Improving Safety Training Through Gamification: An Analysis of Gaming Attributes and Design Prototypes

Leonard D. Brown(✉) and Mary M. Poulton

Lowell Institute for Mineral Resources, University of Arizona,
P.O. Box 210012 1235 E. James E. Rogers Way, Rm. 229,
Tucson, AZ 85721, USA
{ldbrown,mpoulton}@email.arizona.edu

Abstract. New approaches are needed to improve outcomes for safety training in hazardous industries. We use an evidence-driven approach to identify the key attributes of serious games that have the potential to improve safety training. Following a detailed needs assessment, we identified four major themes of usability problems which may be addressed through gamification: Limited accessibility, lack of context, lack of consequence, and absence of practicum. Based on our analysis, a series of application prototypes was developed to improve safety training in the mining industry. In particular, we discuss *Harry's Hard Choices*, a game for mining emergency response training. Pilot tests indicate high levels of user satisfaction and engagement and anecdotal evidence of training transfer.

Keywords: Serious games · Training · Mining · Usability · Contextual Inquiry

1 Introduction

Many industries worldwide rely increasingly on workplace training. Training was a $61.1B industry in the U.S. in 2014, with safety-oriented training comprising 38.7% of the global training market [1]. With respect to safety, the global mining industry is an excellent case study, as it works to eliminate fatalities and serious injuries. Despite the time and money spent on training, efforts are not as effective as they could be. In particular, the quantity and complexity of information covered in mine safety training, the unique technical vocabulary of the industry, the dynamic nature of the mining workplace, and the changing demographics of the workforce all suggest a need for major changes in the way mine safety training is performed.

Lutz and Lutz [2] analyzed U.S. mine fatalities in 2013, 2014, and 2015 and their relationship to training. In 2013, 12 fatality reports noted that the miners killed lacked some type of training. In two of the 12 fatalities, basic safety training was missing. In the remaining 10 fatalities, task training was either completely missing or significant portions of it were missing. In 2014 there were 11 fatalities in which investigators at the Mine Safety & Health Administration (MSHA) noted inadequate task training. Furthermore, MSHA investigation reports are often vague about what type of training had

D. N. Cassenti (Ed.): AHFE 2018, AISC 780, pp. 392–403, 2019.
https://doi.org/10.1007/978-3-319-94223-0_37

been performed. An analysis of surveillance data provided by the National Institute for Occupational Safety and Health (NIOSH) [3] showed that most trainers were still using didactic (i.e. lecture-based) methods, which research has shown to be of limited effectiveness [4]. Peters, Vaught, & Mallett summarize the situation:

"Collectively, our nation's miners sit through millions of hours of mandated S&H training each year, and mining companies spend millions of dollars to provide this training. Unless effective training materials and methods are used, miners are unlikely to learn what they need to know to actually help reduce their risk of suffering occupational injury and illness. Many miners sit through the same training lectures and films year after year in order to fulfill the requirements of the law. In these situations, their 'training' ends up being a very unfortunate waste of time and resources i.e., a wasted opportunity" Peters et al. [5].

Salas *et al*. [6] find that "properly designed training works and… the way training is designed, delivered and implemented can greatly influence its effectiveness." A large body of research has been published on strategies to improve learning for various types of occupational training [7–10]. Serious games are increasingly being used for training in fields ranging from medical science to homeland security. Building upon work by NIOSH to use gamification for underground mine map reading training [11], we have pursued an in-depth study of serious games for safety training. In this article, we identify major usability problems in mine safety training and discuss our preliminary work to address those problems using serious games.

2 Related Work

A major goal in designing serious games is to identify the specific attributes and capabilities that will enhance learning. An overwhelming variety of game attributes and design patterns have been identified. For example, Garris et al. [12] suggested that six key attributes are necessary: Fantasy, rules/goals, sensory stimuli, challenge, mystery, and control. Wilson et al. [13] expanded these six to include adaptation, assessment, conflict, interaction (equipment, interpersonal, social), language/communication, location, pieces/players, progress and surprise, representation, and safety. Other researchers have proposed similar collections of attributes [14–17]. Although an exhaustive survey is not possible due to space considerations, we outline some key attributes of serious games relevant to this work.

