Prevention
Through Design

A Curriculum Model to Facilitate Hazard Analysis & Risk Assessment

By David W. Wilbanks

In September 2011, ASSE announced the approval of ANSI/ASSE Z590.3, Prevention Through Design (PTD): Guidelines for Addressing Occupational Risks in Design and Redesign Processes. The standard requires hazard analysis and risk assessment whenever "new facilities, equipment technologies and processes are being planned, designed, acquired or installed" (ANSI/ASSE, 2011, p. 4), when alterations are made, following incident investigations and even when demolition or decommissioning work is performed. Hazard analysis and risk assessment require an organization to ask key questions, such as, What are the functions, features or requirements? What can go wrong? What are the effects? How often does it happen? How can it be prevented and detected? (ANSI/ASSE Z590.3, Addendum H).

In Section 8, the standard cites three specific basic techniques for addressing most assessment needs: preliminary hazard analysis and risk assessment; what-if/checklists analysis methods; and failure mode and effects analysis.

Applying the standard presents organizations with significant opportunities to identify and eliminate problems before they are created, but it also carries significant implementation challenges. Chief among them might be the standard's requirement that top management: designate personnel within the organization who

IN BRIEF
•Hazard analysis and risk assessment are the keystones of ANSI/ASSE Z590.3, Prevention Through Design.
•OSH professionals must help personnel develop skills to facilitate these analyses and assessments.
•Academia is uniquely suited to develop novel approaches for industry's ultimate use. This article discusses models for assessing training outcomes, and proposes a concept hazard analysis/risk assessment skill development model.

have the necessary knowledge *and* [emphasis added] skills to anticipate, identify and analyze hazards and assess the risks deriving from them and determine that appropriate training to acquire the necessary knowledge and skills is given. (ANSI/ASSE Z590.3, 2011, p. 15)

Beyond organizational commitment and provision of resources, successful implementation and maintenance rest significantly on the availability of effective expertise in facilitating hazard analysis and risk assessment. Success is not merely contingent on personnel who know and understand appropriate analysis and assessment techniques, but on those who master such techniques along with other soft skills so that they may be performed well.

This article presumes the curriculum adopted by academia for teaching hazard analysis and risk assessment will ultimately become either a significant constraint or powerful lever for industry members endeavoring to implement PTD. Nearly 200 institutions provide some form of higher-education OSH courses in the U.S. (ASSE, 2014); this constitutes ample preparation opportunity for those soon to enter industry. Engineering, science and business education programs must also take note as hazard analysis and risk assessment are never the exclusive domain of the OSH professional. It is also hoped that industry might benefit from the examples provided for its related training efforts.

A Challenge Unmet?

ASSE's Risk Assessment Institute (2013) describes the ability to "understand and apply the basic concepts of various common risk assessment techniques" (p. 1) as a core competency for practicing safety professionals. It establishes that knowing is not enough; application is key. Lyon and Hollcroft (2012) further posit that some common risk assessment pitfalls include the prevalence of team members who either are not adequately knowledgeable, experienced or objective. Finally, Center

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for Chemical Process Safety (2008) observes that "effective hazard evaluation leaders have strong interpersonal skills and an in-depth understanding of the scope and objectives of the study." Furthermore, "in most cases, the success of the study depends directly upon the skill of the leader" (p. 43).

Famed music conductor Leonard Bernstein was ridiculed early in his career for his energetic and flamboyant style. "There is nothing Lenny can't do supremely well," an acquaintance remarked, "if he doesn't try too hard" (Henahan, 1990). As much can be said of the analysis/assessment facilitator, both technician and interpreter, demonstrating that making music is less about direct control and more about indirectly bringing out the best in project participants.

In addition, Jain and Anjuman (2013) point to the criticality of soft skills such as conflict resolution, diplomacy, communication and collaboration over technical skills alone, valuing their importance to success at 85% with technical skills valued at 15%. In sum, bringing out the best from those assembled to complete hazard analysis and risk assessment is as much art as a technician's task, the difference being a wasteful, ineffective, perfunctory exercise or a rich amalgam of learnings that ultimately protect and preserve complex systems from previously unrecognized hazards.

Manuele (2013) states that "learning to do hazard analysis and risk assessment is fairly easy" and that "skill improves with application." Dreyfus (2004) describes a five-stage model for adult skill acquisition (Figure 1) that generally agrees, perhaps with a caveat. Acquiring any skill is involved and practice might be trusted to make permanent more than perfect. Intuitive, expert demonstration of any skill is never guaranteed, nor is competence.

