by the following, generally agreed-upon constructivist principles that relate directly to instruction:

- Learning results from a personal interpretation of the world.
- Learning is active with meaning developed on the basis of experience.
- Learning is collaborative with meaning negotiated from multiple perspectives.
- Learning should occur (or be situated) in realistic contexts.
- Testing should be integrated with the task, not a separate activity.

Comparing the instructional implications of objectivism and constructivism, we note that constructivists would seem to be
more concerned with the design of learning environments and less concerned with the selection and sequencing of instructional events. A major instructional goal of both paradigms is to make a lasting impression on the learner. Specifically, both hope to facilitate retention, understanding and the active use of knowledge and skills. However, the objectivist class of theories assumes that the learner will adopt the accepted meaning and predetermined interpretations intended by the developer (instructional designer, author, text publisher, lecturer, software programmer). Constructivists believe that prespecification of knowledge, content, and objectives along with the expectation that all learners will take the same thing away from the instruction fails to take into account the unique set of understandings, perspectives and personal goals that each learner brings to each learning experience.  

A leading cognitive scientist, Donald Norman, has estimated that for any complex activity, it takes a minimum of five thousand hours (about two years of full-time effort) to turn a novice into an expert. Surveys of engineering managers from industry seem to indicate that this clock starts on the first day at work. Studies show that student-to-professional transition problems center around missing or insufficiently developed abilities to work on a team, a lack of awareness of workplace expectations, and deficiencies in communication skills. Shouldn’t some of this transformation occur at the university? Some scholars feel that a rich learning environment supported by instructional technologies may help to improve this situation by transferring the context and culture of the workplace into the university.

**Linking Theory to Practice**

Cognitive scientists refer to the notion of learning knowledge and skills in contexts that reflect the way they will be useful in real life as situated cognition. This framework maintains that cognition is not confined to the individual, but is coded by and connected to the activity and environment in which it was developed. Thus, a key component of situated cognition is an environment that is authentic, realistic, meaningful, and purposeful. Learning environments should represent, in an honest and pragmatic way, the context of the target culture. Many constructivists have aligned themselves with the situated cognition movement, asserting that because cognition depends on our experience base, formalized subject material should relate to everyday practice. How do we make school more authentic? We need a nontraditional environment designed to facilitate personalized knowledge construction in relevant settings: equipped with the authentic tools and distributed knowledge of engineering.

**Authentic Activities at the University of Colorado** The Boulder campus College of Engineering and Applied Science is planning a new central laboratory facility that will be devoted to providing undergraduate engineering students with rich, authentic, experiential environments intended to strengthen creative problem solving skills of students in multi-disciplinary teams. The Integrated Teaching Laboratory (ITL) is projected to be ready for its first students in January 1997. Located primarily in a new 45,700 square foot, three story building, the ITL is envisioned as featuring open, state-of-the-art laboratories, multimedia lecture and seminar rooms, and support space. Enhancements in flexibility and visibility designed into the ITL are expected to impact curricula from the freshman through senior years, supporting approximately 2,400 students pursuing bachelor’s degrees in six departments. An extensive network will link computers and electronic instrumentation in the facility, including workstations for data acquisition, simulation, and multimedia instruction. The ITL concept incorporates a new freshman engineering projects course, hands-on homework, and vivid lecture demonstrations, computer simulations, innovative laboratory modules to augment theory courses, and multi-disciplinary capstone design projects.

Physically, the ITL will implement situated cognition through the use of authentic engineering analysis, design, and test tools. One unique feature that is aimed at increasing the undergraduate retention rate is the high visibility of creative projects unfolding within the ITL. This will spark student curiosity and provide a context for the theoretical foundations of engineering. Open, generic lab stations will take on the character of specific equipment fixed up to them. A generic lab station might be dedicated to a fluid mechanics experiment one hour, and a controls experiment the next. Also, dedicated experimental equipment for interdisciplinary use will be defined by fixed equipment. For example, the fluid mechanics area would support civil engineering interest in open channel flow, mechanical engineering study of gas flow in tubes, and aerospace experiments in flow around bodies. The fluid mechanics area will allow for the study of how both compressible and incompressible fluids behave in a variety of situations, including laminar and turbulent conditions. Proposed experiments include impulse forces of water jets, visualization of flow around a cylinder, vortex generation, and a water tunnel simulation of environmental phenomena. Other experimental focus areas will include: electronics and microprocessing, measurement and instrumentation, heat transfer, mechanics and materials, controls, manufacturing, and environmental engineering.