Challenge. Challenge relates to the level of difficulty inherent in a game. Hays [18] listed challenge as a major factor contributing to user enjoyment and argued that challenge results from uncertain outcomes. Uncertainty can be designed into a game by using multiple levels of goals, hidden or incomplete information, and randomness [18, 19]. Furthermore, research suggests a need for an optimal level of challenge– that is, a balance between game play that is too easy and game play that is difficult [12]. Wilson *et al.* [13] hypothesized that, "As the challenge feature in a game increases, so will declarative knowledge and learner's retention of that knowledge. However, a point will be reached when too much challenge will hinder and decrease learning (i.e., an inverted U relationship)."

Fantasy. Fantasy, as defined by Wilson *et al.* [13], is a "make-believe environment, scenario, or characters. It involves the user in mental imagery and imagination… and analogies for real-world processes. The user is required to take on various roles in which they are expected to identify." Activities in the game environment allow users to explore situations that are detached from daily realities [12]. The fantasy world can model specific parts of the real world as necessary to meet game objectives. Fantasies allow users to assume different roles and explore different mindsets [9]. Garris et al. [12] suggested that "material may be learned more readily when presented in an imagined context that is of interest than when presented in a generic or decontextualized form."

Flow. An appealing aspect of serious games rests in their ability to engage an audience. Csikszetmihalyi [20] describes a state in which "people become so involved in what they are doing that the activity becomes spontaneous, almost automatic; they stop being aware of themselves as separate from the actions they are performing." For this state, Csikszetmihalyi [20] suggested the notion of *flow* as an optimal experience that merges individuals' actions with activity. Furthermore, Hays [18] described flow as a sense of enjoyment, where "one 'loses' oneself in the activity." Research suggests that achieving a "flow state" may have significant advantages for learning in both the short term and long term [21, 22].

Rules. Game rules define the structure, boundaries, and goals of a game [12]. Rules may be aligned with reality or completely artificial, depending on the circumstances of the game. Garris et al. [12] noted that "goals should be clearly specified, yet the possibility of obtaining that goal should be uncertain. Games should employ progressive difficulty levels, multiple goals, and a certain amount of informational ambiguity to ensure an uncertain outcome."

Assessment. We define *assessment* as a measure of achievement within a game [13]. It is enabled by the tracking of in-game activities. A cycle of practice, re-teaching, and revision can be used to create embedded assessments in which students are engaged in the content and achievement is improved [23]. In particular, Gee [14] suggested that games allow users to engage in "reflective practice," through a four-step cycle of probing, hypothesizing, reprobing, and rethinking. Shute *et al.* [23] described an ideal situation that called "stealth assessment," in which the embedded assessments are "so seamlessly woven into the fabric of the learning environment that they are virtually invisible."

3 Field Studies

A major goal of this work was to identify the endemic usability problems of safety training. As a first step, we conducted a three-year, comprehensive field study of current training pedagogy. Our objectives were two-fold: First, we wanted to gain a holistic view of training – how the individual parts of the training regimen came together to shape the miners' understanding of safety; second, we wanted to examine the protocols, data sets, and flow of information that workers experienced.

Our field studies employed a data-driven method called Contextual Inquiry (CI), which is the first step in a usability engineering process called Contextual Design [24]. As a participatory design process, CI immerses a multi-disciplinary team of experts in the application domain, allowing them to closely engage with end users and see problems from the users' points of view. Each field study involved three stages. In the first stage, our research team participated in each of the training activities as a form of apprenticeship. The second stage involved observation, in which we watched the interactions between trainers and students in the classroom without disrupting the natural flow of their activities. Observation periods generally ran from 4 to 6 h at a time. The third stage was an open-ended debriefing, in which we interviewed both students and trainers. Many of our questions were prompted either by our personal experiences during apprenticeship and our observations in stage 2.