The task of tying one's shoes is illustrative. Simple? Hardly. Tying shoes requires complex motor skills and correctly sequenced procedural steps. If the term *simple* can ever be connected with this task, it is only appropriately concluded from the distance afforded by time, experience and confidence based on repeated success. Learners are observed to make many mistakes along the way and probably no one performs the example task perfectly at first; frustration is normal; shortcuts will be attempted that result in ineffective outcomes and setbacks.

Salvucci (2013) uses the term *integration* as a technical touchstone directing attention to a larger process that involves accessing and reusing unrelated knowledge across the learner's entire experience domain; reuse or repetition is important but not enough. Evidence also exists that some individuals are better able to use cues to acquire complex skills because of a higher ability to correctly and quickly classify emerging information and environment features (Wiggins, Brouwers, Davies, et al., 2014). In lay terms, some get it more naturally than others, and some will never get it.

Figure 1
Levels of Adult Skill Acquisition
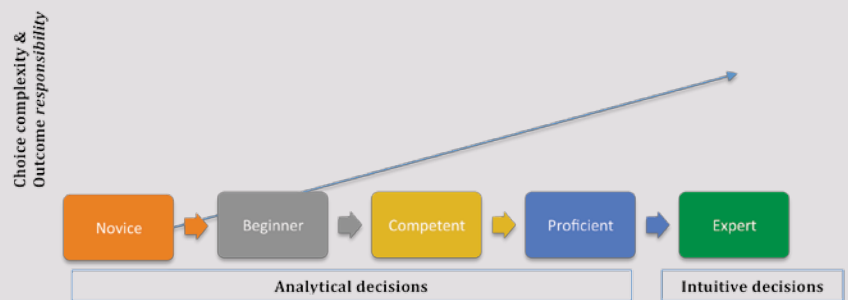
Note. Adapted from "The Five-Stage Model of Adult Skill Acquisition," by S.E. Dreyfus, 2004, Bulletin of Science, Technology and Society, 24(3), Table 1, p. 181.

Manuele's (2013) encouragement is needed and welcome. OSH professionals must start somewhere, and hazard analysis and risk assessment concepts are fairly easy. However, care must be taken not to unwittingly mask the work required to achieve facilitation competence (that is required) or give inadequate import to the expert status (that should be desired). Base knowledge and its application are two different things (Yates, 2010).

The question posed is not whether hazard analysis and risk assessment can be taught relatively quickly to a wide audience (through knowledge transaction), or whether practice is important, but rather how can stakeholders best go about transacting this learning to minimize the consequences of inadequately completed assessments due to skill deficits. How are personnel best prepared to understand and apply risk assessment terminology and techniques, evaluate and analyze risk, select hazard control techniques, monitor implemented controls for effectiveness and implement management of change? These questions speak loudly to the importance of curriculum, that is, "a plan, an intended program or some kind of expert opinion about what needs to take place in the course of study" (Ellis, 2004, p. 4) for best preparing those who will lead hazard analyses and risk assessments or participate in their conduct.

Income the Outcomes
ANSI/ASSE Z490.1-2009, Criteria for Accepted Practices in Safety, Health and Environmental Training, provides a road map for answering the questions raised, although other learnings can also prove instructive and should be observed. For example, academia now values less what institutions do to teach students and values more whether students can, in fact, apply what has been learned (Walvoord, 2010). Leathwood and Phillips (2000) describe a shift toward capability-based curriculum.

The outcome approach predominates, and student capabilities are key. Shuman, Besterfield-Sacre and McGourty (2005) observe that ABET's adoption of Engineering Change 2000 alleviated

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Comparison of Outcomes Based Learning & Training Models

Level #	Kirkpatrick: Four Levels of Evaluation	Meier: Four Levels of Learning	Bird, Germain & Clark: Proper Task Instruction
A	Reaction	Preparation	Motivate
B	Learning	Presentation	Tell and show
C	Behavior	Practice	Test
D	Results	Performance	Check

Note. Adapted from "The Four Levels: An Overview," by D.L. Kirkpatrick, 1998, Evaluating Training Programs, *pp. 19-24; and from "The Four Phase Learning Cycle," by D. Meier, 2000,* The Accelerated Learning Handbook, *p. 53, New York, NY: McGraw-Hill; and from personal communications from F.E. Bird, G.L. Germain and M.D. Clark, 2003,* Practical Loss Control Leadership, *pp. 244-245, Duluth, GA: Det Norkse Veritas.*

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decades of strident rules in favor of three pages and 11 outcomes for students of its accredited programs. The mantra in higher education has become *outcomes, outcomes, outcomes,* and pedagogy appears forever changed.

