Beyond Learning Styles: Understanding the Learning Processes of Engineering Students through the Interactive Learning Model™

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Abstract: *Many engineering educators have noted that engineering students present some distinctive challenges in the classroom. In an effort to develop teaching strategies that more effectively reach these students, engineering educators have made use of the concept of learning styles. However, while useful, learning styles approaches are both limited and limiting. They are often personality based, and personality is known to change over time or in response to variations in context. These approaches also result in narrow characterizations of students as learners, usually identifying them as somewhere on a continuum between two binary definitions. Moreover, they offer students and teachers few options or strategies for situations where particular styles or talents cannot be accommodated. This paper discusses the expanded understanding of the learner available via the Interactive Learning Model™. The richer understanding available from this approach is explained, and applications of these insights to student learning in engineering courses are outlined. In particular, the paper focuses on how I have used the model in writing courses for engineering students.*

The question of how students learn has become a focus for both research and pedagogy in engineering education. In 1988, in response to concerns about engineering students' performance in the classroom, Richard Felder and Linda Silverman published "Learning and Teaching Styles in Engineering Education." In this article, Felder and Silverman diagnosed various student problems—inattentiveness in class, poor test results, discouragement, and poor retention in engineering or even in college—as an incompatibility of teaching styles and learning styles. Their concept of learning styles combines terminology from Jung, Kolb, and Myers-Briggs to describe several binaries corresponding to how students receive and process information: sensory vs. intuitive, visual vs. verbal, active vs. reflective, and sequential vs. global.[1]

This approach was, from the beginning, extremely influential within engineering education. Numerous other methods and instruments have arisen, and research into the impact of learning styles on student learning and the implications for teaching has burgeoned. (For an excellent overview and comprehensive links to resources, see the University of Michigan College of Engineering webpage on learning.[2] See also Felder's review of four commonly cited learning styles theories.[3] An overview of several approaches and an annotated list of online instruments can be found on the University of Guelph Learning Styles page.[4]) Yet, for all the insights that can be gained by attention to learning styles and multiple intelligences, some shortcomings remain:

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- The categories tend to lead to generalizations. Felder's instrument, the Index of Learning Styles[5], yields a profile of preferences within each set of binaries. However, the results can only be used to identify tendencies.

- Although it is acknowledged that students need to learn how to function in learning situations where their learning styles are not being accommodated, no specific mechanism for how this adaptation occurs is explained. It is assumed that with the measure of confidence achieved through having been allowed to learn some subject matter through their preferred learning styles, students will be able to attempt learning through other styles when exposed to them.

Considering these two issues and looking at how Felder describes his methodology, it becomes apparent that the problem is that the learning styles categories are descriptive. That is, the categories are not based on a theory that describes what is actually happening in the mind of the learner. There are references to different kinds of mental processes and experiences, but these different operations are not systematically identified or tracked. For example, although confidence is discussed as a key component of the student's ability to adapt to unfamiliar learning styles, the specific role of affect is not developed or clearly explained. As a result, although it is clear that knowledge of how students learn is imperative to successful teaching, the only real available strategy for improving performance is to try to match learning styles to teaching styles. This is not always possible.

Further, the problem with this strategy is that it does not help students to become independent learners. In "Applying the Science of Learning," Halpern and Hakel argue that this is particularly important at the post-secondary level. Colleges and universities do not aim for minimum competencies; rather, the assumption behind advanced education is that "knowledge, skills, and attitudes learned in this setting will be recalled accurately, and will be used in some other context at some time in the future"[6]. Post-secondary teaching, then, should not be directed only at optimizing student performance in the school setting but should instead promote transfer of learning. This assumption suggests that the fundamental strategy behind the use of learning styles—offering diverse modes of learning so that students are exposed at least occasionally to compatible pedagogies—does not adequately prepare students for settings beyond the classroom where conditions might be more restricted. Thus, what students really must do is learn how to learn. More specifically, they need to learn *how they learn* and how to apply or, if necessary, adapt, how they learn to the demands of the situation.

Felder's model rests ultimately on experiential and personality-based theories, along with some use of multiple intelligences, which is a genetic, talent-based concept. Another methodology is available that is based on a much more developed theory of how the mind operates. The Interactive Learning Model (ILM) departs from approaches such as Felder's in being more comprehensive and having greater explanatory power, as well as providing more flexible strategies for improvement of teaching and learning.

