Serious Game Design Report

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Section 1
Introduction

1.1 Overview of the benefits of serious games

Whether they are designed purely for entertainment or for more serious purposes, all games require players to engage in some form of learning. A player must first be introduced to the game, which typically entails learning the objective or goal of the game, as in a pre-mission briefing, and how to play the game, which may involve reading the rules of the game or, in the case of most digital games, being tutored by the game itself until the player acquires the rudimentary skills necessary to play the game. Thereafter the player must employ those skills in diverse and increasingly challenging situations while also acquiring and refining new knowledge and skills. In this fundamental way, games are environments for experiential learning. When deciding whether to undertake the creation of a serious game, designers should understand the types of learning that games can and cannot promote in order best to leverage the distinctive features that games offer.

Games capitalize on the relationship between action and cognition (learning by doing)

A well-designed game can provide authentic practice in thinking and working in specific roles and contexts. A player can play a medic in a desert combat zone or a computer security expert in a windowless lab or a Navy Seal on a stealth mission in a remote village. Games can provide exposure to and interaction with/in models of other cultures and can help to develop in the player context- and role-dependent knowledge, skills, and understandings of other identities, perspectives, and values.

Rather than acquiring knowledge divorced from instrumentality, a player must use acquired knowledge (and continue to acquire new knowledge, often on a just-in-time basis) within the game environment to solve problems in order to overcome obstacles and proceed toward the current goal. This generally involves formulating strategies by using inductive and heuristic reasoning, logic, and hypothesis testing. Through the gaming experience, players learn to reflect on their failures and successes because those new insights will be crucial in subsequent attempts as well as in new situations.

Games promote team development, social learning, and social cohesion

All games provide some sort of competition, whether it is between a single player and the game system or between multiple players or multiple teams. However, games can also be designed to require cooperation and collaboration among players. Again, the competition may be between a team and the game system or between teams of players. Multiplayer games provide shared experiences that can be collectively examined, discussed, and recalled when relevant to new situations. When players take on roles within cooperative games, they develop and learn to utilize distributed knowledge, that is, they learn to recognize and draw on the resources of their fellow players, which is a critical component of effective teamwork. Cooperative gameplay provides practice in these and other teaming skills and leads to increases in the collective efficacy of the players.

Games enhance learner engagement and effort

Recent advances in our understanding of the neurology of learning have found that games trigger our brain's dopamine-reward system, generating feelings of pleasure and increasing motivation. The sense of immersion and flow that a player experiences while playing a well-designed game leads to prolonged and focused engagement. When learners devote more time to learning tasks, they naturally learn more (Berliner, 1990). In the game cycle of playing, failing, reflecting, and trying again until success becomes the norm, players gain a sense of control and autonomy. The resultant feeling of self-efficacy is an important influence on persistence and willingness to undertake new learning tasks (Schunk, 1991). Throughout this report we discuss design methods for increasing motivation.

Games provide a safe environment for learning

Many professions that involve hazardous conditions and/or responsibility for the health and safety of others (e.g., military, police, fire fighting, surgery) have turned to games and simulations to provide practice in thinking and acting under pressure in critical situations. While it is necessary eventually to train in real-world settings, games and simulations can scaffold learners toward the required competencies before risking life and limb.

Games are customizable

Games can be designed so that they provide appropriate and variable levels of authenticity, which can be useful in reducing cognitive load for novices so that they can focus on the most critical aspects of a task. At the same time, the level of difficulty can be dynamically tailored to the learner's current knowledge and skills to provide optimal challenge. For a serious game to adapt appropriately, tasks in the game must be related to learning objectives so that they serve as formative assessment of the learner's progress. Furthermore, if the learner is failing to attain the objectives, the game can provide various types of just-in-time instruction via an instructional overlay.

When a game incorporates formative assessment combined into an instructional overlay, the need for human trainers is greatly reduced. Furthermore, trainees have greater flexibility for when and where they participate in training. While developing a complex serious game can be labor intensive, the overall cost efficiency for instruction can make the endeavor worthwhile if a sufficient number of trainees is available.

1.2 Criteria for selecting serious games as an instructional strategy

In this section we discuss criteria for determining the appropriateness of developing a serious game as an instructional strategy. Criteria to consider include the potential effectiveness in promoting learning and the potential efficiency in terms of both time and cost. We end by highlighting certain situations when games are clearly inappropriate.

Effectiveness

As described in the previous section, serious games require learning by doing—by taking actions, observing results, and modifying behavior until achieving satisfactory outcomes. If the skills required to accomplish the learning goals can be modeled as actions in a game environment with sufficient fidelity, a game may be an appropriate learning environment.

