Metrics and the Holistic Learner

Jennifer Karlin
South Dakota School of Mines and Technology, Rapid City, SD, USA
Jennifer.Karlin@sdsmt.edu

Stuart Kellogg
South Dakota School of Mines and Technology, Rapid City, SD, USA
Stuart.Kellogg@sdsmt.edu

***Abstract**: The shift to a global economy, the move to lean management structures, and the need to develop an intellectually and culturally diverse engineering community requires a curriculum that more fully develops the complex thinking skills required by today's industries. This paper presents a summary of the holistic nature of student development which values alternative modes of intellectual inquiry as well as alternative measures of student development. A summary of suitable metrics by which to student development is included.*

Introduction

The shift to a global economy, the move to lean management structures, and the need to serve an increasingly diverse learning community requires a new approach to engineering education. It requires a transformative curriculum that not only embraces the changing requirements sought by industry, it requires a model that develops the complex thinking skills required to help industries be successful in today's global market place. Very few companies stress only technical skills anymore. Some companies stress corporate culture and the ability to work on multi-disciplinary teams. Others focus on value added opportunities to understand the impact of globalization and lean enterprise management. Still others focus on leadership skills or creative problem solving skills. South Dakota currently has a focus on technology innovation, economic development, and critical thinking.

Regardless of the industry, almost all of the hiring metrics used by industry today can be restated within one or more frameworks for cognitive development. Indeed, one of the clarion calls associated with 21st Century Skills is a need to ensure that students understand fundamental concepts and can transfer these fundamental skills to new technologies and to new problems for which a general theory may not yet exist. The Industrial Engineering department has adopted a three tiered framework for cognitive development as a mechanism for bridging the needs of students, industry requirements, and the theoretical educational frameworks needed to bring these changes about. We call this overall model the Holistic Learner Development (HLD) model which values

- Alternative modes of intellectual inquiry
- Social development
- Intellectual development
- Identity development
- Learning neighborhoods

While there is a significant and growing body of research in many of the individual parts of the Holistic Learner Development (HLD) Model, none of these parts individually describes the complex world of the learner. Learning theory would suggest that in order to help students develop better complex thinking skills one needs to provide a curriculum that is challenging while simultaneously recognizing that individuals develop along multiple dimensions. The "individual development" part of the HLD model recognizes that there are separate but overlapping areas of individual development. These areas are grouped in the HLD model as: Identity/Psycho-Social Development, Intellectual Development, and the Learning Neighborhood.

Research Question

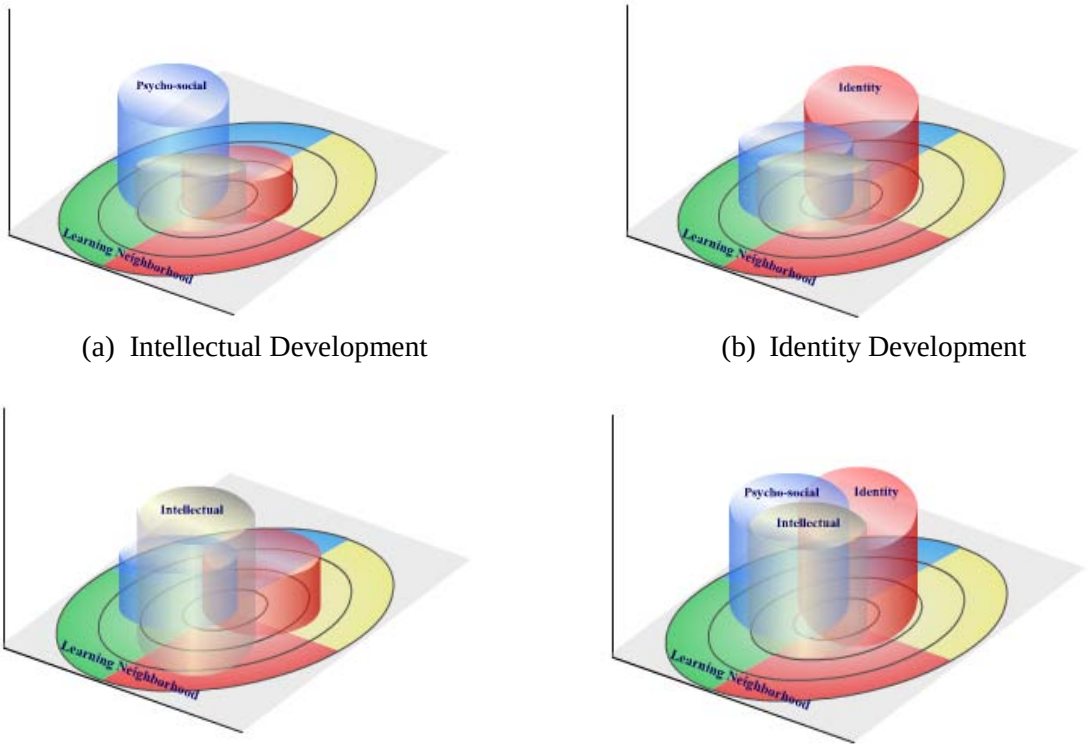
While education practitioners pose questions related to strategies for improved student learning, such improvements are likely to remain elusive due to the inherent complexity of the HLD model as well as limited knowledge as to the efficacy of different assessment metrics. Proponents of undergraduate design centers, for example, often cite student development as the overriding theme but typically struggle with effective measures for student development. Does student development refer to improved teaming acumen, improved persistence, improved self-efficacy, better typological understanding, or intellectual development? In this paper, we propose a theoretical framework for understanding the HLD model, a general research methodology for understanding the interrelationships between HLD components, and different metrics and instruments for assessing these interrelationships.