The mining industry is regulated by Title 30 of the U.S. Code of Federal Regulations (CFR), which directs MSHA to oversee all mining activities in the United States. The CFR Title 30, Parts 46 and 48, outlines safety training requirements, including courses for new miners, annual refreshers, and newly hired experienced miners. At least 27 topics are specified for each of these courses, although there is substantial overlap in content. Note that compliance is based on seat time alone. As it was impractical to perform Contextual Inquiry on all of the required training topics, we selected a subset in consultation with a panel of industry experts in mine safety. Representative activities were selected to include didactic training (e.g. lecture-based with slides), simulation software, and training videos, for the following:

- *Introduction to the Workplace.* New and experienced miner training courses must include an introduction to the work environment. Mine sites are complex and dynamic, so training activities must include tutorials on mine structure, methods, equipment, maps, and terminology.
- *Situational Awareness.* A survey of mine fatalities suggests that many accidents involve similar workplace hazards and risk-taking behaviors. As a result, there are numerous training topics which emphasize situational awareness. Specific training activities included surveying fatal accidents, recognizing hazards, and identifying mitigation strategies.
- *Emergency Preparedness.* Potential emergencies can result from a variety of events, such as explosions, fires, inundation, and ground falls. Emergency preparedness training is a two-part process that involves both generic classroom instruction and site-specific drills. Each mine must also maintain a first responder team which is required to conduct monthly refreshers.

4 Usability Themes

Contextual Inquiry [24] uses a data-driven discovery process to quantify the design space and identify significant usability problems. In our case, CI allowed us to transform a collection of field study observations and measurements into a hierarchical model, called an Affinity Diagram, which suggested some of the most significant obstacles to mine safety training. This analysis served as a starting point for designing more effective training through serious games.

4.1 Empirical Evidence

In our field studies, we collected a large body of empirical evidence. In particular, three types of evidence were collected:

- *Observations.* Observations were collected during the apprenticeship and "pure observation" phases and were based on events that were directly apparent and required no interpretation. Examples include "Text on slide is hard to see" and "No explanation given for technical terminology." Note that observations may or may not have related comments or inferences.
- *Comments.* Comments represent a direct form of user feedback. Comments consisted of verbal and written quotes obtained during the debriefing session. They illustrate users' opinions outright. Examples include "The instructions were confusing" and "We do it differently at my site." Where feasible, comments were collected from both trainers and trainees.
- *Inferences.* Inferences stem from observations that led to specific lines of questioning in the post-session debrief. They are based on the interpretations of our research team and further validated by user feedback. Inferences are valuable because they offer deeper insight into the user experience and can suggest causality. Examples include "The user is visibly frustrated that he cannot find his way" and "Dealing with computer interface distracted user from task goal."

Over one thousand pieces of evidence were collected in our three field studies. Through an aggregation process, we then reduced the evidence to 473 discrete data points. Aggregation involved eliminating duplicate data, such as observations that were recorded by different members of the team for the same application, coalescing similar inferences into one interpretation, and removing multiple instances of analogous user comments which might have slightly different wording. However, we did not eliminate observations, inferences, or comments that were similar if they occurred in multiple field studies, as this would have diminished the strength of the evidence.

4.2 Affinity Diagram

Based on the three types of evidence that we collected, an Affinity Diagram [24] was constructed to identify the major themes of usability problems. The diagram is built inductively from the ground up; similar evidence is recursively grouped together and labeled. The diagramming process results in a hierarchy of problem categories which at the top level identifies the principal themes of usability problems. Note that a piece of evidence may be placed into more than one grouping as necessary. A strength of the Affinity Diagram is that it does not use preconceived groups; the problem categories arise spontaneously based on the intrinsic structure of the evidence. The number of pieces of evidence in a category also suggests the frequency of the problem.