One way that games scaffold learning is by beginning with the simplest version of a whole, authentic task (the "epitome") and providing variations of the version, and then offering increasingly difficult versions of the task so that the learner must continually "level up" in order to progress in the game (Reigeluth, 1999). Therefore the tasks associated with the learning goals must be sufficiently variable and complex.

Another important consideration is the risk associated with failure in the real world. If there is a chance of significant injury or death, it may be worthwhile for learners to acquire foundational knowledge and skills in the safety of a game environment before attempting real-world tasks.

Efficiency

Efficiency has two related dimensions: time and cost. Both the time and cost required to develop the instruction (for which a game can take longer and be more expensive than traditional instruction) and the time required to reach mastery (for which a game with instructional overlay can take less time and expense than traditional instruction) must be considered.

While game design/development alone can be time consuming, the additional requirements of instructional design—in particular, designing the simulation-game environment and formative evaluation to ensure that gameplay leads to the desired learning goals—can significantly extend the design process and subsequently increase the cost. Depending on the nature of the game, it may be possible to license an existing game engine to accelerate game development. In our approach to serious games, the instructional overlay is not optional; therefore, additional time should be spent in designing a flexible, extensible engine that can manage instruction not only for the current task, but also for ones to be designed in the future. In section 4, we discuss in detail the elements of the instructional overlay and other kinds of scaffolding.

In terms of time and cost of learning, primary considerations include the time available for learning, the size of the target audience, and the potential cost of inadequate training (failure to reach mastery). If a game lacks a well-developed instructional overlay to guide and support learning, learners must engage in exploratory, trial-and-error learning, significantly increasing the time required to achieve instructional objectives; in this case, a game may not be the best instructional solution. If the learning requirements are quite complex and game development will demand extensive time and effort for a relatively small audience, an alternative approach to instruction may be more appropriate. However, if there is a potentially high cost that could result from inadequate training, such as endangerment of valuable personnel and resources, then efficiency may be less important than effectiveness.

Situations in which games are inappropriate

Technological limitations in particular can make games unsuitable for certain situations. If highly physical training is needed (e.g., basic training), a game will not be useful, although advances in motion detection technology may change that. Microsoft's Kinect can currently detect and correct a player's yoga posture, for example.

Similarly, if very high fidelity is needed, current game technology may not be appropriate. Advances in screen displays have improved *perceptual* fidelity, which is the presentation or appearance of the game environment; and it is possible to make controllers (or in the case of the Kinect, do without a controller) that provide *functional* fidelity, but whether these offer the degree of fidelity necessary for, say, the continuing training of those with expertise is a matter of judgment. In sum, games are not yet appropriate for all types of training.

Section 2
A Fuzzy Vision of Serious Games

In this section, we present a "fuzzy" vision of what a serious game should be like for the Air Force, based on literature about serious games and instructional theory. Therefore, this section begins with a brief introduction to six fundamental design principles, followed by a subsection that provides a bit more detail on each of those principles. In this manner, we present a holistic view of serious games upon which we elaborate to considerable depth in Section 3. The six principles are authenticity, levels of difficulty, scaffolding, part-task mastery, feedback, and motivation.

1. Authenticity. Picture the **scenario, roles,** and **contextual factors** for the game as being highly authentic – that is, consistent with whole, real-world tasks, including portrayal of values, attitudes, beliefs, and cultures and provision of situational understandings. This means it is usually a multi-player game, though non-player characters (NPCs) are often created to play some or all of the other roles.

2. Levels of difficulty. Picture the game as having levels of difficulty/complexity, each of which must be mastered by each player (role) before the players are allowed to progress to the next level, to avoid cognitive overload. Within a level of difficulty, cognitive load may be further reduced, if necessary, by reducing representational fidelity.

3. Scaffolding. To enhance the effectiveness, efficiency and appeal of the game as a tool for learning, scaffolding is integrated into the game. It can take any of three major forms. The task environment can be *adjusted*, such as by providing easier cases for the player to deal with. *Coaching* can be provided to help the player develop understandings or learn important information. And the game can be paused so that an *instructional overlay* can develop needed knowledge, skills, and attitudes (KSAs). All of these kinds of scaffolding can be provided automatically for all players "just in time," or it can be triggered by certain player actions, or the player can request it at any time. The scaffolding makes it quicker, easier, and more enjoyable for the player to acquire the necessary KSAs to succeed at the current part of the task being performed in his/her role at this level of difficulty.

4. Part-task mastery. The virtual mentor does not allow the player to return to the game until s/he has reached mastery on the immediately needed KSAs. Such mastery encompasses the entire range of situations in which the KSAs are used at this level of difficulty, and may require automatization of skills. The player returns to the game immediately after reaching such mastery, and that mastery is noted in the player's record of attainments.