The ILM describes mental processes in terms of three domains, which appear in various other learning styles approaches but not consistently and not as equally important components. The three domains are:

1. **Affective**: how we feel, our engagement, including values, self-esteem, and self-efficacy
2. **Conative**: what we do, our action, including skills and aptitudes, pace or "tempo" of learning, and degree of desire for autonomy or for social interaction
3. **Cognitive**: what we think, our understanding, including multiple intelligences, internal reflection, level of abstraction, and prior experience[7]

Learners experience these three dimensions through four patterns of mental processes, each of which engages affect, conation, and cognition in distinct ways. The extent to which a learner exhibits each of the four patterns is captured in an instrument called the Learning Connections Inventory (formerly the Learning Combination Inventory) or LCI. The LCI, developed by Christine Johnston and Gary Dainton of Let Me Learn™ and the Rowan University Center for the Advancement of Learning, is a survey that asks students to respond to statements about preferred ways of learning and expressing their learning (for example, they are asked whether they would rather write a paper or build a project, or whether they want explicit instructions before doing an assignment or would like to figure it on their own). Respondents also give written answers to three open-ended questions about what promotes or obstructs their learning. Responses to the LCI statements, using a Likert scale ranging from Always to Never Ever, yield scores for each pattern in the ranges of Avoid, Use as Needed, and Use First.[8,9] The four learning patterns were identified through extensive validation procedures performed on the LCI instrument, which established recurring sets of statements in the written portion that corresponded to trends in the scores as well as to described or observed examples of subjects' performance and work products.

The patterns are present in all learners, but individual learners exhibit observable preferences and avoidances of each pattern. Briefly, the **sequential** pattern is associated with order, structure, and organization. Sequential learners are distinguished by a need for clear instructions, a tendency to learn through practice, and a desire for examples to clarify expectations. The **precise** pattern is associated with accuracy, detail, and information. Precise learners are recognized through a need to be informed, a desire to share their knowledge, and a need for detailed and correct expression. The **technical** pattern is associated with relevance, hands-on learning, and problem-solving. Technical learners exhibit a need for practical application, a tendency to prefer projects over written activities, and a desire to work quietly alone. The **confluent** pattern is characterized by risk-taking, intuitive understanding, and innovation. Confluent learners have a need for options and open-endedness, a desire for creative expression and performance, and the ability to generate unique ideas and approaches.[10]

Table 1 is an overview of the four learning patterns and their associated modes of affect/feeling, conation/doing, and cognition/thinking.

Table 1. Overview of four learning patterns and how they are manifested through feeling, doing, and thinking.[11]

Pattern	Affect: how I feel	Conation: what I do	Cognition: what I think
Sequence	I thrive on order and consistency.	I plan, make lists, organize, work step by step.	I confirm expectations and instructions; I compare with known models.
Precision	I enjoy knowing things and being correct.	I research, ask questions, write.	I confirm accuracy; I gather details.
Technical	I want practical relevance and autonomy.	I solve problems, tinker and test, work hands on.	I find out how things work; I apply.
Confluence	I like innovation and risk.	I brainstorm; I try alternatives.	I think outside the box; I look for the big picture.

The ILM departs from other learning styles theories in the following key ways:

- Learners are not identified by a single category. Although many learners do have a dominant pattern or patterns and can be characterized according to some typical hallmarks, all learners exhibit unique combinations of the four patterns. In engineering, the technical learning pattern tends to be common and very pronounced. However, depending on the students' other patterns, their learning processes may differ considerably. This is discussed further below.

- The mechanisms by which affect, conation, and cognition work together to motivate and sustain learning are described as a systematic and interactive process. The ILM describes, for example, what kinds of thinking and doing produce positive or negative affective experiences for each learning pattern. This interaction is what permits the development of strategies for coping effectively with learning situations that conflict with the student's learning patterns.