The abridged Affinity Diagram may be found in Fig. 1. For brevity, the diagram omits the individual pieces of evidence that were used to derive its structure; the abridged diagram represents the top three levels of the hierarchy. Our analysis suggests that there are 45 specific usability problems in safety training (*bottom level of chart*). The mean was 10.47 data points, with a standard deviation of 4.21, per usability

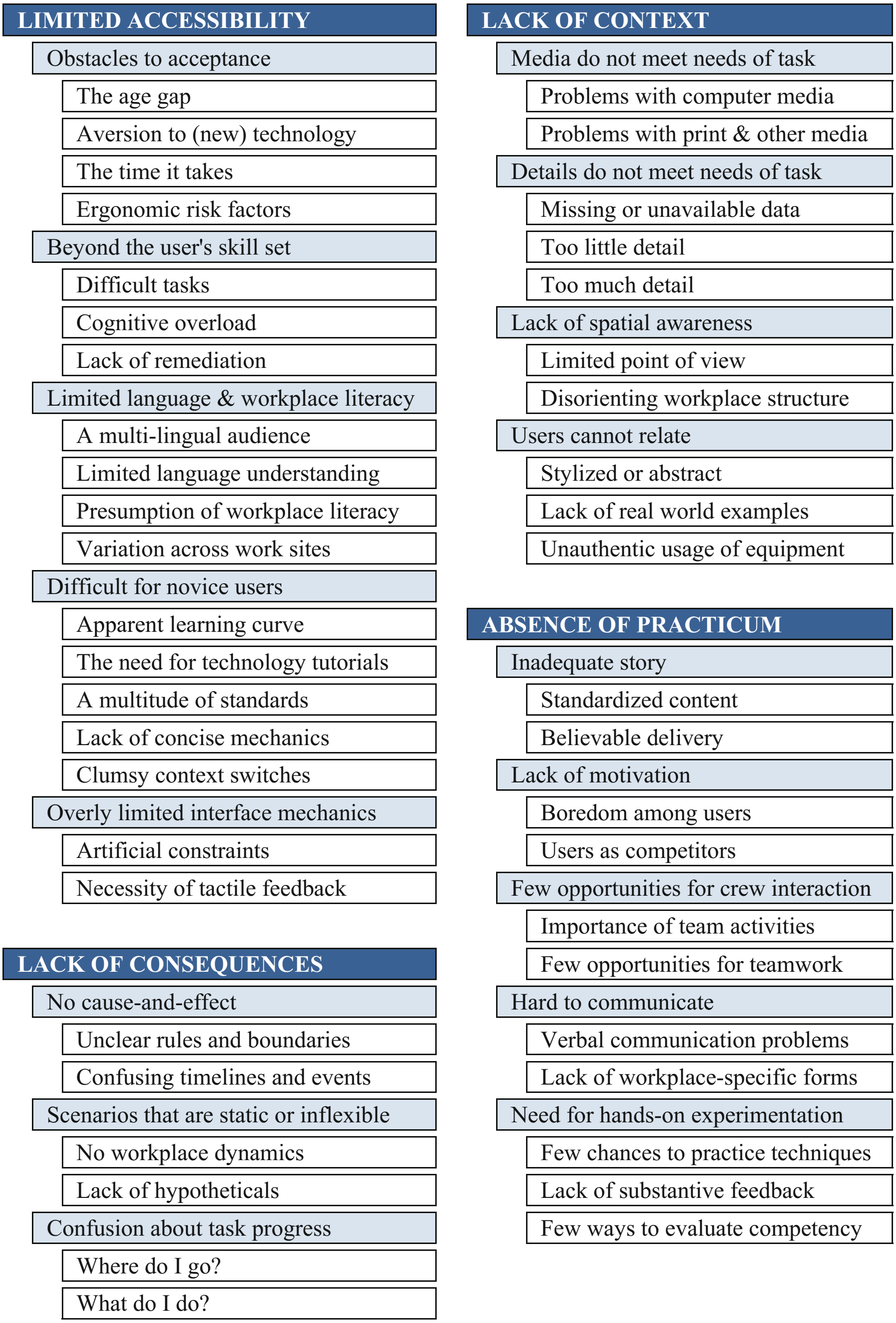

Fig. 1. Abridged Affinity Diagram. A hierarchical clustering of the evidence from our field studies suggests that there are four principal themes usability problems in mine safety training.

