Evaluating Competency and Risk through Synthetic Learning Environments

Leonard Brown
Rustin Reed
Karen Noiva
Workplace Health and Safety

Average LTIIR for Western M/NM Mines

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>LTIIR Based on 200,000 Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>4.5</td>
</tr>
<tr>
<td>2001</td>
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</tr>
<tr>
<td>2002</td>
<td>3.5</td>
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<tr>
<td>2003</td>
<td>3.0</td>
</tr>
<tr>
<td>2004</td>
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<tr>
<td>2005</td>
<td>2.0</td>
</tr>
<tr>
<td>2006</td>
<td>1.5</td>
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<td>2007</td>
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<td>2009</td>
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<tr>
<td>2010</td>
<td>0.5</td>
</tr>
<tr>
<td>2011</td>
<td>1.0</td>
</tr>
<tr>
<td>2012</td>
<td>1.5</td>
</tr>
<tr>
<td>2013</td>
<td>2.0</td>
</tr>
<tr>
<td>2014</td>
<td>2.5</td>
</tr>
<tr>
<td>2015</td>
<td>3.0</td>
</tr>
<tr>
<td>2016</td>
<td>3.5 (approximate)</td>
</tr>
</tbody>
</table>

Legend:
- All Mines
- Sur. Metal
- All SSG
- Small SSG
Creating an Expert Workforce

- Seat time in the training room is not equal to learning and does not build transferable expertise
Creating an Expert Workforce

• Seat time in the training room is not equal to learning and does not build transferable expertise

• Create **learning environments** that build experts versus training environments that create perpetual beginners

• Facilitate a **cycle of improvement** that includes learning, competency evaluation, and risk management

Four Levels of Evaluation

• Kirkpatrick’s Four Levels of Training Evaluation

1. **Reaction:** Satisfaction with trainer & training (Smile sheets)
2. **Learning:** Evaluation of knowledge, skills, abilities (Pre/Post tests)
3. **Behavior:** Changes in job performance (Job task analysis)
4. **Results:** Improved safety outcomes (Reduction in injuries)

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  4. **Results:** Improved safety outcomes (Reduction in injuries)

• Research: 80% of all companies are stuck at Level 1

• Objective: Help mining industry reach Levels 2, 3, 4

Overview of Talk

- Learning Environments
- Safety Training
- Stealth Evaluation
- Operational Resiliency
Overview of Talk

Survey of our synthetic learning environments

- Learning Environments
- Safety Training
- Stealth Evaluation
- Operational Resiliency
Overview of Talk

Survey of our synthetic learning environments

Usage paradigm: Health and safety training

Learning Environments

Safety Training

Stealth Evaluation

Operational Resiliency
Overview of Talk

Survey of our synthetic learning environments

Usage paradigm: Health and safety training

Usage paradigm: Evaluation and assessment
Overview of Talk

Survey of our synthetic learning environments

Usage paradigm: Health and safety training

Usage paradigm: Evaluation and assessment

Usage paradigm: Operations and planning
Synthetic Learning Environments

Survey of our synthetic learning environments

- Safety Training
- Stealth Evaluation
- Operational Resiliency
Needs Assessment

- 3-year comprehensive survey of safety training
- Contextual Inquiry
  - Beyer & Holtzblatt (1998)
- Multi-disciplinary team
  - HCI designers
  - Educators
  - Psychologists
  - Domain experts

Apprenticeship
- Actively participate in training tasks
- Model communities of practice (Lave & Wenger, 1991)
- Collect representative training data artifacts

Pure Observation
- Watch domain users in training session
- Record tasks, flow of information, data
- No direct interactions learners or trainer

Debriefing
- Interviews learners, trainers post-session
- Ask questions based on observations
- Collect comments from participants

Assimilation
- Combine empirical evidence from experimenters
- Derive & label work models, task sequences
- Cross-check with 3rd party domain experts
# Design Guidelines for Safety Training