5. Feedback. Each player receives natural consequences (as would be experienced in performing the real task) as the major form of feedback while playing the game. At appropriate times, the player may ask the virtual mentor for explanations about a consequence. At the end of a performance (which is for a part of the whole task for a given level of difficulty), the mentor provides a debriefing on the performances and contextual factors to cultivate heuristic reasoning. Finally, immediate feedback is provided in the instructional overlay.

6. Motivation. Each player in the game receives a score reflecting the quality of his/her performance in his/her role. Motivation is also enhanced by collaboration with teammates (when appropriate), by the authenticity and relevance of the scenario and role, and by building confidence through appropriate levels of difficulty.

Each of these six principles is now discussed in greater detail.

2.1 Authenticity

In Air Force training, the purpose of a game is usually to learn a task (or an entire job). Therefore, the game must be highly consistent with the task in many ways. In a word, it must be authentic. The main dimensions of authenticity include: the scenario, objects, roles, tools, actions, causal dynamics (consequences of actions), setting (contextual factors), and representations. These dimensions are discussed in greater detail in Section 3.

Scenario. The scenario is a description of the sequence of actions and settings that form the plot. While a story is not a necessary part of all games, role-playing games generally have some sort of narrative framework within which the player makes decisions and takes action. The scenario should have high authenticity, so as to enhance motivation and transfer of expertise to the real world.

Objects. Objects are the components of the game system that embody and enable the game mechanics (actions governed by rules), including players' avatars and non-player characters (NPCs). The objects should also have high authenticity, so as to enhance transfer of expertise to the real world.

Roles. A role defines the possible actions that a particular object may employ to effect change on the game state. An avatar's role may include special abilities and functions. For example, a sniper and a medic in the same scenario have different abilities and fulfill different functions. The most important role is the one that the player will perform after training. Other roles include those played by other people in the scenario, including teammates, collaborators, adversaries, and innocent bystanders. Most roles may be played by NPCs (non-player characters). However, if a specific team is being built for deployment, a multiplayer game in which all team members interact serves an important team-building function. Each role, whether played by a team member or a NPC, should have high authenticity to enhance motivation and transfer to the real world.

Tools. Tools are objects that the players are able to manipulate to perform their roles. Authenticity of tools enhances both motivation and transfer of skills to the real world.

Actions. Actions are moves that can be made by any of the players, including NPCs – friend, foe, and neutral. They should have high authenticity to enhance transfer.

Causal dynamics (consequences of actions). Causal dynamics are the way the simulation responds to the player's actions based on the rules that govern the associated game mechanics. Authenticity enhances the development of mental models and skills that are aligned with the real world.

Setting/Contextual factors. The setting is the situation in which the scenario unfolds. It is a set of contextual factors that may or may not influence the objects and tools available and the actions that are possible. The setting, with all its contextual factors, should not only be authentic, but also be varied systematically from one episode of the game to another, to represent the full range of divergence that the player is likely to encounter in the real world (which enhances motivation and transfer).

Representations. Representation is the fidelity with which visual, audio, tactile, and movement elements of the game are portrayed. If cognitive or perceptual overload is likely, then the representations should initially have lower fidelity or authenticity, but should progress to high fidelity by the end of each level of difficulty. The player's score is adjusted based on the fidelity of representations.

2.2 Levels of Difficulty

A complex task has many *versions* of the task. Each version can be thought of as a class of performances or cases of the task that are similar in many ways. Some versions of the task are more complex and therefore more difficult than others (Reigeluth, 1999). Training that starts with the most complex version of a task usually creates a huge cognitive overload (Sweller, 1994). Therefore, as game developers have recognized, a game should be designed as a series of levels of increasing complexity and difficulty, each of which must be mastered before the next level is "unlocked." Each level is a version of the task, and each version is made up of many individual performances or cases of the task that share the characteristics of that version.

Versions should be arranged in a progression of difficulty by using the Simplifying Conditions Method (Reigeluth, 1999) to identify the conditions that distinguish more complex versions from simpler versions. *Levels of complexity* should be identified (where the versions all build on each other), but *dimensions of complexity* should also be identified (where they do not build on each other, so any dimension can be done before any other). Different dimensions of complexity offer opportunities for flexibility in sequencing, based on such factors as learner preferences, frequency of encounter in the real world, risk to personnel or assets, and much more.

There is often a lot of *variation* within a version of the task. In such cases, mastery is required by each player (role), not just on one performance of the version of the task (the level of difficulty), but on several divergent performances that represent the full range of "dimensions of divergence" for that version of the task. Each of the performances is called a case. Some dimensions of divergence may be more difficult than others, in which case the performances can be arranged in an easy-to-difficult sequence if cognitive load is a concern. And cognitive load may be further reduced, if necessary, by reducing representational fidelity (see Principle 1).

2.3 Scaffolding

It is helpful to think in terms of three different kinds of scaffolding: adjusting the game, coaching the learner, and instructing.