- Validation research on the ILM has shown that, unlike personality, learning patterns are stable over time and not significantly influenced by situation or environment.[12] Learning patterns are established through random developmental processes early in life and are detectable as early as pre-school age (though not reliably measurable through the LCI until about the third grade). Learning patterns are not, however, genetic nor do they correlate with gender, race, ethnicity, or culture. This is particularly important because learning styles tend to lead to generalizations about entire categories of people (an illustration of this problem can be seen in an article published by the American Association for Higher Education[13]). We can expect that we will find similarities in the learning patterns of engineering students as a population because they are drawn to the engineering profession as a compatible learning context, and we can safely make some across-the-board adjustments meant to benefit the majority of the students. However, we can also, with instruments like the LCI, discern differences among the population that allow us to move beyond generalizations and avoid stereotyping. It is more potentially harmful to assign characterizations that extend beyond particular learning contexts to broader categories such as female or African-American students; such information could be used to discourage or limit these populations from entering certain professions, educational environments, etc.

The most important implication of the ILM is that each learner can understand and articulate his or her own unique learning processes and develop strategies for using them deliberately based on the demands of a given learning situation. By knowing their learning patterns, being able to analyze assignments in order to discern what learning patterns are being called for, and being able to use the vocabulary of the ILM to purposefully operationalize all of their learning patterns, students gain an extremely powerful way to optimize their own learning in any setting. This strategic approach is what makes the ILM a metacognitive model of learning. Felder's approach, and those of others seeking to understand what drives and promotes learning, are steps in the right direction, but they do not provide students with the power to shape their learning, forcing them instead to rely on teachers' accommodations, nor to cope with situations where their learning styles simply did not mesh with the learning tasks and expectations.

I turn now to the engineering education context I am most familiar with, the writing classroom. Challenges associated with engineering students' ways of learning have been felt particularly keenly in terms of writing instruction. Since ABET EC2000, expectations regarding writing skills have been significantly raised, resulting in considerable attention to what constitutes effective teaching of writing to engineering students. The issue of student learning differences matters in all writing classrooms, but the discussion here will focus on some observations that can be made about writing in engineering (for examples of learning styles theories applied to writing and writing in engineering, see Reimer[14] and Sharp, Harb, and Terry[15]).

The majority of Rowan engineering students score as Use First in the technical learning pattern. Out of a possible score of 35, most will score in the 30s; a score of 26 or higher is considered Use First. As a result, some hallmarks of these students are that they:

- Prefer to learn by doing
- Want practical relevance and despise busywork
- Prefer to work alone
- Keep knowledge in their heads rather than writing it down
- Are reluctant to express feelings
- Like to figure things out
- Want to get right to work and find the most efficient way to get the task done
- Are not likely to read instructions
- Will seek assistance and further information as needed

These learning preferences can lead to conflicts in writing courses. Writing courses often center on a great deal of reading and reflection. Writing assignments are often accompanied by theory and background, which may be delivered in part through assigned reading or perhaps through detailed assignment sheets. Writing assignments often require the expression of ideas or feelings, with explicit detailing of what they are based on. Writing courses are often "social," involving discussions or group work, while at the same time, the audience and purpose of student writing is often not "real." There may be a hypothetical scenario, or the context may simply be the assignment with the teacher as reader. All of these conditions are enormously frustrating for engineering students.

The strategies I am developing attempt to resituate the writing assignment in ways that allow technical learners to find ways of working with and sometimes around their dominant pattern. Some strategies deal with motivating engineering students to want to learn to write better by making the "problem of writing" an appealing challenge; others are ways of harnessing their strengths as ways to encourage learning processes normally associated with other patterns. In any case, strategies for helping technical learners work more effectively with writing assignments need to engage the learner in all three areas of their mental processes:

Affective: Technical learners must feel engaged in the assignment. Where possible, they should be allowed to choose their topic and approach. If not, the purpose of the assignment must be explicit and apparent, or the student must be encouraged to develop an angle that builds a sense of investment in the assignment. It is very helpful to relate desired writing practices to real-world situations. For example, because technical learners do not usually write down information and are not good note-takers, I present note-taking as documentation and relate this to quality assurance practices in industry.

Conative: Technical learners learn by doing. They should be allowed to "try out" the assignment, receive feedback, and then "fix" it, thus making the opportunity to revise a key aspect of effective learning. They also work best when the assignment is presented as a problem to be solved, with a desired concrete result against which they can "test" their solution. Thus, rather than having them read about background for an assignment, I have them use a detailed heuristic for analyzing audience and situation in order to derive an effective approach. I provide brief overviews of instructions or background information, and then have them apply this knowledge to an in-class assignment that previews a longer out-of-class assignment. Technical learners will seek further information or instructions when they feel the need. I therefore try to anticipate needs and provide resources or assistance in forms they can access when they are ready for help. The best methods are one-on-one consultation and asynchronous resources that they can use on their own, such as WebCT (online course modules) and online writing resources.