<table>
<thead>
<tr>
<th>ACCESSIBLE</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DG1</td>
<td>Choose resources that promote acceptance of learning objectives across sites and demographics.</td>
</tr>
<tr>
<td>DG2</td>
<td>RemEDIATE skills with custom tutorials that incorporate best practices in training pedagogy.</td>
</tr>
<tr>
<td>DG3</td>
<td>Allow novices to manipulate all relevant data easily and synonymously.</td>
</tr>
<tr>
<td>DG4</td>
<td>Streamline context switches and the flow of information to support dynamic task needs.</td>
</tr>
<tr>
<td>DG5</td>
<td>Promote hands-on interaction with equipment through realistic forms, constraints, and usage.</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>CONTEXTUAL</th>
<th></th>
</tr>
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<tbody>
<tr>
<td>DG6</td>
<td>Support a range of effective training media and presentation needs on demand.</td>
</tr>
<tr>
<td>DG7</td>
<td>Make information available to learners when and where they need it, at a suitable level of detail.</td>
</tr>
<tr>
<td>DG8</td>
<td>Provide suitable perspective on environment, with clear relationships between important data.</td>
</tr>
<tr>
<td>DG9</td>
<td>Use realistic, site-relevant examples that ground information in the learner's experience.</td>
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<tr>
<td>DG10</td>
<td>Underscore the progression of time and correlate events across media.</td>
</tr>
<tr>
<td>DG11</td>
<td>Incorporate dynamic exercises and media that require tough choices in hypothetical situations.</td>
</tr>
<tr>
<td>DG12</td>
<td>Provide learners with timely, context-relevant feedback on their progress, actions, and decisions.</td>
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<thead>
<tr>
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<tr>
<td>DG13</td>
<td>Use story-driven scenarios and evolving content to engage learners and encourage participation.</td>
</tr>
<tr>
<td>DG14</td>
<td>Encourage team activities that allow for dynamic discourse among learners.</td>
</tr>
<tr>
<td>DG15</td>
<td>Use an apprenticeship model that couples situated learning with competency-based evaluation.</td>
</tr>
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Software Development Platform

Fatalgram Simulator

Fatalgram 1
Fatalgram 2
...
Fatalgram N

Harry's Hard Choices

Hazardous Day

Future Game

Unreal Engine

Game State Model
Story Telling Framework
Interaction Framework

Dynamic Safety

Creation Toolkit

Asset Database
Harry’s Hard Choices

- Scenario: Mine disaster
  - Egress 9 trapped miners
  - Race against fire & clock

- Emergency response
  - Mine Evacuation
  - Mine rescue

- Learning objectives
  - Evacuation strategies
  - Resource management
  - Situational awareness
Harry’s Hazardous Day

- Scenario: ‘Normal’ day
  - Multi-role, team-oriented
  - Persistent environment

- Dynamic hazards
  - Hierarchy of controls
  - Mitigation strategies

- Learning objectives
  - Workplace examinations
  - Operating procedures
  - Situational awareness
Testing & Evaluation

• Consulted with 20+ companies during development
• Deployed with 1000+ industry professionals to date
• Tested with students, miners, and certified trainers
• Conducted human factors and acceptance testing
• Developed instructional design and efficacy tests

• What have we learned?
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- What have we learned? Our SLEs are versatile!
Paradigm: Health & Safety Training

Usage paradigm: Health and safety training
Active versus Passive Learning

Higher Order of Thinking

Retention

90%
70%
50%
30%
10%

Active Learning

• Perform the task
• Participating in a role play
• “Serious” games
• Hands-on puzzles
• Group scenarios/solutions

Passive Learning

• Panel discussions
• Using a simulator
• Interactive demonstrations

Lower Level of Learning

• Watching a simulator
• Group discussions
• Watching a demonstration

• Watching a video
• Site visit
• Watching a role play
• Reading
• Lectures

(Dale 1969)
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(Dale 1969)
SLE Design Attributes

• Contextualized active learning
  • Story-telling as basis for class discussion
  • Explore various context-specific scenarios

• Topic-centric role-playing
  • Story evolution depends on user choices
  • Multiplayer: Various subplots and job tasks

• Traps keyed to hazards
  • Dependent on situation and environment
  • Consequences are realized for all actions
Scenario-based Training

Use Scenario-Based Learning to Develop These

- Advanced Job Skills
- Basic Skills and Simple Procedures
- Job Knowledge: Facts, Concepts, and Processes

https://www.convergencetraining.com/blog/using-scenario-based-learning-for-manufacturing-training
Pre-Planning Strategy

• Identify and focus on topics covered by SLE
  • Limited training or resources available
  • Noted deficiencies or industry trends

• Scenario may be divided into many blocks
  • Identify topical areas covered by each block
  • Align each block to specific training modules

• Replace stale or less effective media
  • Passive learning: Lecture slides, videos
  • Active learning: Games, discussion groups
Example: Hazards Recognition

- Manifest workplace hazards
  - Test recognition rates
  - Test job hazard analysis
  - Show bad outcomes

- Factorial # of possibilities
  - Random placement
  - Random frequency
  - Unusual situations