The least obtrusive is a variety of scaffolding (Cazden, 1983; Wood, Bruner & Ross, 1976) that is achieved by *adjusting* aspects of the game to provide an appropriate level of difficulty for a given player – that is, to place the player within his or her zone of proximal development (Vygotsky, 1978). Examples include providing easier cases first and including artificial prompts or cues for the player's performance (ones not present in an authentic case). Adjusting the learning environment may be done universally for all players if they are expected to need it, or it may be provided individually when triggered by certain player actions.

Coaching (Nowack & Wimer, 1997), another form of scaffolding, entails providing cognitive and/or emotional support to the player. It can be provided universally to all players, it can be provided individually when triggered by certain player actions, or it can be provided on request from the player. The player can ask a question of the virtual mentor, can request a specific type of assistance, and can ask for clarification or elaboration on the assistance. Furthermore, the coaching can be inquisitory (i.e., in the form of questions, as in Socratic dialogue, to aid the player's understanding), or it can be expository (i.e., in the form of statements to provide the player with important information). It is typically provided when the player just needs a little help to perform a part of his/her role.

Instructing, on the other hand, involves more than providing information. It entails the player engaging in specific activities to promote learning. The instructional overlay is provided just-in-time – only for those KSAs that are needed in the next "episode" of the game (the next part of the task). The nature of the instruction depends on the nature of the KSAs being developed.

- Sometimes, the role requires the player to have *memorized some information* (rote knowledge), in which case drill and practice is provided until the player reaches specified criteria for accuracy and speed (Salisbury, 1990).
- Sometimes the role requires the player to have a *generalizable skill*, in which case the virtual mentor provides tutorial instruction that includes demonstrations of the skill, usually simultaneously with explanations (generalities), and practice in performing the skill, with immediate feedback until the player reaches the specified criteria for accuracy and speed of performance (Merrill, 1983; Romiszowski, 2009). The demonstrations and practice must reflect the full range of divergence found in the current version (difficulty level) of the task. The player can be allowed to ask the virtual mentor for demonstration, explanation, or practice at any time, and could even be allowed to request more or less difficult demonstrations or practice, or those decisions could be automated.
- Sometimes the role requires the player to have *conceptual understanding* (meaningful knowledge) related to the task or context. Different dimensions of conceptual understanding are developed through different instructional strategies (Reigeluth, 1983). For example, superordinate relationships are developed by providing context (e.g., an atom is a part of a molecule); coordinate relationships are developed by providing comparison and contrast (e.g., the differences between a civil war and a revolutionary war); subordinate relationships are developed by analysis of varieties and/or components (e.g., atoms are made up of electrons, protons, and neutrons); analogical relationships are developed through analogies; experiential relationships are developed through concrete cases; and so forth. What is often called "cultural understanding" is typically comprised largely of conceptual understanding and remember-level learning.
- Sometimes the role requires the player to have *causal understanding* (meaningful knowledge) related to the task and context (Corrigan & Denton, 1996; Perkins & Grotzer, 2005; Reigeluth, 1983). Such understanding is developed through observation and manipulation of causes and/or effects, which can usually be done most effectively and efficiently with a simulation. For example, one could pinch a touch screen to change the thickness of a convex lens and observe what happens to the focal length and size of the image as it changes. Most causal models involve more than one cause and one effect, but simulations can be equally powerful in helping players to understand multiple effects (and their interaction effects), chains of effects (and their contingencies), and probabilities of effects, as well as multiple causes, chains of causes, and probabilities of causes. Prediction (given a cause, predict its effect), explanation (given an effect, explain what caused it), and solution (given a desired effect, make it happen) are three behaviors associated with developing such understanding (Reigeluth, 1989).
- Sometimes the role requires the player to have an *understanding of natural processes* (meaningful knowledge), such as the life cycle of a flowering plant. Such understanding is developed through observation of the sequence of events that comprise the natural process, as well as descriptions of what preceded or followed any given event (Reigeluth, 1989). Simulations, with their ability to control time, are often the most powerful way to develop this kind of understanding.

- Sometimes the role requires the player to have a certain *attitude* or *set of values*. Attitude change has three components: cognitive, affective, and psychomotor (Kamradt & Kamradt, 1999). The goal of the instruction is to move all three components by the same amount in the same direction in stages, using rapid shifts in instructional tactics from one component to another within a safe environment in which to practice the new attitude. This is done by creating a situation that is dissonant with the player's current attitude, and beginning by addressing the component that is most dissonant. For the cognitive component, persuasion is used; for the affective component, operant conditioning techniques are used; and for the psychomotor component, demonstrations and practice are used. The attitude is consolidated at one point on the continuum before proceeding in stages to the full extent of the target attitude. Due to the close relationship between attitudes and values, both are developed in the same way.