Cognitive: Technical learners think in terms of applying knowledge to practical contexts. Where possible, project-based or case-based learning is most effective. At Rowan, engineering students take a special version of our required second semester course, which is linked to a project-based sophomore level engineering design course. Many of the assignments relate directly to the project, and all are engineering-related. Thus, writing instruction provides applicable practical knowledge that is immediately put to use in connection with a real problem or need. This also helps them to understand that level of detail is determined by the needs of the particular audience they are writing to. Again, because technical learners do not write down information, they do not always provide enough for others; their writing is often overly concise to the point of being vague and unclear. They need to focus outward, on audience needs. Finally, I have also been experimenting with hands-on activities in the writing classroom to allow them to use their natural learning patterns to generate content, understand organization, and analyze audiences. For example, I asked them to create flow-charts showing how a preliminary design report would be read in order to help them connect with reading in a functional sense, as they envisioned a reader flipping through the report, scanning headings, looking for visuals, and processing what they were looking at.

An example from my most recent class illustrates the three components in action. When the students began their preliminary design proposals for the semester project, a crane, they were forced to work from little or no hands-on experience with the project. The size of the crane, designed to lift a minimum of 400 pounds, precluded the construction of any prototypes. This feature of the project was intended to discourage "guess and check" approaches to solving the design problem and encourage instead a deliberate design process based on research and mathematical modeling. However, this left students with no way to begin the preliminary design proposal through their "use first" learning pattern, and thus, from their perspective, no way to begin at all. The initial affective reaction was one of frustration, and this thwarted their otherwise positive feelings toward what they saw as an interesting and challenging project. To provide them with a place to start that would then allow them to move to their "use as needed" and even "avoid patterns, I offered some modest opportunities in class one day for them to use their technical learning to begin their learning. One option was to use Lego MindStorm kits (advanced Legos with pulleys, gears, programmable motors, and other sophisticated mechanical parts) to construct prototypes that would allow them to analyze the design issues. Another option was to go to the project lab and view the base structure for the crane as well as the materials that they would use to fabricate a lifting apparatus to attach to the base. Students reported afterwards that these activities did help them find a route to using research and modeling to do the abstract design work. One student memorably told me that once he saw the raw materials, he could "build the crane in his head" and then work from that model through the design process.

What was occurring as students used these options for working on the project was their use of their technical conation—their hands-on way of doing things—to comprehend the problem; they had to handle the materials or build a prototype, however crude, to cognitively grasp the design problem. This contrasts markedly with students who would, for example, break the project down into steps before beginning (using sequence first), or those who would read about cranes before beginning the project (using precision first) or those who would brainstorm and sketch several possibilities without paying particular attention to whether they were realistic (using confluence first). In the case of the technical learners, they began to intuitively grasp the issues of force, stress, and strain involved in the crane, and figure out how the application of various mechanical possibilities would address the design issues. They were then ready to apply the design tools and mathematical analysis they were learning about in class.

These descriptions of the technical learner are not unfamiliar to anyone who has been trying to analyze individual learning behaviors, whatever their approach, nor are any of the strategies necessarily new. What is important is that both teacher and learner have access to a matrix of descriptors of feeling, doing, and thinking and a vocabulary for discussing how they are manifested in assignments and in their own learning habits. When my engineering students tell me "Writing is not my thing," we now have a way to reflect on why that is and what we can do about it. For example, knowing as I do that technical learners keep knowledge in their heads and don't feel a desire to express it, I can utilize the surprisingly simple but helpful strategy of asking them to explain a concept or process to me orally, and then telling them to write what they said. This is particularly useful because I can ask for elaboration or explanation, thereby helping the student understand what level of detail is needed. (Interestingly, telling people to write the way they would speak has long been discouraged by composition pedagogy, but recent research on how composing orally can help some students supports the idea that technical learners may benefit significantly from doing this.[16])