<table>
<thead>
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<th>Trap</th>
<th>Consequence(s)</th>
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<tr>
<td>Irrespirable Gas</td>
<td></td>
</tr>
<tr>
<td>Roof fall</td>
<td></td>
</tr>
<tr>
<td>Fire zone</td>
<td></td>
</tr>
<tr>
<td>Defective SCSR</td>
<td></td>
</tr>
<tr>
<td>Defective gas meter</td>
<td></td>
</tr>
<tr>
<td>Inoperative refuge</td>
<td></td>
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<tr>
<td>Inoperative mantrip</td>
<td></td>
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<tr>
<td>Inoperative shuttle</td>
<td></td>
</tr>
<tr>
<td>Methane pocket</td>
<td></td>
</tr>
<tr>
<td>Broken lifeline</td>
<td></td>
</tr>
<tr>
<td>Uneven ground</td>
<td></td>
</tr>
<tr>
<td>Collapsed pillars</td>
<td></td>
</tr>
<tr>
<td>Damaged electricals</td>
<td></td>
</tr>
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<tr>
<td>Irrespirable Gas</td>
<td>Fatigue, asphyxiation</td>
</tr>
<tr>
<td>Roof fall</td>
<td>Blocked egress, crushing</td>
</tr>
<tr>
<td>Fire zone</td>
<td>Blocked egress, burns</td>
</tr>
<tr>
<td>Defective SCSR</td>
<td>Asphyxiate</td>
</tr>
<tr>
<td>Defective gas meter</td>
<td>False gas readings</td>
</tr>
<tr>
<td>Inoperative refuge</td>
<td>Asphyxiate, time penalty</td>
</tr>
<tr>
<td>Inoperative mantrip</td>
<td>Time penalty, fire</td>
</tr>
<tr>
<td>Inoperative shuttle</td>
<td>Electrical fire, burns</td>
</tr>
<tr>
<td>Methane pocket</td>
<td>Explosion, loss of crew</td>
</tr>
<tr>
<td>Broken lifeline</td>
<td>Disoriented, loss of miner</td>
</tr>
<tr>
<td>Uneven ground</td>
<td>Stumbling, leg injury</td>
</tr>
<tr>
<td>Collapsed pillars</td>
<td>Blocked, time penalty</td>
</tr>
<tr>
<td>Damaged electricals</td>
<td>Electrocution</td>
</tr>
<tr>
<td>Damaged phones</td>
<td>Loss of communication</td>
</tr>
</tbody>
</table>
Example: 101 Bad Outcomes
Implementation & Outcomes

- Rich environment for group activities, discussion
  - SLE may have many types of decision points
  - Trainer should pause/freeze SLE at decision points

- SLEs are computer programs: Deterministic!
  - Cannot cover every hazard, vulnerability, or outcome
  - Trainers must develop curriculum to address gaps

- Strategy: We suggest a *blended* delivery format
  - Use SLE as a *key component* of topical training
  - Greatly increases training acceptance/engagement
Terrible vs. Wonderful (L2-Q1A)
Frustrating vs. Satisfying (L2-Q1B)
Dull vs. Exciting (L2-Q1C)
Easy vs. Challenging (L2-Q1D)
Content Effectiveness (L2-Q7)
Willingness to Replay (L2-Q8)

Technology Acceptance Model

Experts
Novices
High User Engagement
Paradigm: Stealth Evaluation

Usage paradigm: Evaluation and assessment
Reinforcing Core Competencies

SLE Design Attributes

• Highly immersive “sandbox” environment
  • Allow player to go anywhere, do anything
  • Game events may be randomized or scripted
  • Emergent stories with persistent consequences

• Evaluate users qualitatively and quantitatively
  • Competency: Define with knowledge, skills, and abilities
  • SLE logs a history of user decision-making and behavior

• Use SLEs for pre- and post-test assessment
Evaluation Platform

- **Game**: Creates a comprehensive log of user behaviors, activities in game
- **Server**: Evaluate against competency framework, save to user history
- **Reports**: Create and customize reports, print or export to LMS
- **Dashboard**: Debrief on scenario outcomes, user tendencies
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Pre-Planning Strategy

• Competency: Define by knowledge, skills, and abilities

• Step 1: Align game’s story elements to competencies
• Step 2: Determine which competencies to test
• Step 3: Develop curriculum around competencies

• **Competency framework**: The foundation for both training content and SLE scenario design
Example: Emergency Response

- Domain 1: Leadership and Decision-Making
- Domain 2: Communications & Crisis Management
- Domain 3: Hazard Recognition & Avoidance
- Domain 4: Regulatory Compliance
- Domain 5: Worker Safety and Health
- Domain 6: Miner Resiliency
## Hazards Recognition & Avoidance

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>3.1 Identify threats and immediate hazards during a mine emergency (explosions, hazardous spill, etc.) and implement primary response methods to control the hazard and minimize injury and/or death.</td>
<td></td>
</tr>
<tr>
<td>3.2 Maintain familiarity with escape route(s) according to site procedures.</td>
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<td>3.3. Select most appropriate action for dealing with the situation (i.e. hazard) according to site emergency response plans and procedures.</td>
<td></td>
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<table>
<thead>
<tr>
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<th>Knowledge, Skills, &amp; Abilities</th>
</tr>
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• Identify and consider all possible risk treatment options. (S)  
• Select most appropriate action for dealing with the situation. (A) |
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• Identify appropriate containment strategies and resources. (K) |
Competency Model Gamification