Two examples from ABET-accredited institutions are illustrative of this shift. Indiana University of Pennsylvania's (IUP) Department of Safety Sciences program requires its undergraduate students to complete the Process and Systems Safety course. One objective of this course is to ensure that students demonstrate competence in various systems safety analysis methods, including those specified by the PTD standard. Some IUP faculty ask students to work in teams of three throughout the semester, applying various techniques to a
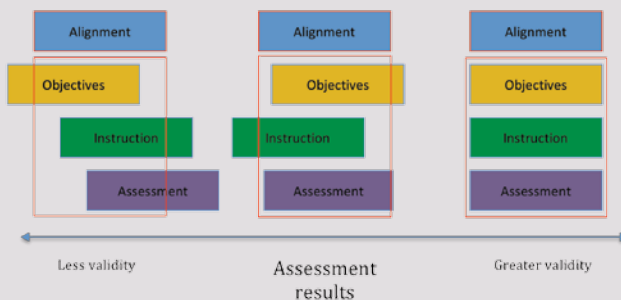
system selected by each team (M. Zreigat, personal correspondence, September 2014).

Students in Murray State University's undergraduate safety and health program must complete the Fundamentals of Risk Control course. It also emphasizes use and competence, requiring students to demonstrate the "ability to use the techniques, skills, and modern scientific and technical tools necessary for professional practice" (J. Wells, personal correspondence, September 2014). Popov, Blunt, McGlothlin, et al. (2013), describe efforts at Purdue University and Virginia Tech to generally integrate PTD into their curricula. This includes requiring students to perform practical risk analysis activities on real-world situations. Trusting the validity of this outcomes emphasis and its pursuit by these respected institutions, it is suggested that both industry and academia (specifically not limited to OSH academia) should broadly consider incorporating some approximation of these efforts into facilitation curriculum.

Outcome Constructs for Incorporation Into a Working Model

A review of popular outcomes-based training models included the following:
- Kirkpatrick's Four Levels of Training Evaluation;
- Meier's Four Levels of Learning;
- Bird, Germain and Clark's Proper Task Instruction model.

Each is described in Table 1 and summarized in the following discussion.

Kirkpatrick's Four Levels of Training Evaluation

Kirkpatrick's (1998) Four Levels of Training Evaluation model emphasizes reaction, learning behavior and results. "What knowledge was learned? What skills were developed or improved? What attitudes were changed?" (p. 39). Kirkpatrick opines that if knowledge transfer is all that is desired, only the elements of reaction and learning need to be assessed. This can be accomplished through such constructs as course critiques and summative assessment.

However, if the objective is to know that the learner can do a certain thing, some means of observing the desired behavior must be added to the evaluation process. In addition, if the objective is to change results, a fourth effort to evaluate training results is needed. Kirkpatrick's focus on evaluation—the reflective checking of the training once performed—provides a retrospective outcomes assessment to ensure that a person can do a certain thing in a certain way for certain outcomes.

Meier's Four Levels of Learning

Meier's activity-based learning concept (2000) eschews lectures and note-taking in favor of the total engagement of all human senses as realistically pos-

The concept of alignment provides a more complete framework for evaluating training outcomes and will complement curriculum planning when combined with the general attributes of the cited models.

Figure 2

Three Component Alignment Model

Note. Adapted from "The Role of Assessment in the Revised Taxonomy," by P.W. Airasian and H. Miranda, Theory Into Practice, 41(4), *pp. 249-254, 2002, College of Education, The Ohio State University.*

sible. Actively moving, doing, talking, hearing, observing, picturing, problem solving and reflecting in relation to the subject taught will decrease training time required while increasing long-term retention and efficacy. Papastergiou (2009) adds credence to this approach; she compared learning in children using traditional classroom methods to their learning using a computer gaming technique alone. To little surprise, the gaming application was the more effective approach. The priority given to activity adds an important curriculum element to achieving desired hazard analysis and risk assessment facilitation training outcomes.

Bird, Germain & Clark's Proper Task Instruction

Bird, Germain and Clark (2003) believe that effective training is not happenstance. Systematic methods are needed that, if applied, will eliminate the trial-and-error learning that frequently results in workplace injury and illness, as well as property damage, productivity and quality losses. Their four-step proper task instruction model conveys the importance of both motivating learners and ensuring that they know how to do their tasks.

The authors emphasize the critical interrelationships of each step and note that the technique was used widely during World War II to rapidly train unskilled civilians to produce war-time equipment. This model places the onus for successful learning on the instruction [e.g., "if the learner hasn't learned, the instructor hasn't taught" (p. 244)]. Faithfully applying each of the four steps, in sequence is promoted as the surest means to achieve learner success; the fourth step ensures that desired outcomes have been met.