problem. Together, these 45 specific problems illustrate 17 major categories (mid-level). We have further grouped the 17 major categories into 4 usability themes for safety training (top level):

1. *Limited Accessibility*. Promote acceptance across a range of worker demographics, engaging a new generation of miners in addition to experienced miners. Accommodations should be made to address computer and workplace literacy issues and second language learners.
2. *Lack of Context*. Provide a meaningful context and level of detail to illustrate important relationships. In particular, training must be grounded in the familiar, relating new concepts to each worker's experience.
3. *Lack of Consequences*. Illustrate the consequences of choices. Workers require a better understanding of timelines and causality if they are to recognize hazards and anticipate the outcomes of good and bad choices.
4. *Absence of Practicum*. Emphasize story-driven scenarios and evaluation. Hands-on activities reinforce learning and allow for the assessment of worker safety competencies.

5 Game Prototypes

Many of the usability problems outlined above can be resolved through active learning techniques [4] using well-designed serious games. In particular, we have developed a suite of computer-based video games for mine safety, including *Harry's Hard Choices*, which teaches mine emergency response. A thorough treatment of this game prototype and several others may be found in Brown [25].

5.1 Harry's Hard Choices

Our serious game *Harry's Hard Choices* (*HHC*) has its inspiration in a series of NIOSH paper exercises for mine emergency response, in which miners "role play" through a disaster story [26, 27]. This type of experiential training allows the miners to think about options in a relevant context. However, the paper exercises do have substantial limitations: They cannot give users a visceral experience that simulates the chaos of a real emergency; they are serialized based on the sanctioned answer to each question; they provide limited information about the emergency situation; and they cannot show cause-and-effect in response to users' free will.

In *HHC*, the user assumes the role of a foreman tasked with evacuating his crew in the face of a rapidly unfolding mine disaster (Fig. 2). Similar to the paper scenarios, our game is set in an underground coal mine and involves a mine fire. However, we have de-serialized the events of the paper scenarios and greatly extended them to create an immersive sandbox where users have free will to explore the environment, use equipment, and engage in a variety of crew-based interactions. Based on realistic situations that miners may face in an emergency, a diverse range of hazards has been added, including roof falls, expiring and defective respirators, inoperative refuge chambers, flammable gases, broken escape lines, and electrical faults. Story events can occur in parallel and there are many possible outcomes. They can also be randomized, so that a different sequence of events is presented each time the game is run.

Fig. 2. *Harry's Hard Choices*. Save a crew of miners (*top*) from an unfolding disaster featuring smoke, fire, lethal gases, ground falls, faulty equipment, and many other hazards (*bottom*).

5.2 Game Attributes for Safety Training

To address the usability themes discovered in our field studies, we sought motivation from best practices in games for entertainment. Entertainment games can be very effective at immersing users in complex virtual worlds where they must spend hours performing sophisticated tasks to achieve game goals. The best games sell millions of copies and maintain a user base for many years; consider The Elder Scrolls V: Skyrim. There are many design patterns that can make games more effective; a non-exhaustive survey may be found in [28]. We have cross-walked the usability themes for safety training with the game attributes that were found to be effective for learning (Sect. 2) and aligned them with design patterns for entertainment games. We then implemented a series of these design patterns in our prototype, HHC (see Table 1).

As an example, consider the "Limited Accessibility" theme of Fig. 1. To address problems with user acceptance, we have applied design patterns that promote *challenge* and *flow* as outlined in Sect. 2. A set of game metrics was implemented, including a scoring system that awards or deducts points based on user decision making. A fatigue metric models exposure and exertion, similar to "hit points" in games for entertainment. The crew of non-player characters (NPCs) is likewise affected; crew members may be injured, incapacitated, or even die. A time metric models the sense of urgency appropriate to mine disasters; as such, time penalties are enforced for poor decisions and procrastination, which can lead to unwinnable conditions as the situation deteriorates. Finally, a morale metric models the impact of users' decision making on the NPC crew. As morale decreases, non-player characters will become increasingly stressed and irritated, culminating in the NPCs abandoning the group. The intent of these design patterns is to draw users into the game and give them a vested interest in the welfare of the crew that they are trying to save. Our preliminary user study, discussed below, suggests that the game metrics substantially increased users' engagement, compelling them to try again and again to improve their outcomes.