Theoretical Framework

While many talk about student development theory, most have a different concept of what student development really means. This is not entirely unreasonable since there are a number of different developmental models available to choose from. Universities that are primarily concerned with a student's psychosocial development typically concentrate on learning communities and providing opportunities for student social networks. Identity development considers student values as they relate to self-efficacy and perceptions of how the individual relates to gender or cultural values. The faculty tends to be primarily interested in intellectual development and a student's ability to solve complex problems and adapt to new learning situations. The Holistic Learner Development (HLD) model provides a conceptual framework that begins to integrate different developmental models by recognizing that student development is a set of complementary models that when considered together begin to provide a more realistic approach to overall cognitive development.

A primary assumption of the HLD model is that in order to maximize a student's ability to develop the complex thinking skills required by today's industry, one must necessarily be concerned with all aspects of a student's development. That is, it is important to consider curricular/co-curricular options that simultaneously address multiple aspects of a student's overall development. An underlying premise to this developmental model is that all students come with different learning styles, different experiences, different motivations, and different attitudes and perceptions towards the learning process. This we call the Learning Neighborhood. Although relatively new, the HLD systems approach is not new and is analogous to a multi-perspective approach first proposed by Felder and Brent in 2005. While an extensive literature base is available for interested readers, Figure 1 below provides a conceptual framework for the HLD model.

Within the HLD framework, strong psychosocial development may lead to strong social networks and leadership potential but may come at the expense of true understanding of the complex thinking skills needed by today's industries. Similarly, strong identity development may lead to a strong belief in one's self but may come at the expense of the fundamental technical skills. Conversely, strong intellectual development without the accompanying psychosocial or identity growth may lead to the stereotypical engineer lacking even the rudimentary social skills required to operate in a defined society. The point is that psychosocial development, identity development, and intellectual development are all important. A fundamental premise of the HLD model is that, because of synergistic interrelationships of different developmental stems, maximizing overall cognitive growth is best achieved by simultaneously developing all three areas of growth. Further, to fully understand student cognitive development, it is important to begin to understand the inter-relationships between alternative development models.



(a) Intellectual Development (b) Identity Development

(c) Psychosocial Development (d) Holistic Development

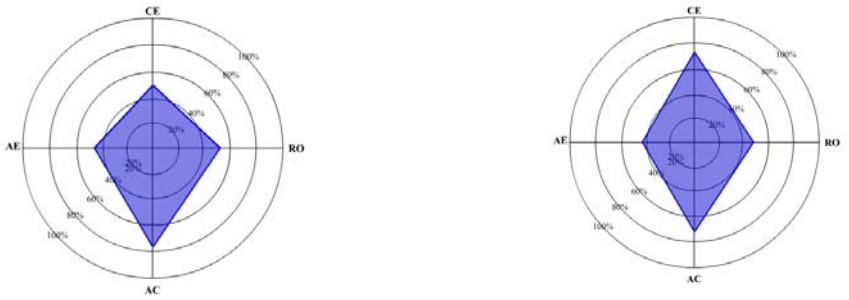
Figure 1. Conceptual Framework for Holistic Development