Occupational Game Mechanics

Class

Core Attributes

Skills

Abilities

Derived Attributes

SOP

Task 1

Task 2

…

Task N

Select Preferred

- SA start level
- SA adv rate
- Class leveling

Governed By

- Cap values

Establish Baseline

- Penalty multiplier

Gain Experience

- SA leveling

Refine & Perfect

- Bonus points

Impact Competency

- Penalty multiplier

Impact Wellness

- Health metrics
- Psych profile

Define handicap

- Task complexity
- Success rate
- Errata likelihood

Build Resilience

- Health metrics
- Psych profile

Penalty multiplier

- SA start level
- SA adv rate
- Class leveling
Competency Model Gamification

Occupational Game Mechanics

Class

Core Attributes
- Governed By
  - Cap values
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Skills
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- Gain Experience
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Derived Attributes
- Impact Wellness
  - Health metrics
  - Psych profile
- Define handicap
  - Task complexity
  - Success rate
  - Errata likelihood

Competency Model Alignment

Knowledge
- Defined

Other Attributes
- Parameterized

Skills & Abilities
- Evaluated

Gamification
- Awarded

Job Task Analysis
- Measured
## Scored Tasks & Events

<table>
<thead>
<tr>
<th>Choice / Action</th>
<th>Score Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose to evacuate</td>
<td>150</td>
</tr>
<tr>
<td>Choose to shelter</td>
<td>-150</td>
</tr>
<tr>
<td>Choose to procrastinate</td>
<td>-200</td>
</tr>
<tr>
<td>Walk out, low CH4</td>
<td>150</td>
</tr>
<tr>
<td>Walk out, mid CH4</td>
<td>150</td>
</tr>
<tr>
<td>Walk out, high CH4</td>
<td>200</td>
</tr>
<tr>
<td>Drive out, low CH4</td>
<td>200</td>
</tr>
<tr>
<td>Drive out, mid CH4</td>
<td>150</td>
</tr>
<tr>
<td>Drive out, high CH4</td>
<td>-100</td>
</tr>
<tr>
<td>Call Operator for status</td>
<td>100</td>
</tr>
<tr>
<td>Annoying the operator</td>
<td>-75</td>
</tr>
<tr>
<td>Choose to fix the truck</td>
<td>-150</td>
</tr>
<tr>
<td>Choose to abandon the truck</td>
<td>150</td>
</tr>
<tr>
<td>Cause engine fire</td>
<td>-100</td>
</tr>
<tr>
<td>Turn off section power</td>
<td>75</td>
</tr>
<tr>
<td>Turn on section power</td>
<td>-100</td>
</tr>
<tr>
<td>Trip injury trap</td>
<td>-25</td>
</tr>
<tr>
<td>Assist injured miner</td>
<td>150</td>
</tr>
<tr>
<td>Take injured miner to refuge</td>
<td>-150</td>
</tr>
<tr>
<td>Abandon injured miner</td>
<td>-200</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Choice / Action</th>
<th>Score Delta</th>
</tr>
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<tbody>
<tr>
<td>Enter refuge chamber</td>
<td>25</td>
</tr>
<tr>
<td>Enter defective refuge chamber</td>
<td>-150</td>
</tr>
<tr>
<td>Remove mouthpiece</td>
<td>-10</td>
</tr>
<tr>
<td>Don SCSR/SRLD</td>
<td>100</td>
</tr>
<tr>
<td>SCSR/SRLD expired</td>
<td>-150</td>
</tr>
<tr>
<td>Miner abandons group</td>
<td>-200</td>
</tr>
<tr>
<td>Miner becomes lost</td>
<td>-200</td>
</tr>
<tr>
<td>Trip roof fall trap</td>
<td>-200</td>
</tr>
<tr>
<td>Miner died</td>
<td>-350</td>
</tr>
<tr>
<td>Procrastinating</td>
<td>-10</td>
</tr>
<tr>
<td>Miner trapped</td>
<td>-200</td>
</tr>
<tr>
<td>Miner rescued</td>
<td>350</td>
</tr>
<tr>
<td>Waypoint reached</td>
<td>100</td>
</tr>
<tr>
<td>Waypoint timeout</td>
<td>-100</td>
</tr>
<tr>
<td>Use pickup truck w/o gas check</td>
<td>-150</td>
</tr>
<tr>
<td>Use SRLD cache</td>
<td>100</td>
</tr>
<tr>
<td>Swap bad gas meter for good</td>
<td>75</td>
</tr>
<tr>
<td>Swap good gas meter for bad</td>
<td>-100</td>
</tr>
<tr>
<td>Use lifeline in smoke conditions</td>
<td>150</td>
</tr>
<tr>
<td>Venture off of lifeline</td>
<td>-150</td>
</tr>
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</table>
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• Select most appropriate action for dealing with the situation. (A) | • EN_LogText_BadLifelineEnter  
• EN_LogText_BadLifelineLeave  
• EN_LogText_NoLineService  
• EN_T_Score_A2_17_EnterRC  
• EN_T_Score_A2_17_EnterBadRC  
• EN_T_Score_A2_17_LeftRC  
• EN_TruckExplosion  
• EN_T_Score_FO_UsePickup  
• EN_T_Score_UsePickupNoGmCheck |
| 3.2 Maintain familiarity with escape route(s) according to site procedures. | • Assess the incident and determine the appropriate method of escape. (S)  
• Access, interpret and apply technical and safety information. (A) | • EN_LogText_AttachedLifeline  
• EN_LogText_DetachedLifeline  
• EN_T_Score_FO_UseLifeline  
• EN_LogText_DisplayedMap  
• EN_LogText_HidMap |
| 3.3. Select most appropriate action for dealing with the situation (i.e. hazard) according to site emergency response plans and procedures. | • Select appropriate personal protective clothing and equipment to the types of hazard(s) identified. (S)  
• Identify appropriate containment strategies and resources. (K) | • EN_LogText_DonnedGoggles  
• EN_LogText_RemovedGoggles  
• EN_T_Score_A1_4_ChooseLoiter  
• EN_T_Score_A1_4_ChooseRC  
• EN_T_Score_A1_4_ChooseEvacuate  
• EN_T_Score_A1_5_ChooseWalkOut  
• EN_T_Score_A1_5_ChooseDriveOut |
Implementation & Outcomes