All three techniques appear consistent and mutually supportive; that is, specific characteristics are repeatedly associated with effective learning and training outcomes and each can be clearly communicated and understood. The popularity of these models may rest in their simplicity. The three models, if not highly differentiated on close comparison, are imminently practical and provide a needed framework for hazard analysis and risk assessment facilitation curriculum.

Diamond (2008) argues that critical skills needed by students are often unmet because the course delivered is not aligned with the curriculum. Airasian and Miranda (2002) agree, and they provide an additional useful taxonomy. They state that alignment between the three components of objectives (expected outcomes), instruction and assessment (of outcomes) are vital for ensuring the validity of assessment results. Greater alignment equates to greater validity (Figure 2).

The idea of three-component alignment seems simple, but, as Airasian and Miranda (2002) observe, one can define knowledge in at least four ways (e.g., factual, conceptual, procedural, metacognitive) and test learning outcomes in at least six ways (e.g., remember, understand, apply, analyze, evaluate, create). The concept of alignment provides a more complete framework for evaluating training outcomes and will complement curriculum planning when combined with the general attributes of the cited models.

Potential benefits include guiding the actual process of training or teaching; providing a structure for complete evaluation, posttraining; emphasizing learner activity throughout the process for comprehension, retention and mastery of essential skill; integrating all concepts emphasized in the respective four-level models; and alignment of objectives, instruction and assessment.

Putting It to Work

The sidebar below presents a fictional course curriculum to help move this discussion from theory to application. Table 2 (p. 50) offers a timeline for the hypothetical course with reference to various aspects of the planned curriculum. The course outline is shared with the knowledge that it falls short of an idealized course design. It is offered not to show how

Fictional Course Description & Objectives

Course: Prevention Through Design: Hazard Analysis and Risk Assessment Techniques Facilitation

Course Description: The development of facilitation skills and the practical application of three qualitative and semiquantitative techniques will be emphasized. Students will become accomplished in facilitating the common techniques (e.g., What-If Checklists, Preliminary Hazard Analysis and Risk Assessment, and Failure Mode and Effects Analysis). ANSI/ASSE Z590.3-2012 will be emphasized as basic framework for the use of hazard analysis and risk assessment techniques throughout a system's life cycle: design, preliminary design, detailed design, build or purchase, commission, production maintenance and decommission.

Course Objectives
1) Develop facilitation skills such that each student can proficiently successfully plan, facilitate/lead and complete the conduct of a hazard analysis and risk assessment.
2) Understand significant applications for the use of hazard analysis and risk assessment in daily safety and health practice.
3) Know and apply the basic vocabulary common used in the practice of hazard analysis and risk assessment.
4) Assess and rank hazards using qualitative probabilistic and impact/severity criteria.
5) Evaluate the strengths and limitations of the common techniques, specifically as defined in ANSI/ASSE Z590.3-2012.
6) Create risk reduction plans that reflect appropriate hierarchical controls in a team environment based on completed risk assessments.

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•Kaner, S. (2007). *Facilitator's guide to participatory decision-making* (2nd ed.). San Francisco, CA: Jossey-Bass.

Hypothetical Course Schedule: Hazard Evaluation & Risk Assessment Techniques & Facilitation

Week	Prevention Through Design: Hazard Analysis & HA & RA Techniques & Facilitation	ASSE/ANSI 590.3 Sections & Addenda	Facilitator's Guide Text Chapter(s)	Meeting 1	Meeting 2
1	Dynamics of Group Decision-Making	1, 2, A.	1	C	C
2	Participatory Values & Role of Facilitator	3, G	2, 3	C	C
3	Listening Skills, Brainstorming	4, F	4, 8	C	C, HW1
4	Chart Writing Technique, Tools for Managing Long Lists	5, 6, C	5, 9	C	quiz
5	Student Facilitated Workshops 1	n/a	n/a	SFW	SFW
6	Facilitating Open Discussion and Open Discussion Alternatives	7.1-7.6	6, 7	C	C, HW2
7	Principles for Building Sustainable Agreements, Gathering Diverse Points of View	7.7-7.13	13, 14	C	mid-term exam
8	Building a Shared Framework of Understanding, Developing Inclusive Solutions	8, 9, A, I	15, 16	C	C
9	Student Facilitated Workshops 2	n/a	n/a	SFW	SFW
10	Dealing with Difficult Dynamics, Striving for Unanimity	8, 9, A, I	10, 18	C	C, HW3
11	Effective Agendas: Desired Outcomes, Process Design	8, 9, A, I	11,12	C	quiz
12	Importance of Clear Decision Rules,	8, 9, A, I	17	C	C
13	Student Facilitated Workshops 3	n/a	n/a	SFW	SFW
14	Reaching Closure, Step by Step, Facilitating Sustainable Agreements	D	19, 20	C	C, HW4
15	Final exam	n/a	n/a	Final	n/a

Note. C = class; HW = homework; SFW = student facilitation workshop.