2.4 Part-task mastery

When a player is performing the task in a version of the game, he or she may begin a new part of the task only to find that he or she lacks certain KSAs to be successful, at which point he or she (or the virtual mentor) pauses the game and activates the instructional overlay. Alternatively, the virtual mentor may step in prior to the negative consequences and advise the player that he or she needs some preparation for the next part of the task. Either way, part-task instruction (van Merriënboer, 1997; van Merriënboer, Clark & de Croock, 2002) is initiated, and it is fully integrated with an assessment function – each player continues to do the practice activities for each of the KSAs in his or her part of the task until the established criteria (usually for accuracy and/or speed of performance) are attained. At that point, a record of the attainment is automatically entered into the player's file, the virtual mentor says good-bye, time is unfrozen for the game, and the player uses the KSAs just acquired to perform his or her part of the task, until additional coaching or instruction is needed. This cycle of game play, instruction/assessment, and game play again is repeated throughout the game, utilizing both criterion-referenced testing (Cronbach, 1970; Glaser, 1963; Haertel, 1985) and mastery learning (Block, 1971; Bloom, 1968; Carroll, 1963).

It is important to note that the practice and accompanying criteria include the full range of *divergence* (Merrill, Reigeluth & Faust, 1979) expected in the upcoming duty environment (for skills and understandings), the level of *automatization* (Anderson, 1983, 1996) required by the upcoming duty environment (for memorization and skills), and the level of *consolidation* (Kamradt & Kamradt, 1999) required by the upcoming duty environment (for attitudes and values).

2.5 Feedback

The game has four major kinds of feedback. Foremost is *natural consequences* (Baek, 2009), which are built into the logic of the simulation-game. This is a major aspect of experiential learning and promotes a variety of higher-order thinking skills, including anticipation, diagnosis, and strategic planning. A second kind of feedback is *explanations* of natural consequences of the player's actions and of other players' perspectives and actions that are relevant to the player's performance. The action is often reviewed with "instant replays" from a "god's-eye view" that encompasses the player's role, superior's role, subordinate's role, adversary's role, and even civilian or protectorate role). The virtual mentor provides this feedback either upon request of the player or when the system is programmed to provide it (at which point the player can reject it). However, this kind of feedback is only provided when it does not interrupt the flow of the game.

A third kind of feedback is *debriefing* (Fanning & Gaba, 2007; McDonnell, Jobe & Desmukes, 1997; Raemer, Anderson, Cheng, Fanning, Nadkarni & Savoldelli, 2011), which is similar to explanations except that the virtual mentor provides it at the end of an episode (which is a part of the whole task for a given level of difficulty). The virtual mentor attempts to cultivate heuristic reasoning and mental model formation by eliciting or providing explanations about the performances, not just performances of the player, but also of other characters involved in that episode of the task, as well as contextual factors and cultural issues. Finally, *immediate feedback* is provided in the instructional overlay. This feedback is often in the form of hints or explanations of causal influences or reasoning to encourage more active cognitive processing and mental model development, but it may also take the form of simple confirmation, and it has motivational elements when warranted.

2.6 Motivation

Motivation is key to the acceleration and quality of learning. A motivated learner is enthusiastic, engaged, focused, and persistent (Garris, Ahlers, & Driscoll, 2002), and games foster these traits by inducing a state of flow (Csíkszentmihályi, 1990) for extended periods of time. Various aspects of games stimulate intrinsic and extrinsic motivation. Malone and Lepper (1987) argue that games promote intrinsic motivation through challenge (providing optimal difficulty for the player), curiosity (providing novelty, uncertainty of outcomes, and incongruity with existing mental models), control (promoting a sense of agency in taking on challenges), and fantasy (providing an appealing setting and a compelling narrative context). Furthermore, many elements of games contribute to extrinsic motivation. One of them is *scorekeeping*. The quality of the player's performance is reflected by a score that is often displayed continuously or at the end of an episode of play. In a multi-player game, each player has his or her own score, but there may also be a team score. The score may take the form of points or objects (e.g., new tools or virtual currency) or a variety of other forms. Peer recognition of one's mastery can be highly motivating, so individual and team achievements in multiplayer online games are often posted for all to see.

Second, motivation is enhanced by *collaboration* with teammates – through personal friendships and loyalties, peer recognition, not wanting to let down your teammates, and for some people, the need for affiliation (McClelland, 1976). Collaboration is appropriate when the task itself entails collaboration. In such cases, the game can be designed to build friendships and loyalties, as well as collaboration skills and teamwork.

Third, motivation is enhanced by the *authenticity* and *relevance* of the scenario and role (Jonassen, Howland, Marra & Crismond, 2008). Airmen want to be successful in their next assignment, so the more authentic and relevant the task is to their next assignment, the more motivated they tend to be.