**Distributed Cognition.** The human mind is limited in capacity. Often, problem solvers in school settings are asked to demonstrate what they have learned by showing the instructor what they have temporarily remembered. Ironically, outside of school in professions such as engineering, architecture and law, reliance on memory is in fact discouraged! In the building of bridges, buildings, and precedent-based legal briefs, too much is at risk to rely on what one can remember. Professional problem solvers are experts at acquiring just the required information, when it’s needed (just-in-time), and using it for the achievement of a goal. Within arm’s reach of real-world experts are reference manuals, monographs, charts, tables, blueprints, case studies, formulas, and fact summaries designed to contain the declarative and procedural knowledge needed for a task. Moreover, in most
professions, the expertise of colleagues is an important resource in one's knowledge "toolkit".

Following John Dewey's lead, many cognitive scientists see knowledge as being similar to a set of tools. Often, students are asked to use the conceptual tools of a discipline (mathematical formulas, for example) out of context. The tool concept of knowledge and its relation to situated cognition and authentic activity is not emphasized in school, resulting in a school environment that fails to instill in learners the notion that much of the knowledge needed to perform tasks outside of school can be found in the tools of the workplace. Of course some remembering is required in any authentic activity. Efficient experts remember chunks of information that are used frequently. However, since school settings are primarily designed for novices, minimization of remembering in favor of active finding and sharing of information within the supporting environment would seem to be warranted. Several cognitive scientists have suggested that human cognition at its richest occurs in ways that are socially, physically, and symbolically distributed. In addition to the extensive information network, project visibility, and collaboration mentioned above, the unusual design of the ITL facility harnesses distributed cognition in that the building itself will function as a source of knowledge. For example, different glazing materials will be used so that students can measure and compare the solar gains and heat losses. Exposed HVAC equipment, demonstrating architectural engineering principles, will include instructional sensors to monitor temperature, air flow, and humidity throughout the system. Different structural systems may be used in different areas of the building, including strain gauges to monitor and compare the effects of snow and wind loading. High technology art within the facility could also provide authentic hands-on experiences. For example, a programmable fountain could serve as a test bed for controls and fluid mechanics experiments.

Learning with Media. There has been a decade-long debate among several cognitive scientists about the role of media in learning. One side claims that it is method or content that is important—media are mere vehicles that deliver instruction and do not influence student achievement. Others argue that the ability to see animated, dynamic modeling of real phenomena influences problem solving and the ability to generate and use representations in subsequently encountered situations. The modern constructivist point of view adopts a middle ground. Media are more than mere vehicles—if selected properly they are resources that can enhance cognitive processing. For example, object-oriented programming has changed the way we interact with the computer; it has become a tool capable of accommodating diverse thinking, learning, and problem solving styles. On the other hand, no matter how engaging or usable the medium becomes, it is not responsible for learning; learners are, people learn from thinking. Media are best used as environments and tools that facilitate knowledge construction, not as conveyors of knowledge.

The ITL will use the media-as-learning-tools idea in a number of ways. Simulations and physical demonstrations will facilitate comprehension of abstract concepts, providing a meaningful adjunct to theory and laboratory experimentation. Simulations using high-performance computer workstations will provide capability for exploration of the effects parameter changes have on physical systems. This can be impossible to do on real systems, and very difficult using an analytical approach. A 50-station collaborative CAD laboratory is now operational and serving as the nucleus for piloting the freshman project course. The ITL will facilitate demonstrations by having lecture spaces designed for them, including video systems capable of large screen projection. Demonstrations will be designed and developed by faculty teaching the courses, and central storage and retrieval of portable demonstrations will encourage their use by faculty teaching similar courses in various disciplines. Also, learning modules will be designed to provide short (three-week) experimental enhancements to traditional theory courses. Each module will be designed to be of pedagogical interest to more than one department to capitalize on the efficiency that a central facility can offer. The modules are being designed by interdepartmental faculty groups sharing technical expertise in the experimental focus areas.