- **Establish**: Play game at start of session to define competency baselines
- **Train**: Address core competency with pedagogy methods and activities
- **Quiz**: Traditional quiz verifies competency is met
- **Advance**: Moving to next competency is contingent on mastering previous
- **Assess**: Play game again with parallel scenario to observe change in competencies
Pilot Study 1: Reinforcing Competencies

- Mine Safety & Health Conference
  - Las Vegas, NV in October, 2016
  - Cohort: Safety trainers (n=15)

- Emergency preparedness & evacuation workshop
  - Leadership & team management
  - Behaviors & personality
  - Communication challenges
  - Situational awareness
Pilot Study 1: Reinforcing Competencies

- Pre / Post Competency Self-Assessment
  - 5-point Likert scales, questions for each topic
  - Communication challenges: Increased confidence
    - Understand the principles of crisis communication
    - Familiarity with hazards assessments
  - Situational awareness: Increased confidence
    - Able to identify threats and hazards
    - Ability to select appropriate actions
    - Continuously monitor hazards and assess controls
Pilot Study 1: Reinforcing Competencies

• Pre / Post Competency Self-Assessment
  • 5-point Likert scales, questions for each topic
  • Leadership & team management: Increased confidence
    • Can assess miner conditions to implement life support measures
    • Able to use PPE and self rescue equipment
  • Behaviors & personality: Increased confidence
    • Employ protective behaviors in response to changing conditions
    • Able to manage psychological stress
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    • Employ protective behaviors in response to changing conditions
    • Able to manage psychological stress

• Significant increases: Topics covered by SLE
Predictive Performance Modeling

• What is “Expert performance”?
Predictive Performance Modeling

• What is “Expert performance”?
• Condition on personality profiles
  • Example: Predictive Index
  • A priori for Bayesian model
Predictive Performance Modeling

- What is “Expert performance”?
- Condition on personality profiles
  - Example: Predictive Index
  - A priori for Bayesian model
- Machine learning may be used to identify patterns of performance

Transitional Probabilities

\[ a_{ij} = P(X_{t+1} = S_j | X_t = S_i) \]

\[ b_j(t) = P(O(t) | X_t = S_j) \]
Pilot Study 2: Performance Modeling

- Novices, Cohort 1: 40-hr new miners (n = 22)
- Experts, Cohort 2: Mine rescue teams (n = 20)
Pilot Study 2: Data Analysis

Cumulative Score

Over time

Different trials

Cumulative Score

Average Crew Morale

Over time
Pilot Study 2: Data Analysis

Breathing Apparatus Usage

% Users Triggering Trap by Type

Gas Check Times by Trial
## Pilot Study 2: Risk-taking Behavior

### Hazard Recognition Failure Rates

<table>
<thead>
<tr>
<th>Trap Type</th>
<th>Cohort 2 (Experts) Failure Rate (%)</th>
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<tbody>
<tr>
<td>Roof fall</td>
<td>65.0</td>
<td>77.3</td>
</tr>
<tr>
<td>Lifeline break</td>
<td>75.0</td>
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</tr>
<tr>
<td>Burned to death</td>
<td>20.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Asphyxiated</td>
<td>20.0</td>
<td>50.0</td>
</tr>
<tr>
<td>Gas explosion</td>
<td>5.0</td>
<td>9.1</td>
</tr>
<tr>
<td>Broken refuge</td>
<td>0.0</td>
<td>18.2</td>
</tr>
<tr>
<td>SCSR expired</td>
<td>20.0</td>
<td>18.2</td>
</tr>
<tr>
<td>Sprained ankle</td>
<td>70.0</td>
<td>25.0</td>
</tr>
<tr>
<td>Truck breakdown</td>
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<td>25.0</td>
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# Pilot Study 2: Risk-taking Behavior