Table 1. A sample of game attributes and design patterns for safety training.

Usability theme		Game attribute(s)	Design pattern(s)
1	Limited accessibility	Challenge, flow	Game metrics
2	Lack of context	Fantasy	Emergent stories, microworlds
3	Lack of consequences	Rules	Game traps
4	Absence of practicum	Assessment	Game metrics

6 Pilot Test

Our field studies suggest that user acceptance and engagement are core requirements for training transfer (see Fig. 1, "Limited Accessibility"), a conclusion that is supported by prior research [12, 14, 22]. A pilot study of user acceptance was conducted using a "beta" version of HHC. This was the first time that domain users participated in rigorously play-testing the game with open-ended interaction and full gamification (Table 1). As such, the objective of the study was to get feedback on the experience, including story design, game metrics, and user interface. Our primary evaluation instruments included pre- and post-session questionnaires. The pre-session questionnaire covered user demographics and prior experience with gaming. Our post-session questionnaire adapted questions from standard usability instruments for the testing of interactive systems [29, 30]. Seven-point Likert scales were used.

A total of 12 users ($N = 12$) participated in our 90-min pilot study. In addition to 8 students from the Dept. of Mining and Geological Engineering at the University of Arizona, 4 professional miners were solicited from a mine site in Arizona. Seven of our users indicated that they had completed a new miner training course. Eight users were male and 4 were female, with a mean age of 28 years (range 18–56). The users reported a diverse range of technology and gaming experience; 25% reported themselves as "gamers." As such, the users were given a 25 min tutorial on the game objectives and mechanics and then allowed to play for up to 45 min. Their objective was to rescue as many crew members (up to 9) and obtain the highest score possible. There were no restrictions on game play, and users could restart at any time.

A summary of user feedback is shown in Fig. 3. Given the low sample size, we did not run a statistical test for significance. Users' opinions of the game were very favorable on all but one metric, "Satisfying vs. Frustrating." This result was attributed to a bug in the game's path-following algorithm that has since been corrected. Users also left favorable comments, such as "Great simulation" and "Fun learning experience." Users mentioned that they were "Surprised by the level of accuracy," and added that the game was "Very real," with "lots of options." A notable question posed to users was, "Would you be interested in playing this game again?" All 12 answered "Yes." In earlier testing, user feedback had been lukewarm, with none of our earlier users indicating the affirmative. The difference in outcomes rests primarily on the addition of game design patterns outlined in Table 1. In our previous test, *HHC* had been implemented as a vanilla simulation, instead of a full-fledged gaming experience. Furthermore, game play observations suggested that users' task performance and decision making improved through subsequent runs of the game. For instance, users' results improved from 0 or 1 crew members evacuated in the first iteration to a mean of 3.80 (out of 9) on the best attempt, which was typically the last. Note that the scenario parameters changed randomly on each run of the game to prevent cheating.

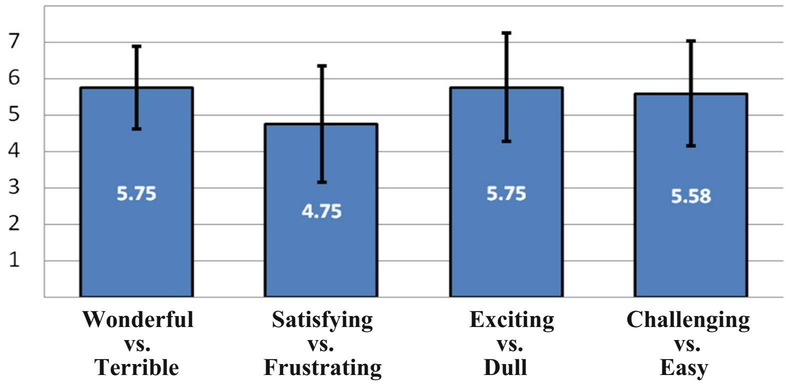

Fig. 3. Pilot study results for user satisfaction, $N = 12$ (*higher is better*).