Anchored Instruction. Traditional teaching places importance on simplification. However, in the real-world engineering context challenges include problems with multiple solutions, real-world situations that fall outside analytical solutions, and economic, environmental, and societal constraints on engineering designs. One criticism of undergraduate engineering curricula is that students are not made aware of the multi-disciplinary nature of the real-world, with the consequence that upon entering their first job, "they are shocked to find that their solution to one kind of problem can be limited or invalidated by constraints from some other discipline entirely. Another criticism is that students are not made conscious of manufacturing or construction processes. They are led to presume that anything they are asked to analyze has, in fact, been produced and that anything they are asked to design can be produced. These comments point to the need to expose students to the complexity of real-world problem solving.

Recent advances in delivery technologies and authoring systems provide opportunities for immersion in realistic problem scenarios in economically feasible ways. For example, the Cognition and Technology Group at Vanderbilt University has developed a promising constructivist strategy for cooperative problem solving environments. Learning activities are anchored in videodisc-based, information-rich scenarios that set up a realistic problem to be solved over an extended period of time. The random-access capability of this technology allows teachers and students to non-linearly search for embedded data and clues needed for a solution. The Vanderbilt Group theorizes that these macrocontexts remove the potential problem of oversimplification and misconception that can result from micro-level examples and cases that are usually used to teach problem
solving. Cognitive research has shown that learners immersed in complex learning environments generate subproblems, subgoals, and strategies for achieving a larger task (generative learning). The rich, cooperative learning environment made possible by the use of a dynamic, visual, and spatial format allows for exploration from multiple perspectives, and provides students with the opportunity to participate in high-quality discussions. The role of the teacher-as-participant as well as guide helps the students learn to solve problems by working with an expert.35, 36

Curricular Shifts toward Cognitive Apprenticeship

Humans seem to learn naturally through enculturation, the imitation of the behavior of a social group in accordance with its norms. Moreover, in most professions the newcomer to the culture is helped in the development of judgment, skills, and knowledge through modeling and coaching. As an alternative to conventional schooling, many cognitive scientists have seized upon the centuries-old apprenticeship framework as a way to integrate the teaching strategies discussed in the sections above.37 The enculturation into a community of practitioners can be enhanced by designing cognitive apprenticeships around authentic tasks and realistic performance using tools-of-the-trade (situated cognition, distributed intelligence), and encouraging collaborative, realistic problem solving in information-rich learning environments (media, anchored instruction). As we would expect from this metaphor, the role of the master craftsman (journeyman, coach, teacher) is crucial.

In apprenticeship learning, skills are learned through observation, coaching and successive approximation.38 After observing an expert execute an activity (modeling), the learner tries it with teacher guidance (coaching). The expert provides reminders (scaffolding) which are removed (fading) once the task can be approximated. Coaching includes taking pains to sequence instruction from simple to complex, increasing the variety of examples and practice contexts, and proceeding from global to specific skills. Novices are encouraged to think about their actions and give reasons for their decisions (articulation), analyze their own performance (reflection), and try out different strategies and observe their effects (exploration).39 Sometimes the social context in which apprenticeship takes place includes a variety of expert models and other learners. Exposure to complexity, multiple ways of accomplishing a task, and varying degrees of skill helps the learner recognize that there is no one embodiment of expertise and encourages him/her to view learning as a continuing process.39

Problem-based instruction designed around the cognitive apprenticeship model can provide the supportive environment for engineering students starting their program. The undergraduate engineering curriculum on many campuses now provides freshmen and sophomores with design and project courses that introduce practical considerations such as project management, analysis, experimental testing, and multidisciplinary teamwork. For example, the introductory freshman project course at the University of Colorado will be offered to approximately 250 students per semester. The goal of the course is to introduce beginning students to the excitement of engineering and to demonstrate the context and need for further study in advanced topics such as fluid dynamics, electronics, and mechanics. In the next section we will look at the details of an innovative program that has paved the way for this sort of curriculum reform.