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## Pilot Study 2: Risk-taking Behavior

### Summary Performance for Cohort 2 (Experts)

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<th>Mean</th>
<th>Stdev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rescued</td>
<td>1.70</td>
<td>2.49</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Time (m:s)</td>
<td>22:57</td>
<td>9:56</td>
<td>3:46</td>
<td>45:59</td>
</tr>
<tr>
<td>Distance (x1000 ft)</td>
<td>4.25</td>
<td>1.77</td>
<td>1.21</td>
<td>7.19</td>
</tr>
</tbody>
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## Pilot Study 2: Risk-taking Behavior

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Pilot Study 2: Risk-taking Behavior
Pilot Study 2: Risk-taking Behavior
Paradigm: Operational Resiliency

- Learning Environments
- Safety Training
- Stealth Evaluation
- Operational Resiliency

Usage paradigm: Operations and planning
Standard Operating Procedures

Warnings for only the most imminent and hazardous events should be issued during late night hours. The EAS may not be effective for delivering late night warnings via radio and television broadcast; therefore, additional, best available channels should be considered.

https://emilms.fema.gov/IS247a/lesson1/IPAWS_Print.htm
SLE Design Attributes

- Serious games are highly customizable
  - Stories treated as like data and loaded at runtime, not hard-coded
  - Simulate custom environments, step by step procedures (SOPs)

- Practice jobs in various hypothetical situations
  - Force things to go wrong and observe outcomes of company SOPS
  - Simulate changes or proposed improvements before implementation

- Roleplay from an operations or management role
  - See the worksite from any angle or viewpoint
  - Capture cascading effects of failures on controls
  - See flow of information and communication
Pre-Planning Strategy

- Motivation: Homeland Security Exercise and Evaluation Program (HSEEP)
  - Guiding principles to structure exercise programs
  - Building block approach to improve capability

- Define specific functional roles and SOPs
  - Incorporate “what if” questions
  - Build or test risk assessment profiles
  - Identify deficiencies in critical controls

- Forms basis for high consequence training
  - Failure of critical controls
  - Failure to follow SOPs

Example: “The Big Pour”

• Act 1: Plan the job
  • Big road project, behind schedule
  • Note issues left from prior shift

• Act 2: Do the job
  • SOPs: Excavate, Load, Haul, Crush
  • Unexpected hazards, things happen

• Act 3: Return to job
  • Return from work stoppage event
  • Mounting production pressures

SOPs for inspections
Dealing with hazards
Holistic SOP evaluation
Example: “The Big Pour”
Example: "The Big Pour"
Example: “The Big Pour”
Example: “The Big Pour”
Example: “The Big Pour”
Implementation & Outcomes

- Explore SOPs step by step under different circumstances
  - Identify gaps in SOPs: What’s missing? How good was the outcome?
  - Success depends on identifying critical decision-making points in SOP

- Trainer can change SLE scenario parameters
  - Assign level of difficulty (1 = easy, 5 = hard) or game configuration
  - Inject hazards or change user roles according to circumstance

- Informs job action sheets (JAS), job hazards analysis (JHA)

- PPE Suite allows post-processing, data analysis
  - Render data visualizations, graphs of KPI
  - Look at performance trends or deviations
Delivering Intuitive Results?
Delivering Intuitive Results?

<table>
<thead>
<tr>
<th>Relative_Time_min</th>
<th>Total_Score</th>
<th>Location_Dist_Interpolated</th>
<th>Total_Morale_Interpolated</th>
<th>Total_Fatigue_Interpolated</th>
<th>Total_Injury_Interpolated</th>
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<tbody>
<tr>
<td></td>
<td>Cor: 0.342</td>
<td>Cor: 0.716</td>
<td>Cor: 0.252</td>
<td>Cor: 0.365</td>
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<td>Int Neka: 0.953</td>
<td>Int Neka: 0.985</td>
<td>Int Neka: 0.963</td>
<td>Int Neka: 0.981</td>
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<tr>
<td></td>
<td>Cor: 0.637</td>
<td>Cor: 0.325</td>
<td>Cor: 0.191</td>
<td>Cor: 0.437</td>
<td></td>
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<tr>
<td></td>
<td>Int Neka: 0.95</td>
<td>Int Neka: 0.985</td>
<td>Int Neka: 0.994</td>
<td>Int Neka: 0.963</td>
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<td></td>
<td>Cor: 0.193</td>
<td>Cor: 0.0542</td>
<td>Cor: 0.548</td>
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<td>Cor: 0.385</td>
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<td></td>
<td>Int Neka: 0.938</td>
<td>Int Neka: 0.989</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Int Neka: 0.265</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Delivering Intuitive Results?
Delivering Intuitive Results?