Research Methodology

To adequately assess the effects of a particular learning strategy, one must move beyond the NSSE data and begin to measure different aspects of student learning as well as the interrelationships of different learning components. For example, consider an undergraduate design center which purports a focus on student development. Depending on the metric and assessment instruments selected, one may very well see significant gains in self-efficacy but not in intellectual development. Alternatively, it may be possible gains are limited to a fairly restrictive learning neighborhood or to a predominant student typology. We propose a general research methodology utilizing multiple regression and a variety of dependent variables (learning outcomes) and independent variables (demographics, learning style, background, etc.) as a mechanism for capturing holistic learning gains, interrelationships between different developmental models, and the efficacy of certain types of instruments. Program logistics, efficacy of different instruments, and student perception dictated that a more pragmatic approach integrating program assessment and curricular strategies be taken. Specifically, although typically implemented within a strategic vision, curricular initiatives are necessarily implemented a component a time. This approach not only provides a format for continuous improvement that students respond well to, it also allows faculty to explore the efficacy of a variety of different assessment instruments. The remainder of the paper is devoted to different components of the HLD model and the assessment status for that component followed by a short summary for tying it back together for holistic assessment utilizing a multiple regression approach.

Learning Neighborhood

Students are individuals and enter the university experience with diverse backgrounds, experiences, attitudes, and learning styles. This collective set of attributes we label as the learning neighborhood. While the learning neighborhood is a rich tapestry that is both diverse and complex, learning styles can be measured and effectively quantified. Further, there is at least some research that suggests that a mismatch between traditional engineering curriculum and a student's learning style may be a contributing factor for student attrition (e.g., Felder and Brent, 2005 and Sims and Sims, 1995).



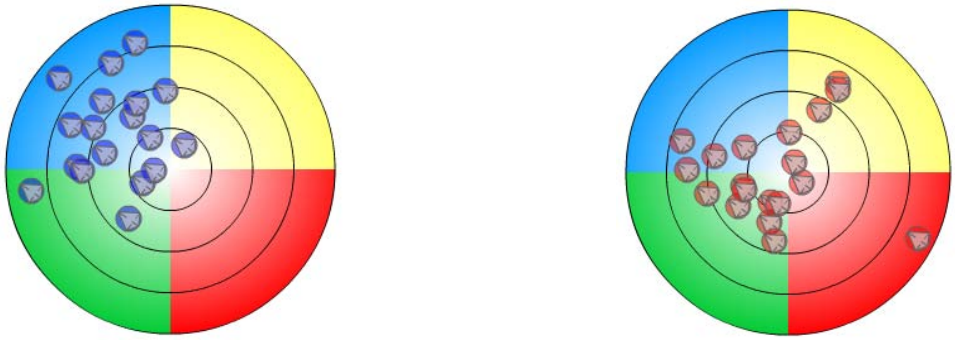
(a) First Year Students (2004) (b) Graduating IE Seniors

Figure 2. Average Kolb Learning Style Kite for Industrial Engineering Students

The department has collected typological (learning preferences) data on first year and matriculating seniors for the past seven years. Baseline data for the Kolb instrument is available online and may be sorted by gender, by year in school, and by discipline (http://ie.sdsmt.edu/firstyear/kolb.html). Figure 2 above compares the average learning "kite" for matriculating seniors in the industrial engineering program to that of first year students for the campus.

In Figure 2, the CE axis denotes an individual's preference for concrete experiences, RO a preference for reflective observation, AC for abstract conceptualization, and AE for active experimentation. Many engineers tend to respond well to active experimentation (AE) and less so to reflective observation (RO) resulting in a long narrow learning kite skewed to the left. Figure 2 would indicate that students have responded to curricular innovations that incorporate a variety of learning typologies. Specifically, retention data, along with Kolb data suggests that students who might otherwise leave engineering due to a typological mismatch are being retained. While Kolb assessment also included gender differences, practical logistics as well as reliability/validity issues of the Kolb instrument caused a realignment of assessment instruments.

