Closing the Cybersecurity Skills Gap:
Increasing cybersecurity capability maturity through competency-based, mastery learning curricula

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TODAY’s AGENDA

• Workforce Trends: The Widening Skills Gap
• Solution Alternatives for Closing the Skills Gap
  • Outcome-Based Education: Accelerating Completion
  • Competency-Based Education: Accelerating Mastery
• Redefining the Taxonomy of Educational Objectives
• Implementing CBE in the classroom and online
• Questions and Comments
Workforce Trends: The Widening Skills Gap
The classic workforce funnel vs the current hourglass

Age

- Education System
- Job Experience
- Core Workforce
- Mentor Workforce
- Retirement

Past | Current

- 20
- 30
- 40
- 50
- 60

- Gen Y
- Gen X
- BB
Demand is high

#1 high-risk skill gap for the federal government

27% say team is currently understaffed

75% say technical security staff leave within 3 years

The skills gap is growing...

80% believe it is difficult or very difficult to find and hire staff that fit all of their requirements

60% say it takes at least 4 to 6 months to fill vacancies

44% cite competition with other firms as limiting access to talent

39% cite poor staff quality

Supply is low
Outcomes-Based Education: Accelerating Completion

“policy makers are looking at student outcomes as a measure of the quality of postsecondary education institutions. One outcome measure that has received most of the attention is graduation rates.”

-- American Council on Education
Thirty-two states have a funding formula or policy in place to allocate a portion of funding based on performance indicators such as course completion, time to degree, transfer rates, the number of degrees awarded, or the number of low-income and minority graduates.

Source: National Conference of State Legislatures
Purdue University “Degree in 3” Program

“If you are student who would like to save thousands of dollars and also show the world that you are real ‘go-getter’ here’s a way to do it,” said Purdue President (and former Indiana Governor) Mitch Daniels.

David Reingold, Dean of Liberal Arts, added “Purdue is the place for students interested in faster time to degree…with an exceptional value proposition. We hear the concerns about the cost of higher education. Degree in 3 offers savings over a four-year degree.”
Principles of Outcomes-Based Education

• Mission: Qualified students
  - Test what was taught
  - Norm-referenced rankings
  - Testing objective: “Cutoff” the qualified from the unqualified

• Goal: Achievement of institutional credentials
  - Degrees
  - Grades
  - Certifications

• Objective: Student Success Rate
  - Efficiency: Number obtaining minimum proficiency in the time allotted
  - Effectiveness: Number of correct answers provided to summative tests

• Focus: The “Ends” of Learning – the outcome
OBE: Challenges and Potential

The Learning Gap (Carroll, 1971)

- Students in the bottom 5% of a course can require as much as five times longer to learn the material than those in the top 5%.

- Learning speed is dependent on abilities possessed at the start: verbal, memory, spatial, etc.

- The steepness of the learning curve is predicted by 1) Opportunity to learn (time available) and 2) Motivation to learn (self-efficacy and engagement).
OBE: Challenges and Potential

Learning for Mastery (Bloom, 1968)

• Introduced the concept of outcome-based education

• Potential to advance beyond the “normal distribution” of education: 1/3 excel, 1/3 fail, and 1/3 pass through

“This selective approach to education is appropriate when labor is plentiful and demand for highly educated workers is low. Under such conditions much of the effort of the schools and the external examining system is to find ways of rejecting the majority of students at various points in the educational system and to discover the talented few who are to be given advanced educational opportunities. Such societies invest a great deal more in the prediction and selection of talent than in the development of such talent. The complexities of the skills required by the work force in the United States and in other highly developed nations means that we can no longer operate on the assumption that completion of secondary and advanced education is for the few.”
The 2-sigma problem (Bloom, 1984)

- Sought interventions that could improve achievement of mastery
- Content improvements yield only a 2% increase above the advantage of socio-economic status
- Student-centered learning yields 50% increase in achievement
- Personalized learning enables 98% of learners to outperform (2-sigma)

**TABLE I**

| Effect of selected alterable variables on student achievement (see Appendix) |
|---------------------------------|------------------|----------------|
| **Effect size** | **Percentile equivalent** |
| **D** Tutorial instruction | 2.00 | 98 |
| D Reinforcement | 1.20 | |
| A Feedback-corrective (ML) | 1.00 | 84 |
| D Cues and explanations | 1.00 | |
| (A)D Student classroom participation | 1.00 | |
| A Student time on task | 1.00 | |
| A Improved reading/study skills | 1.00 | |
| C Cooperative learning | .80 | 79 |
| D Homework (graded) | .80 | |
| D Classroom morale | .60 | 73 |
| A Initial cognitive prerequisites | .60 | |
| C Home environment intervention | .50 | 69 |
| D Peer and cross-age remedial tutoring | .40 | 66 |
| D Homework (assigned) | .30 | 62 |
| D Higher order questions | .30 | |
| (D)B New science & math curricula | .30 | 62 |
| D Teacher expectancy | .30 | |
| C Peer group influence | .20 | 58 |
| B Advance organizers | .20 | |
| Socio-economic status (for contrast) | .25 | 60 |

*Note: This table was adapted from Walberg (1984) by Bloom.*

*Object of change process—A-Learner; B-Instructional Material; C-Home environment or peer group; D-Teacher.*

*Averaged or estimated from correlational data or from several effect sizes.*
Competency-Based Education: Accelerating Mastery

Competency- or Practice-based Education “is a pedagogy that prepares students for a practice or occupation. PBE aims to realise the goals of developing students’ occupationally-relevant social, technical and professional capabilities, forming their occupational identities, and supporting their development as positively contributing global citizens.”