Finally, motivation is enhanced by building *confidence* through appropriate levels of difficulty (Keller, 1983, 1987). Confidence, or expectancy for success, is an important motivator for learning. Receiving training that is within their zone of proximal development (Vygotsky, 1978) is important to building players' expectancy for success, and the levels of difficulty (Principle 2) help to keep training within their zone of proximal development.

Conclusion

These six principles – authenticity, levels of difficulty, scaffolding, part-task mastery, feedback, and motivation – provide a holistic view for the design of any game for training Air Force personnel. In the next section, we elaborate on this holistic view.

Section 3
Elements of the Game Space

The previous section of this report describes fundamental principles that designers may use to develop a fuzzy vision of a game for learning. To transform that fuzzy vision into a designed experience, designers must understand the game space, the essential elements that comprise that space, and the kinds of decisions they must make regarding those elements.

*The **game space** is the context in which the rules of a game pertain*. In the seminal text *Homo Ludens*, Huizinga (1955) lists examples of "temporary worlds" in which play takes place, one being "the magic circle" (p. 10), a term which has come to stand for the game space (Klabbers, 2009; Salen & Zimmerman, 2004). The game space may encircle a literal space (e.g., a board, field, or screen) or simply be an agreement among people to play, thereby transforming their shared space into a magic circle. From a systems perspective, the magic circle is a boundary which players cross to engage with and within the game system. The game space created by designers contains the potential for experiences that are realized through rule-based play.

*The **elements** of the game space are all of the aspects of the game that must be designed in order to create the necessary conditions for the game experience.* Various game designers and game scholars have described the elements of the game space in different ways but with some consistency in terminology and meaning. Schell (2008) identifies four basic elements of games: mechanics, story, aesthetics, and technology. Koster (2005) refers to elements as "game design atoms," and Brathwaite and Schreiber (2009) use the same term to encompass game state, game view, players, avatars, game bits (objects), mechanics, dynamics, goals, and theme. Many of these atoms are included in Schell's broad definition of mechanics. Avedon (1971) lists ten elements: purpose (or goal), procedure for action, rules governing action, number of participants, roles of participants (function and status), results or pay-off, abilities and skills required for action (cognitive, sensory motor, and affective), interaction patterns, physical setting and environmental requirements, and required equipment. He notes that some of these are not always necessary (e.g., equipment to play *Twenty Questions*). Järvinen (2008) describes three categories with a total of nine elements of games: systemic elements (components, environment), compound elements (ruleset, game mechanics, theme, interface, information), and behavioral elements (players, contexts).

We have synthesized these attempts to identify standard game elements, using as a primary foundation Järvinen's approach, which is based on a thorough empirical analysis of over a hundred games of various types. Our intent is to provide guidance regarding the kinds of decisions that instructional designers must make in designing games for learning. Therefore, we focus on the *elements that must be designed* rather than aspects that emerge during the game experience. For example, game state is the configuration of game elements at a given time during gameplay. It is an important aspect of gameplay and is useful in analyzing gameplay, but it is not directly created by the game designers. The 10 elements we discuss include goals, game mechanics, rules, players, environment, objects, information, technology, narrative, and aesthetics.

We do not include motivation here, since it is not designed but results from the design of other elements. We include roles and theme under narrative, although they could be discussed separately. We discuss game dynamics as player interaction that arises from mechanics and rules, even though—like game state—dynamics are created during gameplay.

We should say up front that there is no standard or "correct" way to undertake the design of a game. The elements of a game system are so intricately inter-related that decisions regarding one influence decisions regarding others. Some games are conceived based on theme or scenario, while others are born of the designers' desire to explore a (set of) mechanic(s). If the purpose of the game includes identity transformation (not only learning something but also becoming something; see Brown & Duguid, 2000; Gee, 2003; Shaffer, 2008; Squire, 2006), then the designers may choose to begin by determining an appropriate role for the player (see **Narrative** below). For Air Force training, we anticipate that the games will be conceived based on real-world scenarios and the tasks that the player will soon need to perform. In summary, serious games are designed with a purpose other than (or in addition to) the desire to entertain; they may seek to teach, to persuade, to provoke, etc. We propose that the purpose should inform all subsequent decisions about the design of the game elements, a principle which we discuss in more detail in our description of goal(s).

The following is a description of each of the 10 elements: 1) goals, 2) game mechanics, 3) rules, 4) players, 5) environment, 6) objects, 7) information, 8) technology, 9) narrative, and 10) aesthetics. Figure 1 provides an overview of the relationships among these game elements.