Because of reliability issues, the department has switched to use of the Herrmann Brain Dominance Inventory (Herrmann, 1990) which is now required in a first course in industrial engineering. Baseline data for nearly half of the industrial engineering majors is currently available and is shown below in Figure 3 by gender.



a. Men b. Women

Figure 3. Baseline HBDI Data for Industrial Engineering by Gender (2008)

Traditional engineering curriculum is focused on analytical thought processes (blue quadrant in Figure 3). Students in the yellow (conceptual), green (details and logistics), and red (collaborative, empathetic) quadrants are often very capable students but feel disconnected from the more traditional curriculum which has stronger analytical approach. Further, the preliminary data shown in Figure 3 suggests that this disconnect is more likely to be experienced by women than by men. This would agree with department retention and matriculation data that suggests that a focus on curricular initiatives responsive to intellectual diversity may be a more productive venue for student retention as

well as intellectual growth. A drawback to the HBDI instrument is that it is more expensive ($45/ student) and requires a certification before it can be administered. One of the current department initiatives is to simultaneously collect both Kolb and HBDI data which, once sufficient data is available, will be analyzed for possible correlation between the two.

Sub-research Questions

1. Can a focus on intellectual diversity help to solve gender gap issues in engineering education?
2. Though epistemological assumptions between the Kolb and HBDI are quite different, is there sufficient correlation between the two that either could be used as effectively?
3. Traditional engineering curriculum is predominantly analytical in nature. An engineer must possess the technical skills necessary to solve the technical problems posed by industry. Can a more diverse typological approach lead to better complex thinking skills or would such an approach come at the expense of technical skills?

Intellectual Development

Much of the current work in intellectual development theory originated with William Perry (1970) from studies of students at Harvard University in the 1950s and early 1960s. Perry observed that two students with nearly identical intellectual capacity may in fact differ markedly in their ability to effectively solve problems and engage in intellectual discourse. One criticism of Perry's work is potential discrimination against the developmental characteristics of women. Belenky et al (1986), conducted research based on Perry's work but specifically on women and devised five cognitive development stages through which women progress, called "Women's Ways of Knowing". While Perry's groups and Belenky's stages are very similar, Belenky's model proposes a slightly alternative progression of stages for women's development. Baxter Magolda's Model of Epistemogical Development integrates the Perry's and Belenky's models by defining alternative patterns for all levels (except for the highest level), with one pattern characterizing more men than women and one model characterizing more women than men. Perhaps one of most widely used and validated current model is the King and Kitchener (1994) Model of Reflective Judgment. The low and intermediate levels of Perry's model are almost identical to the low and intermediate levels supported by King and Kitchener but the upper levels diverge somewhat depending the level of reflective thinking of the individual. Though not as widely accepted, a newer model which is soundly rooted in Reflective Judgment Theory but which provides practical implications for the classroom is the Steps for Better Thinking Model of Wolcott and Lynch (2002). Regardless of the model used, research repeatedly illustrates that intellectual gains fall short of both what is desired by industry and by what should be developmentally possible.

Though a number of instruments exist to measure intellectual growth, most require considerable training and most are quite labor intensive. The department has incorporated the Steps for Better Thinking rubric (available on request) with preliminary results indicating higher levels than the national average (see Figure 4 below).

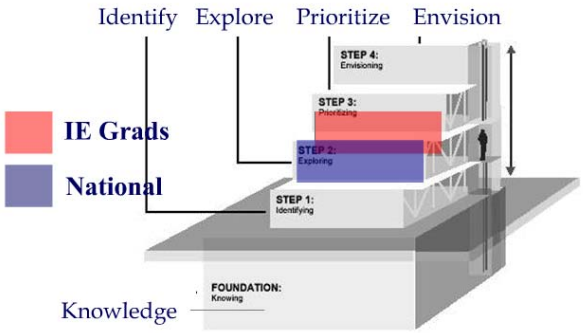


Figure 4. Preliminary Assessment Utilizing Steps for Better Thinking Rubric

This result is consistent with results obtained from the Learning and Studying Strategies Inventory (LASSI) collected in 2006. Baseline LASSI data is available for First Year students at SDSM&T but is no longer utilized by the department as an assessment component for intellectual growth. While the initial study was designed to look at the idea of cognitive, the instrument is aimed at promoting the transitional skill sets students need for college success. And, while this skill set is important for intellectual growth, the instrument itself does not measure intellectual growth. Further, without cross campus incorporation for comparative analysis, the department opted to focus on alternative instruments with stronger developmental measure. Baseline developmental data was obtained on First Year students in 2006 utilizing the Reflections on Current Issues (RCI) data. Additional baseline data as well as data on matriculating seniors will obtained during the next academic year. Results will then be compared to 2006 data for intellectual growth as well correlated with results from the Steps for Better Thinking Rubric.