- Rephrase in terms of worker and industry needs and goals
Delivering Intuitive Results?

- Rephrase in terms of worker and industry needs and goals
- Provide a visual way to evaluate Standard Operating Procedures
  - Processes
  - Constraints
- Assess each step with existing Knowledge, Skills, and Abilities
  - Quantitative
  - Measurable
- Aligns with Competency Models
Motivation: Evacuation Procedures

Standard Operating Procedures
Standard Operating Procedures

Hazard Mitigation

1. Assess Situation
2. Hazard Found? YES → Hazard Event
   NO → Proceed with Activity
3. Proceed with Activity
4. Implement Controls
5. Hazard Mitigated? YES
   NO → Move to Safe Area
6. Move to Safe Area
7. C
8. C
9. C

Task Flow Key
- Z: Operating Procedure
- Action Block
- Decision Point
- User Decision Point
- Problem (Detected)
Hazard Mitigation

1. Assess Situation
   - Hazard Found?
     - YES: Hazard Event
       - Implement Controls
       - Hazard Mitigated?
         - YES: Move to Safe Area
         - NO: Hazard Mitigated?
2. NO: Proceed with Activity

Crew Management

1. Assemble Crew
   - Crew Accounted For?
     - YES: Evaluate Condition
     - NO: Miner Missing
       - Miner Missing Protocol
2. NO: Miner Injured?
   - YES: First Aid Protocol
   - NO: Communicate Situation
     - YES: Miners Injured?
       - YES: Place in Refuge
       - NO: Miner can be Moved?
3. NO: Communicate Situation
   - Miners Injured?
     - YES: Place in Refuge
     - NO: Miner can be Moved?
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     - NO: Place in Refuge
10. NO: Communicate Situation
    - Miner can be Moved?
      - YES: Miner can be Moved?
      - NO: Place in Refuge
11. NO: Communicate Situation
    - Miner can be Moved?
      - YES: Miner can be Moved?
      - NO: Place in Refuge
12. NO: Communicate Situation
    - Miner can be Moved?
      - YES: Miner can be Moved?
      - NO: Place in Refuge

Task Flow Key

- Z: Operating Procedure
- Action Block:
- Decision Point:
- User Decision Point:
- Problem:
- Problem (Detected)
Example: Performance Analysis

Cohort: Day shift, Crew 2 (n=10)

Note: Proof of concept. Not real cohort data.
Example: Performance Analysis

Day shift, Crew 2 (n=10)

Cohort Aggregate Performance:

- **Hazard Mitigation:**
  - A: 47%

- **Crew Management:**
  - B: 95%

- **Incident Reporting:**
  - C: 81%

**Performance Key**:

- ≥ 90% KSAOs Passed
- ≥ 70% KSAOs Passed
- ≥ 50% KSAOs Passed
- < 50% KSAOs Passed

Note: Proof of concept. Not real cohort data.
Drill Down: Hazard Mitigation

Hazard Mitigation

Day shift, Crew 2 (n=10)

Note: Proof of concept. Not real cohort data.
Drill Down: Hazard Mitigation

Day shift, Crew 2 (n=10)

Note: Proof of concept. Not real cohort data.
### Aggregate KSAOs for Decision Point: Hazard Found?

**Categories Passed:** 75%

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Observed</th>
<th>Threshold</th>
<th>Pass (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>K: Identified missing guards on moving machine parts</td>
<td>4.7 times</td>
<td>5</td>
<td>93</td>
</tr>
<tr>
<td>K: Identified obstruction of fire extinguisher</td>
<td>1.9 times</td>
<td>2</td>
<td>91</td>
</tr>
<tr>
<td>K: Identified missing chocks on vehicle wheels</td>
<td>2.0 times</td>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>A: Time to make decision (Reaction time)</td>
<td>11.5 secs</td>
<td>10</td>
<td>57</td>
</tr>
</tbody>
</table>

**SOP Task Key**

- **Z**: Operating Procedure
- **Action Block**: User Task or Activity
- **Decision Point**: User Decision Point
- **Problem (Detected)**: Problem