> The course outline is shared not to show how a perfected curriculum appears, but to demonstrate the utility of an outcomes taxonomy via a sample curriculum.

a perfected curriculum appears, but to demonstrate the utility of an outcomes taxonomy via a sample curriculum. However, it is hoped that these items can serve as models for refining courses of greater or lesser length and complexity. The example course is equivalent to three semester credit hours, but it could be abbreviated depending on user needs (e.g., academia or low- to moderate-risk industries).

It is also intended that such a course should conform to ABET criteria even though ABET accreditation may not be sought or relevant. Hill (2013) effectively argues that ABET accreditation is a worthy consideration for all academic OSH programs seeking to ensure quality learning. ABET (2013) criteria places specific emphasis on student outcomes that are strongly aligned with the skills inherent in effective hazard analysis and risk assessment facilitation, including:

 b) An ability to design and conduct experiments, as well as to analyze and interpret data.
 c) An ability to formulate or design a system, process or program to meet desired needs.
 d) An ability to function on multidisciplinary teams. . . .

f) An understanding of professional ethical responsibility.
 g) An ability to communicate effectively. . . .
 k) An ability to use the techniques, skills and modern scientific and technical tools necessary for professional practice. (p. 2)

The suggested course reference, *Facilitator's Guide to Participatory Decision-Making* (Kaner, 2007), is intended to provide a framework for instilling the soft skills that may determine as much as 85% of a facilitator's effectiveness (Jain & Anjuman, 2013). Many other texts are also available.

Conclusion

Figure 3 presents a hazard analysis/risk assessment facilitation curriculum model. The three techniques specifically prescribed within ANSI/ASSE Z590.3 are noted in the center. Outside the center are the levels of adult skills acquisition (Dreyfus, 2004)—from novice to expert. The vertical line that dissects the model is intended to represent quality, defined long ago as "conformance to requirements" (SkyMark, para. 4). This definition reminds that lower levels of skill acquisition are likely to produce lower-quality results while higher-quality results should correspond to higher-level skill acquisition.

The quality line connects the objective of hazard analysis/risk assessment facilitation to the proposed best means to achieve it: outcomes-based learning in which objectives, instruction and assessment are adequately aligned. If the model is applied in its entirety, it is anticipated that personnel will be able to expertly facilitate hazard analysis and risk assessment. Conversely, failure to observe its lessons may risk the "price of nonconformance" (SkyMark, para. 4).

The objective of PTD ostensibly is to remove the price of nonconformity from the incident ledger. The hypothesis entertained is that skilled facilitators invariably minimize ledger entries, both in terms of their frequency and severity. Unskilled facilitators may not erase ledger entries at all, but may contribute to their increase. Industry and academia can and should invest now to ensure that hazard analyses and risk assessments are expertly facilitated, confident that both will be the first to enjoy their earned dividends. **PS**

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Figure 3

Hazard Analysis & Risk Assessment Facilitation Curriculum Model
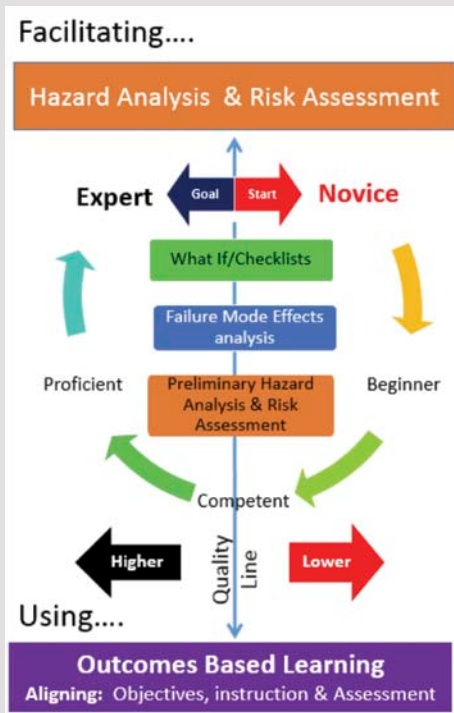
Note. Adapted from D. Wilbanks, 2014.