7 Conclusions

This work represents a multi-disciplinary effort to improve training in safety-focused industries. We have taken an in-depth look at the mining industry, and, based on three years of field studies, identified four major themes of usability problems. In particular, our studies suggest that user acceptance and engagement are of utmost concern in safety training. To address these usability problems, we propose to draw from lessons learned in games for entertainment; that is, better use of gamification can lead to more effective training and better outcomes. Consider our prototype, *Harry's Hard Choices*, which draws users into mine emergency response with a challenging game experience full of realistic happenings, temperamental coworkers, and imperfect outcomes. Pilot tests suggest a high level of user satisfaction, which is a pre-requisite for high acceptance and engagement.

We are continuing our analysis of field study data with the goal of identifying design guidelines. We are also developing a suite of serious games that will provide effective training and competency assessment, in a medium that encourages discussion of safety culture. *Harry's Hard Choices* is now being deployed in industry training courses, and efficacy tests are under way. Although this work focuses on the mining industry, we hope that the insights and technologies developed here will be transferable to other industries where workplace safety is of principal concern.

Acknowledgements. We thank Michael Peltier for his significant contributions to the serious games development. We also thank Eric Lutz, Aly Waibel, Michelle Lutz, and the many industry experts who participated in our field studies. This work was supported by NIOSH award 1U60-OH010014, Science Foundation Arizona award SRG-0330-08, and MSHA Brookwood-Sago awards BS-22468-11-60-R-4, BS-23833-12-60-R-4, and BS-26353-14-60-R-4. The authors have disclosed a financial interest in Desert Saber, LLC to the University of Arizona. These interests have been reviewed and are being managed by the University of Arizona in accordance with its policies on outside interests.

References

1. Pappas, C.: Top 10 e-Learning Statistics for 2014 You Need to Know (2014). http://elearningindustry.com/top-10-e-learning-statistics-for-2014-you-need-to-know
2. Lutz, M., Lutz, E.A.: The future of training in a data-driven mining industry. In: SME Annual Meeting, 24 February 2016. SME, Phoenix (2016)
3. McWilliams, L.J., Lenart, P.J., Lancaster, J.L., Zeiner Jr, J.R.: National Survey of the Mining Population: Part II Mines. U.S. Department of Health & Human Services, CDC/NIOSH IC 9528, NIOSH Pub. 2012-153 (2012)
4. Dale, E.: Audio-Visual Methods in Teaching, 3rd edn. Dryden Press, New York (1969)
5. Peters, R.H., Vaught, C., Mallett, L.: A Review of NIOSH & US Bureau of Mines research to improve miner's health & safety training. In: Brune, J. (ed.) Extracting the Science: A Century of Mining Research, pp. 501–509. Society for Mining, Metallurgy & Exploration, Littleton (2010)
6. Salas, E., Tannenbaum, S., Kraiger, K., Smith-Jentsch, K.: The science of training and development in organizations: what matters in practice. Psychol. Sci. Public Interest **13**(2), 74–101 (2012)
7. Burke, L., Hutchins, H.: Training transfer: an integrative literature review. Hum. Resour. Dev. Rev. **6**(3), 263–296 (2007)
8. Juul, J.: The game, the player, the world: looking for a heart of gameness. In: Copier, M., Raessens, J. (eds.) Proceedings of Level Up: Digital Games Research Conference, Utrecht, Netherlands, pp. 30–45 (2003)
9. Malone, T.W., Lepper, M.R.: Making learning fun: a taxonomy of intrinsic motivations for learning. In: Snow, R.E., Farr, M.J. (eds.) Aptitude, Learning and Instruction III: Conative and Affective Process Analyses, vol. 3, pp. 223–253. Hillsdale, NJ, Erlbaum (1987)
10. Thiagarajan, S.: Team activities for learning and performance. In: Stolovitch, H.D., Keeps, E.J. (eds.) Handbook of Human Performance Technology, pp. 518–544. Jossey-Bass/Pfeiffer, San Francisco (1999)