Note: Proof of concept. Not real cohort data.
Exporting Job Action Sheets

### Job Action Sheet

<table>
<thead>
<tr>
<th>Immediate Response (0 – 5 minutes)</th>
<th>Performance Measure</th>
<th>Metric</th>
<th>Accomplished (check if yes)</th>
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</table>
| Conduct initial assessment (size-up).  
  - Gather intelligence, information and likely impact from environmental sources and personnel  
  - Determine initial incident site perimeter | Potentially impacted areas are considered | Yes/No |                        |
| Establish and maintain communications with surface/responsible person | Time in which initial incident conditions are reported | Within 2 minutes of incident alert and/or notification (i.e. alarm) |                         |
| Ensure that appropriate safety measures and risk reduction activities are initiated | Safety and health program(s) is in place which includes procedures to identify and assess hazards, and includes personal protective equipment (PPE) component that adequately addresses respiratory protection and exposure protection for initial response. | Yes/No |                         |
| Initiate and implement mine level Incident Command System (ICS) | Percent of personnel trained and exercised on incident command and management protocols and procedures in compliance with NIMS | 100% |                         |
# Exporting Job Action Sheets

## Job Action Sheet

### On-Site Incident Manager

Reports to: Responsible Person

Mission: Organize and direct emergency response operations and support activities for all incident impacted miner’s.

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Exporting Job Action Sheets

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<td>Yes/No</td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
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<tr>
<td>Establish and maintain communications with surface/responsible person</td>
<td>Time in which initial incident conditions are reported</td>
<td>Within 2 minutes of incident alert and/or notification (e.g. alarm)</td>
<td><img src="timer.png" alt="Timer" />: 1:39</td>
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<tr>
<td>Ensure that appropriate safety measures and risk reduction activities are initiated</td>
<td>Safety and health program(s) is in place which includes procedures to identify and assess hazards, and includes personal protective equipment (PPE) component that adequately addresses respiratory protection and exposure protection for initial response.</td>
<td>Yes/No</td>
<td><img src="checkmark.png" alt="Checkmark" /></td>
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75%
Learning Management Systems

- SCORM compliant output may be imported into any LMS
- Proprietary integration Marine Learning Systems’ LMS
Learning Management Systems

- Drill forms: Grade performance markers for worker, team
- Mobile skill assessor: Real-time job task analysis on phones

### Drill Form

<table>
<thead>
<tr>
<th>Perform Initial Actions</th>
<th>Perform and verify initial action within 3 minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Sound the alarm (First Stage Response/Crew alert/GEA)</td>
</tr>
<tr>
<td>5</td>
<td>Notify / Brief Master</td>
</tr>
<tr>
<td>8</td>
<td>Notify / Brief ECR</td>
</tr>
<tr>
<td>9</td>
<td>SMCS pre-planned actions and low-level lighting activated.</td>
</tr>
<tr>
<td>3</td>
<td>Commence incident log</td>
</tr>
<tr>
<td>7</td>
<td>Verified initial actions completion with checklist and stated</td>
</tr>
<tr>
<td>8</td>
<td>Time within 3 minutes</td>
</tr>
<tr>
<td>2</td>
<td>Time within 2 minutes*</td>
</tr>
</tbody>
</table>

### Initial Announcement

- Sounding the appropriate alarm followed by the accompanying announcement
- Not Applicable
- Applicable shipboard team(s) activated
Learning Management Systems

- Drill forms: Grade performance markers for worker, team
- Mobile skill assessor: Real-time job task analysis on phones
- Learning environment: Automatic JTA and report generation
Summary: Usage Paradigms
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1. Supplementing training for specific deficiencies
2. Providing modules for scenario-based training
3. Teaching and performing job hazard analysis
Summary: Usage Paradigms

1. Supplementing training for specific deficiencies
2. Providing modules for scenario-based training
3. Teaching and performing job hazard analysis
4. Reinforcing and evaluating competencies
5. Assessing “true self” and risk taking behavior
6. Preparing for drills and apprenticeship
Summary: Usage Paradigms

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3. Teaching and performing job hazard analysis
4. Reinforcing and evaluating competencies
5. Assessing “true self” and risk taking behavior
6. Preparing for drills and apprenticeship
7. Developing worker job action sheets
8. Enhancing standard operating procedures
9. Testing mine emergency response plans
Continuous Improvement Lifecycle

Analytics

Safety Policy
Controls & SOP
Resilience

Risk Management
Patterns of Performance

Safety Assurance
Competency Evaluation

Safety Promotion
Targeted Training
Continuous Improvement Lifecycle

- Moving toward holistic Safety Management Systems approach
  - Heterogeneous data collection framework and new data sources
  - Competency-based user assessment
  - Analysis and prediction of performance
  - Deployment of ‘learning laboratories’
Continuous Improvement Lifecycle

- Moving toward holistic Safety Management Systems approach
  - Heterogeneous data collection framework and new data sources
  - Competency-based user assessment
  - Analysis and prediction of performance
  - Deployment of ‘learning laboratories’

- Developing next-generation SLE platform: Dynamic Safety™
  - Persistent and perpetual game world
  - Integration of key health metrics (injury, exposure, chronic conditions)
  - Multiplayer with AR/VR capabilities
Acknowledgements

• Contact: rustin2@email.arizona.edu

• Research & development
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