Sub-Research Question

1. Belenky's model suggests differences between men and women at certain stages of development. Is the Steps for Better Thinking and/or RCI instrument subject to the same problem? Would incorporation of alternative measures and/or instruments to provide a more effective measure of gender differences (e.g., Buczynski, 1993)?

Psychosocial and Identity Development

There is considerable literature to suggest that faculty and administrators have a responsibility to help students develop physically, intellectually (cognitive), socially and morally. Perhaps one of the best known theorists in this area is Erik Erikson (1980) who believed that personality develops in a series of stages that describes the impact of social experience across the whole lifespan. According to Erikson, our ego identity is constantly changing due to new experiences and information we acquire in our daily interactions with others. Indeed, this notion forms the fundamental basis for a nation-wide movement towards the blurring of curricular and co-curricular lines and incorporation of university learning communities (e.g., Goodsell and Tinto, 1994). In such a learning community, primary interest in psychosocial development generally rests with residence life or student affairs personnel.

The Student Affairs division has assumed primary responsibility for meeting student transitional needs and leadership development and has done so through an innovative STEPS (STudents **E**merging as **P**rofessional**S**) program which includes programming for time management, study skills, learning strategies, cultural diversity, and leadership development. Implemented in 2006, assessments include baseline data for the campus utilizing the LASSI inventory as well as a self-assessment of gains in leadership, diversity, communication, respect, and life-long learning. LASSI data has been useful but will require broad campus involvement with first year mentors before significant gains are likely. Lack of a comprehensive campus initiative is prompting the department to review the Constructive Thinking Inventory (CTI), the Self-Perception Profile for College Students, and the General Perceived Self-Efficacy scale as alternative or complementary measures for student growth in this area.

Other Assessments

For engineering, a critical element for developing complex thinking skills rests with a student's ability to function effectively on multi-disciplinary teams and to understand and articulate a professional construct for the engineering profession. New team assessments implemented in the Fall 2008 include the Comprehensive Assessment of Team Member Effectiveness (CATME) and the Team Knowledge, Skills, and Abilities inventory (Team KSA) with the CATME used primarily for behavioral assessment and development and the Team KSA as the primary assessment for evaluating student understanding of team processes. A departmental portfolio system also implemented in Fall 2008 includes course and cross campus portfolio articles that will be evaluated utilizing the Steps for Better Thinking Rubric. By incorporating required articles of self-reflection pertaining to professional

development, the department hopes to gain additional insight as to more productive areas of student development.

Tying It All Together

Recognizing the complexity of student development has motivated the department to view curricular initiatives and programmatic assessment in a more systemic fashion. A variety of instruments have been reviewed for reliability, validity, and overall efficacy based on logistics, appropriateness of the measure, and perceived consistency with program initiatives. Currently, primary instruments used to assess holistic learner development include the following.

- Intellectual Diversity: Kolb (1999-2007), HBDI (2007-2009), Enrolment and retention
- Team Development: CATME (behaviorally anchored rating scale), Team KSA
- Intellectual Development: Cross campus portfolio, RCI (Reflections on Current Issues, Steps Rubric
- Psychosocial/Identity Development (Student Life, STEPS program)

By viewing students and student learning holistically, the assessment data has led to several strategies for developing the complex thinking skills required by industry.

- Formal, purposeful introduction to intellectual diversity through the Herrmann Brain Dominance Inventory and whole brain thinking in the sophomore year
- Formal introduction to team tools, team processes, and team evaluation in the sophomore year
- Formal reflection components through cross-campus and course portfolios
- Reduced reliance on lectures and greater faculty-student / student-student interaction through open-ended problem solving, service learning components, and creative problem solving
- Foundational support scaffolding through technology modules and classroom inversion
- Value added opportunities in safety, innovation, engineering management, and quality control
- Better student engagement through real world projects and service learning components

Considerable data and progress has been made on understanding and responding to intellectual diversity but considerable work remains to better understand intellectual development and psychosocial gains. New initiatives related to assessment of team processes, cross campus portfolios and self-efficacy instruments will provide new understanding as to how student differences impact intellectual development, psychosocial development and team processes.

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