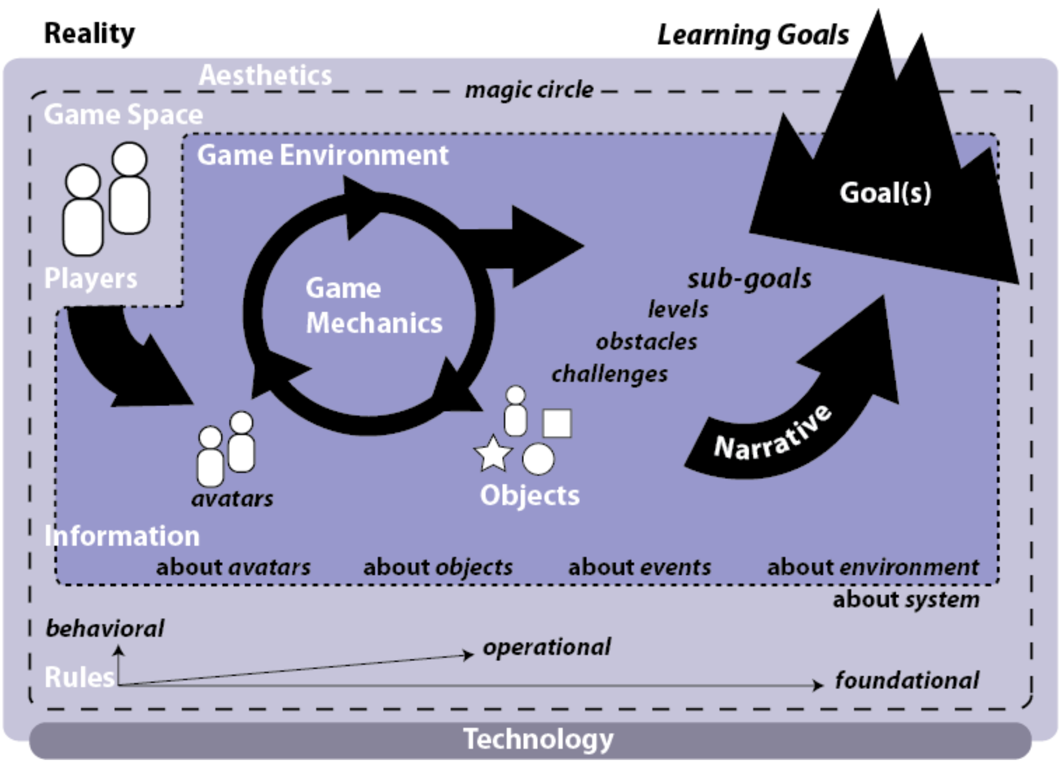

Figure 1: The elements of games

3.1 Goal(s)

We have not taken on the task of defining the difference between a game and a simulation; despite several decades as a field, researchers and practitioners are still struggling to create a generally accepted taxonomy (Klabbers, 2009; Wolfe & Crookall, 1998). However, there is some consensus that every game has a goal (and usually sub-goals), whereas a simulation does not (Alessi & Trollip, 2001; Gredler, 2004; Heinich, Molenda, & Russell, 1993; Salen & Zimmerman, 2004).

The ***goal*** *of a game is to win – to achieve the configuration of game elements that matches the winning state defined in the rules*. For Air Force training, the goal of the game should essentially be the goal of the task(s) for which the airman is being trained. Following Schell (2008), the goal of a game should be made clear to the players and should seem achievable (difficult enough to be challenging but not impossible) and worth achieving.

While we may distinguish between the *goal* of an instructional game and the *learning goal(s)* of that game, they are closely related in that achieving the goal of the game should require the players to achieve the learning goals. Therefore, the actions and strategies needed to succeed in the game should be aligned with those needed to achieve the desired learning outcomes. In practice, it makes sense to begin by identifying the desired learning outcomes, as these are the real purpose of the game and should inform design decisions about the other elements of the game. This kind of activity-goal alignment also helps to ensure that the game elements that are intended to increase engagement and motivation do not distract from the meaningfulness of the activities from a learning perspective (Shelton & Scoresby, 2010). If a player is able to achieve the goal of the game without also achieving the desired learning outcomes, this is a design failure that calls for redesign. This design failure is avoided by making the goals and tasks of the game functionally the same as the goals and tasks that the airman must attain in the post-instructional environment (the principle of authenticity).

The subgoals of a game can be conceived as two types. The most common conception is related to subtasks whereby the performance of all subtasks is combined to perform the task, and the achievement of all subgoals is combined to achieve the goal of the game. The second conception is related to typical games in which players master one level before moving on to another level of the game. In this conception, each subgoal represents a different level – a different version of the task corresponding to progressively higher levels of complexity or difficulty. Therefore, design decisions regarding goals and subgoals may be influenced primarily by the fundamental principles of authenticity, levels of difficulty, and motivation presented in Section 2. To facilitate integration and transfer, goals should require the completion of whole, authentic tasks that have an appropriate degree of fidelity with the real world (discussed in more detail under **Aesthetics**). Subgoals should be created for the various levels of difficulty within and across task classes. These subgoals should be obtainable only by completing interesting and challenging tasks of optimal difficulty for the learner. The learner's intrinsic motivation is fueled by cycles of acquiring abilities and tools required to complete the tasks, developing skillfulness through repeated attempts at the tasks, and finally achieving the subgoal through mastery.