Colorado School of Mines EPICS Program. The Engineering Practices Introductory Course Sequence (EPICS) is aimed at enhancing undergraduate engineering students' abilities in: 1) open-ended, team-based problem solving, and 2) oral, written, and graphical communications. All Mines freshman and sophomore students (about 1200 per year) are required to take the four-semester, 11 credit-hour sequence. The program has been in place since 1985, and was pilot for three years before that. Students learn fundamental skills in engineering graphics (visualization, sketching, and drafting), and computer applications (word processing, spreadsheets, presentation graphics, scientific data presentation, and computer-aided design). They also learn and practice technical oral and written communications and teamwork in the context of project work. Each semester in the project/communications (PC) component of EPICS, students work in teams of 4-5 to solve real-world, open-ended problems for clients from industry and government.40

At the freshman level students focus on learning to work well as a team; learning leadership skills, developing client relationships and professional ethics, and applying problem solving strategies to complex, ill-defined problems. Students are expected to educate themselves in the pertinent background information for their project and to consider technical and non-technical (ethical, economic, societal, aesthetic) constraints in their solutions. In the sophomore year students learn to apply computer programming as a problem-solving tool and continue practice in team-based problem solving and technical communications. Students complete their EPICS experience in EP 202, a design course where student teams solve client problems using their developing problem solving, teamwork, and communications skills, and technical knowledge from their engineering and science courses.

Throughout EPICS, we implement the cognitive apprenticeship teaching model by treating students as young professionals using an engineer/manager rather than a student/teacher relationship. The EPICS culture mirrors the professional workplace. Students are expected to meet required deadlines, arrive for classes and meetings on time, strive to continuously improve the quality of their team processes and work products, and meet their clients' expectations. As an illustration of how PC courses function, we will describe work in EP 102, the second course in the EPICS sequence.

Students entering the course have already completed one semester of team-based project work in which they participated in explicit team-building exercises, received instruction in
technical writing and report preparation, and completed a modest open-ended project. In EP 102, students receive instruction and practice in professional oral communications in addition to continued practice in problem solving, teamwork, and technical writing. They work on a new semester-long, open-ended project for an industrial or government client. This project requires students to apply the technical knowledge they are acquiring in their other engineering and science courses in addition to considering numerous real-world constraints such as economic, environmental, social, political, legal, and cultural issues. As in all EPICS project work, EP 102 P/C sections are taught by an instructor or team of instructors.

In the second half of the semester, the design teams begin an intense period of problem solving, including brainstorming alternative solutions, considering applicable constraints and assumptions, building consensus, studying information gathered earlier in the course and acquiring supplemental information if necessary, and developing their solution and recommendations for the client. During spring semester 1993, design teams also visited the remediation sites, visited interested parties including landowners and county officials, and met frequently with their client. Students continue to practice oral communication by defending their team's proposed solution in a cross-examination exercise. They present their recommendations to the client both orally and in a written report.

EPICS has been extensively evaluated using a variety of qualitative and quantitative instruments, including student perception questionnaires, structured interviews with EPICS students and alumni, feedback from upper division engineering instructors, employers, and Perry model testing of students' intellectual development. Anecdotal evidence shows that students initially experience a great deal of frustration during their first and second project experiences, but they resolve these feelings and improve their teamwork, problem solving strategies, and communications skills markedly in the sophomore-level projects. Perry model test results suggest a greater degree of student intellectual development than would be expected from typical student maturation between the first and fourth semesters of engineering studies. Upper division design instructors often comment about the ability of EPICS students to quickly bond as a design team and begin attacking a difficult, open-ended problem without fear or confusion. Employer feedback also indicates that School of Mines graduates work well in diverse teams, can solve real-world problems, and communicate the results of their work effectively. Thus, there is convincing evidence that EPICS positively influences students' abilities to learn and work in an authentic, experiential environment in which they must create their own knowledge and meaning, rather than relying on passive, lecture-driven instruction.

Assessment

Now we come to an intensely-debated issue in all areas of education. If we are not going to prespecify the details of what is to be learned, as constructivists would recommend, how do we assess the learner's progress? Standard objectivist strategy requires mastery of the material in order to answer whatever questions might be asked on a test. Some educators raised on this tradition interpret the constructivist emphasis on personal meaning-making as a move toward goal-free assessment, or self-evaluation. They worry that the result will be academic chaos. The constructivist asks: "If meaning is negotiated, why shouldn't we also negotiate the goals of learning or use the negotiation process, in the form of argumentation, as evidence of learning?"
Consider a final exam for a traditional engineering course. Typically, engineering students are tested on analysis techniques from their coursework. The questions have nothing to do with the individual student; rather, they represent the faculty member's view of the domain. Also, the student's task is not representative of what the student will do as a practitioner in the field. An alternate, constructivist strategy would strive to present the student with an authentic task—one in which it is up to the engineer to define the issue, focus, and approach. Assessment of the work might be based on how well the student considered the perspectives on the issue, and on oral discussions in which the student is asked to reflect upon and support the approach. The constructivist asks: Who can assess knowledge construction better than the constructor?