Mastery Learning Progression

- Mastery Learning begins with instruction in threshold concepts forming the declarative knowledge base.
- Procedural knowledge is the understanding of concept application.
- Conditionalized expertise is formed by learning procedural variations.
- The ability to respond effectively in novel situations is facilitated by understanding which conditions apply in scenarios differing in the level of VUCA (volatility, uncertainty, complexity and ambiguity).

Threshold Concept: “akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress...They must be transformative, irreversible, integrative, bounded, and troublesome” (Meyer & Land, 2003)
Accelerating Mastery Through Capability Maturity
Principles of Competency-Based Education

• Mission: Capable learners
  - “Teaching to the Test” -- Formative learning cycles
  - Criterion-referenced rankings – Competency Profiles or “Scouting Reports”
  - Testing objective: Discover what was misunderstood, misconceived, or misapplied in order to recognize readiness to learn subsequent material

• Goal: Achievement of mastery
  - Proficiency: Comprehensive knowledge of a domain
  - Competence: Skillful application of proficient understanding
  - Mastery: Ability to transfer competence across domains within a field

• Objective: Learning Success Rate
  - Efficiency: Breadth of mastery within the time allocated
  - Effectiveness: Number of learner errors that have been eliminated

• Focus: The “Means” of Learning – Ensuring readiness to learn
Redefining the Taxonomy of Learning Objectives

*Education begins when a student fails to understand*
Defining the path to competent job performance

- Novice
  - Identify vulnerabilities
  - Analyze and map vulnerabilities
  - Develop mitigation strategy
- Perform tasks safely and lawfully
  - Maintain awareness of current status of regulation
  - Identify regulatory gaps in legislation
  - Protect sensitive data collection
  - Understand how federal regulations apply to testing
- Manage the Project
  - Develop the project plan
  - Monitor the project plan
- Educate Team and Clients
  - Educate team
  - Educate clients
- Understand Real World Impact of Threats
  - Specific target impact
  - Determine implications and plan response
  - Communicate impact
- Identify and Penetrate Targets
  - Identify targets
  - Analyze targets
  - Develop and execute penetration strategy
- Identify the Critical Vulnerabilities
  - Identify vulnerabilities
- Exploit Vulnerabilities
  - Infrastructure
  - Web and applications
  - Other
- Recommend mitigating actions to discovered vulnerabilities
  - Identify resources
  - Plan and document actions
  - Communicate actions
- Score on the Performance Exam
  - 442
  - 550
Proficiency Levels in Competency-Based Education

- **Declarative knowledge**: Knowing *What* something means; the concepts; facts, propositions and the richly interlinked associations among them.
  - A learner knows what are the letters in the alphabet and that the word “apple” means: The fruit 🍎.

- **Procedural knowledge**: Knowing *How* declarative knowledge is sequenced, interrelated, or intermixed to produce an output
  - A learner knows how to write the word apple. An “a” followed by two “p”s, an “l” and an “e”

- **Conditional knowledge**: Knowing *When* a step in or branch of a procedure should be executed; the “if” state that determines “then” a procedure path should be executed
  - A learner knows when to write the word apple with an “s” at the end. If there are multiple 🍎🍎🍎 then “s” is needed at the end.

- **Situational knowledge**: Knowing *Where* conditions exist: the environmental factors that are necessary or sufficient for conditions to be present
  - A learner knows where in written prose the first letter in the word apple is uppercase or lowercase. Such conditions would be at the start of a sentence or if Apple is a proper noun.
CBE: Enhancing Grades With Profiles

The Individual Competency Profile

- Supports development planning
- Benchmarking on strengths and opportunities
- Continual credentialing

Maturity Levels

- Level 1: Beginner
- Level 2: Proficient
- Level 3: Competent
- Level 4: Expert
- Group Average

Responsibility Area Maturity vs. Peers

- 9 High
- 2 Average
- 3 Low

Analyzing Security Incidents
Assess and manage risk
Communicate Results
Develop and Manage Personnel
Exploit Penetration Targets
Identify and mitigate vulnerabilities
Identify penetration targets and map attack vectors
Implement security monitoring
Log Security Incidents
Manage process and procedures
Manage projects and budgets
Manage security operations
Respond to intrusions
Understand and demonstrate real-world impact of threats and vulnerabilities
Implementing CBE in the Classroom and Online
Focus learning experiences on assessed competency gaps

Practice knowledge application until performance is consistent

Vary practice activities using simulations with increasing difficulty

Rotate internship experiences with practicing experts to develop mastery
Response Confidence: A self-expressed level of belief by a learner in the accuracy of their knowledge for choosing the selected answer which are valid indicators of confidence (Stajkovic & Luthans, 1998)

Understanding: Complete and accurate knowledge accompanied by high confidence in the belief that one’s knowledge is complete and accurate

Insufficient understanding: Incomplete or lack of knowledge accompanied by low confidence in the belief that one’s knowledge is complete

Misunderstanding: A recognized inaccurate knowledge accompanied by low confidence in the belief that one’s knowledge is accurate

Misconception: An unrecognized inaccurate knowledge accompanied by high confidence in the belief that one’s knowledge is accurate

Concept inventory: A “reliable, validated assessment instrument [that] focuses on common student misconceptions [in] a specific domain” (Almstrum, Henderson, Harvey et al., 2006).
CBE: Learn, Reflect and Apply

• Plan for 7+ attempts, reflecting on low-confidence topics between each attempt
• Monitor closely your sense of confidence in your answers
Stacked Credentials: Build Competency, Increase Completion Rates, and Reduce Time to Mastery
Closing The Cybersecurity Skills Gap

QUESTIONS AND COMMENTS