11. Mallett, L.G., Orr, T.J., May, I., Cole, G.P., Lenart, P.J., Unger, R.L., Beshero, D.C., Hall, E. E., Vaught, C., Brune, J., Klein, K.: Underground Coal Mine Map Reading Training. U.S. Department of Health & Human Services, NIOSH/CDC, Pub. No. 2009-143c (2009)
12. Garris, R., Ahlers, R., Driskell, J.E.: Games, motivation, and learning: a research and practice model. Simul. Gaming **33**(4), 441–467 (2002)
13. Wilson, K.A., Bedwell, W.L., Lazzara, E.H., Salas, E., Burke, C.S., Estock, J.L., Orvis, K. L., Conkey, C.: Relationships between game attributes and learning outcomes. Simul. Gaming **40**(2), 217–266 (2009)
14. Gee, J.P.: What Video Games Have to Teach Us About Learning and Literacy, 2nd edn. Palgrave/Macmillan, New York (2007)
15. Pavlas, D., Bedwell, W., Wooten II, S.R., Heyne, K., Salas, E.: Investigating the attributes in serious games that contribute to learning: flow and grow. In: Proceedings of Human Factors and Ergonomics Society 53rd Annual Meeting, vol. 53, no. 27, pp. 1999–2003 (2009)
16. Van Staalduinen, J.P., de Freitas, S.: A game-based learning framework: linking game design and learning outcome. In: Khyne, M.S. (ed.) Learning to Play: Exploring the Future of Education with Video Games, pp. 29–45. Peter Lang, New York (2011)
17. Yusoff, A.: Conceptual framework for serious games and its validation. Ph.D. dissertation, University of Southampton, Southampton, UK (2010)
18. Hays, R.T.: The effectiveness of instructional games: a literature review and discussion. Naval Air Warfare Center Training Systems Division Pub. 2005-004 (2005)
19. Malone, T.W.: Towards a theory of intrinsically motivating instruction. Cogn. Sci. **5**(4), 333–369 (1981)
20. Csikszentmihalyi, M.: Flow: The Psychology of Optimal Experience. Harper, New York (1990)
21. Lieberman, D.A.: What can we learn from playing interactive games? In: Vorderer, P., Bryant, J. (eds.) Playing Video Games: Motives, Responses, and Consequences, pp. 379–397. Erlbaum, Mahwah (2006)
22. Squire, K., Jenkins, H.: Harnessing the power of games in education. Insight **3**(1), 5–33 (2003)
23. Shute, V., Ventura, M., Bauer, M., Zapata-Rivera, D.: Melding the power of serious games and embedded assessment to monitor and foster learning: flow and grow. In: Ritterfeld, U., Cody, M.J., Vorderer, P. (eds.) Serious Games: Mechanisms and Effects, 295–321. Routledge, New York (2009)
24. Beyer, H., Holtzblatt, K.: Contextual Design: Defining Customer-Centered Systems. Morgan Kaufmann, San Francisco (1998)
25. Brown, L.D.: Design, evaluation, and extension of serious games for training in mine safety. Ph.D. dissertation, University of Arizona, Tucson, USA (2015)
26. Vaught, C., Hall, E.E., Klein, K.: Harry's hard choices: mine refuge chamber training. U.S. Department of Health & Human Services, NIOSH/CDC, IC 9511 (2009)
27. Brnich, M.J., Vaught, C., Kowalski-Trakofler, K.M.: Man's mountain refuge: refuge chamber training. Report of Investigations RI 9685, U.S. Department of Health & Human Services, NIOSH/CDC (2011)
28. Björk, S., Holopainen, J.: Patterns in Game Design. Charles River, Rockland (2004)
29. Chin, J.P., Diehl, V.A., Norman, K.L.: Development of an instrument for measuring user satisfaction of the human computer interface. In: Proceedings of Human Factors in Computing Systems (CHI), pp. 213–218. ACM Press (1988)
30. Davis, F.D.: Perceived usefulness, ease of use, and user acceptance of information technology. MIS Q. **13**(3), 319–340 (1989)