I have focused on the technical learning pattern because it is by far the dominant learning pattern of Rowan engineering students. This may not necessarily be the case at other institutions, and it is even more likely that the profiles of the three other patterns will differ. The Rowan student population in general tends to be in the range of Use As Needed to Use First in sequence and Use As Needed to Avoid in precision, and this holds true among our engineering students. Although the emphasis is on students' developing their own strategies to respond effectively to learning situations, the ILM is also used by teachers to examine their assumptions about learning as reflected in their teaching and to tailor their teaching where possible to better accommodate students' learning patterns. Teachers also take the LCI and provide their scores along with a graph of the entire class. It is often instructive to see the range of scores and to see where teachers may have significant differences from their students. Rowan faculty are higher in precision and confluence and lower in sequence than the student body on average, which tells us that we may need to provide students more guidance (sequence) so that they may effectively deal with the levels of detail (precision) and open-endedness (confluence) that we prefer. The important conclusion to draw here is that we cannot necessarily apply the strategies discussed here for dealing with technical learners to another setting without knowing specifically what the distribution of all patterns in that setting is. The ways in which my students in general operate as technical learners are strongly shaped by these co-occurring preferences for sequence and avoidances of precision. The importance of this distinction is apparent to me when I work with a student who is not only technical but also precise, or a student who is highly confluent. These students have entirely different needs.

As I have repeatedly emphasized, the ultimate value of the Interactive Learning Model lies in the ability of the students to use knowledge of their learning patterns deliberately. I have not yet done a formal study of the impact of the LCI on student performance in engineering, but plan to do so in the fall of this year. This study will be based on one I am currently doing in a general composition course, which I will briefly describe here. The current study will measure the effect of having students regularly analyze assignment expectations and personal learning patterns, develop pattern-specific approaches to the assignment, and reflect on the effectiveness of the strategies they used. Students completed a brief assignment at the beginning of the semester to document their competency at several course-specific learning objectives. They were also asked to describe or draw how they learn, to analyze the assignment and explain in their own words what they were being asked to do, and to describe how they went about doing the assignment. A similar assessment will be performed at the end of the semester. Content analysis will be done on each set and a scale for comparison developed. Meanwhile, for each assignment done during the semester, students are filling out a "grid" that describes how each learning pattern is manifested in their personal learning processes, how each learning pattern is called for by the assignment, and how they will strategically adjust to differences in their normal use of a pattern versus the assignment expectations. For example, a student who avoids precision would first describe personal tendencies resulting from this avoidance, including perhaps resistance to excessive information, dislike of research, and disinclination to "write things down." He or she would next focus on the assignment, identifying words, phrases, or implied expectations that are linked to the use of precision. To do this, students use a list of "cue words" associated with each pattern. For precision, some important cue words are explain, detail, elaborate, research, support, and discuss. Finally, he or she would develop personalized strategies for using precision. These strategies may involve actions the student can use to "do precision"—the student may say, "I will take notes on what I read." Or the student might leverage another pattern that they more naturally use—"I will outline what I read" (sequence) or "I will come up with a unique angle so that I will be interested in the research" (confluence). Or the student might harness a positive affective result as a motivator—"I will feel more confident if I know more about my topic, so I will find more information about it." Evidence from a number of settings that use the ILM, including not only higher education settings but primary and secondary schools, indicate that student performance is improved with this kind of deliberate approach.

The Interactive Learning Model provides a richer and more useful understanding of what many engineering educators will recognize as a common and even typical *modus operandi*. Like other methods of describing learners, the ILM helps us understand that when a learner struggles, it does not necessarily indicate that something is wrong with the learner. Conscious understanding of differences among learners leads to a deeper understanding of learning in general that will enrich teaching. Yet it is apparent that generalizing about engineering students as learners, while certainly helpful, is only part of a larger picture. There is only so much that teachers can or even should do to accommodate students; we also need to provide them with tools for coping on their own. The ILM offers a powerful depiction of learning processes with the potential to impact not only writing instruction in engineering, but other areas as well. In fact, the ILM is also proving very useful in working with student teams by helping students understand and deal openly with pattern differences among themselves. For a discussion of work being done with this at Rowan, please see "Developing Metacognitive Engineering Students through Team-Building" (Kevin Dahm, James Newell, and myself), also presented at this conference.

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