Portfolios are valuable ways to assess products of learning. Assembly of work by a student after exploration of subject matter encourages synthesis of learning through reflection and metacognitive awareness (knowledge of our own learning strategies and processes). Multimodal/multimedia presentations of individual or group interpretations of assignments and stages of product development reviewed by multiple evaluators are a better match to the workplace. Many portfolio arrangements allow for a follow-up submittal to improve quality or performance after initial evaluation and feedback. When you think of it, few authentic tasks in engineering involve a single product or outcome evaluated once by a single person. The constructivist asks: Why should students have only one chance to demonstrate their knowledge to one teacher?

Both the University of Colorado at Boulder and the Colorado School of Mines are adopting the engineering design review as a good model of an authentic assessment setting. In industry, self-evaluation of products and solutions takes place during trade studies by the engineer or team. Subsequent collegial argumentation by peers and management during presentation is directed at the overall goal, but significant latitude is allowed as to how achievement of the goal is approached (especially during the preliminary design phase). Also, assessment is integrated into the activity. For example, a peer from the Structures Department might ask, "Did the team look at the acoustic environment in that compartment?" Novel ideas, hypotheses, individual perspectives, and the professional skepticism that a practicing engineer must have are communicated, and the collaborative assessment process generates negotiated decisions and action-items (better take a look at the acoustics). Collaborative activities allow us to test our own ideas and understandings and evaluate alternative perspectives.

Conclusion

Think of your own undergraduate education. Do you remember seeing a lot of your professor's back? Was it generally accepted that knowledge was being transferred to you via the blackboard? Now think of your own teaching style: Is it characterized by the idea that I have it, I have all you need, and I will transfer it to you? Information presented in this manner, with little active cognitive work by the learner, is likely to become what is called "inert knowledge." This is knowledge that can be recalled when people are explicitly asked to do so, but is not used spontaneously in problem solving, even though it is relevant. Constructivist scholars suggest that more usable knowledge (i.e., transferable to dissimilar tasks and problem situations) results from learning environments which provide rich, complex contexts, authentic tasks, collaboration, real-world tools, modeling of problem solving by experts, and apprenticeship-mentoring relationships.

The cognitive teaching frameworks briefly discussed in this article are receiving sustained attention from social scientists and instructional technologists. One reason is that they provide learners with opportunities for the multiple perspectives mentioned regularly in recent literature. The constructivist camp attaches a dual meaning to the term. First, the learner should be exposed to the perspectives of other individuals and groups. Secondly, the learner should be able to construct his/her own multiple perspectives on an issue through exposure to it in different contexts. In our Colorado institutions we are working to provide opportunities for our students to actively experience engineering from multiple perspectives in the form of collaborative activities and varied contexts, while affording apprenticeship-like exposure to expertise and the culture of engineering. Also, we believe that technology-supported teaching strategies show promise as a means of providing our students with richer, more authentic representations of engineering science and problem solving situations.

Recently published literature is starting to show evidence that engineering educators and cognitive scientists are gravitating toward each other; however, encouragement is needed. Areas such as assessment could benefit from collaboration. The development of holistic evaluation strategies, such as portfolios that encourage synthesis of learning, is an area that is receiving much attention in the social sciences; whereas, engineering schools are implementing strategies, such as project design reviews, where trade studies and collegial argumentation provide authentic evaluation experiences. We invite our engineering colleagues to form partnerships that can build theoretical foundations and research-based justification for curriculum restructuring, new teaching paradigms, and assessment strategies. We also encourage readers to seek out the cited references to further investigate the philosophical orientation of their own practice, and perhaps stretch the boundaries of perceptions about learning.

References


34. Ref. 10, p. 132.

35. Ref. 33, p. 145.


37. Ref. 16, p. 2.

38. Ref. 10, p. 132.

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James L. Teslow practiced aerospace engineering for 20 years. He obtained his undergraduate degree at the University of Washington, and a Masters at the University of Colorado. His engineering positions included work in the areas of liquid and solid rocket propulsion system analysis and design, launch support, IR&D new technologies, and business development. He became interested in education, obtained a teaching certificate in mathematics, taught for the Department of Defense Dependants Schools in Germany and Japan, and is currently a doctoral candidate in instructional technology at the University of Colorado at Denver.

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