3.2 Game mechanics

The term *game mechanics* is commonly used in the field of game design, but there seems to be no standard definition (Lundgren & Björk, 2003; Sicart, 2008). Brathwaite and Schreiber state that mechanics are "how something works" (2009, p. 28) and are synonymous with rules. Similarly, Schell defines mechanics as "the procedures and rules of your game" (2008, p. 41). However, Avedon (1971) makes a clear distinction between mechanics and rules, with procedures being a “procedure for action” and rules governing the action and the results. We find this distinction useful for designers as it facilitates thinking about an *action* (a mechanic) separate from all of the possible *constraints* on and *outcomes* of that action, which may vary greatly from game to game. A common example is the trading mechanic, which allows players to trade with each other or with the game system. The specific rules governing the trading (what, how, when, with whom) vary depending on the game. Furthermore, the relationship between mechanics and rules is many-to-many: a mechanic may embody several rules and a rule may govern several mechanics.

Following this approach, *a **game mechanic** is an action governed by rules that a player may take with or on one or more other game elements*. It is important to note that a mechanic may consist of several discrete actions combined into a procedure. For example, some videogames employ a shooting mechanic that consists of at least a few of the following actions: equipping a weapon, aiming, firing, and reloading. A mechanic usually involves several elements at once, often including the player (or the player’s avatar), one or more game objects, the game environment, and the associated rules.

Through interaction with game mechanics in digital games, players come to understand the underlying rules of the game and to formulate strategies for leveraging those rules, which is to say they learn to recognize temporal patterns of cause and effect and to apply that knowledge to succeed in the game. It follows, then, that instructional designers should conceive of or translate the desired learning outcomes into actions (including cognitive actions) that form the basis for playing the game (the principle of authenticity). For one application of this approach, see Aleven, Myers, Easterday, & Ogan (2010). The range of possible actions and the rules for the results of these actions should be directly related to the prior attainments of the player and his or her current abilities and skills.

The literature contains many proposed classifications of game mechanics. For example, Salen and Zimmerman (2004) define a *core mechanic* as a recurring action or set of actions that are central to a game and enable players to make meaningful choices. Järvinen (2008) follows this definition but goes on to distinguish between *primary mechanics*, which relate to the highest-order goal of a game at a given time, and *submechanics*, which relate to lower-order goals that are nonetheless instrumental in achieving the highest-order goal. Sicart chooses to address only core mechanics, which he defines as “the game mechanics (repeatedly) used by agents to achieve a systemically rewarded end-game state” (2008, “Interlude,” para. 3). He then divides core mechanics into primary mechanics, which are used extensively and are necessary for overcoming obstacles to achieving the end state, and secondary mechanics (similar to Järvinen’s submechanics), which are used occasionally or in combination with primary mechanics. Sicart opts not to categorize non-core mechanics, which are not related to achieving the end state.

We have synthesized these approaches to classifying game mechanics and have related them to their use in designing games for learning. Our classification consists of three types: core, compound, and peripheral.

Core mechanics *are most fundamental in accomplishing the goal(s) of the game*. If a player fails to master a core mechanic, he or she cannot achieve the goal(s) of the game. Core mechanics should be introduced early in the game and recur frequently. Therefore, they should quickly become skill-based (automatic) through practice, including part-task practice in the instructional space, if necessary. Sometimes it may be desirable to challenge players by modifying a core mechanic (or the elements upon which it acts) once it has been mastered. For example, once a player has mastered the driving mechanic in a videogame, a faster car may become available that requires increased proficiency by the player.

Compound mechanics *consist of two or more core mechanics combined by a rule*. They are also necessary in accomplishing the goal(s) of the game, but they recur less frequently. They may remain rule-based or become skill-based, depending on the availability of practice for the player. For example, a player may need to learn how to use the driving mechanic and the shooting mechanic simultaneously to solve a problem and proceed toward the end state of the game.

Peripheral mechanics *are optional or non-vital in accomplishing the goal(s) of the game*. They are usually novel (non-recurrent) and knowledge-based (i.e., require more cognitive processing). For example, in *Assassin's Creed Brotherhood* if the player's avatar enters a body of water, a prompt informs the player which game controls to use to make the avatar swim. However, swimming is not necessary to achieve the end state of the game.

Fabricatore (2007) describes a progression of mechanics usage. First, the player must learn the mechanic itself—how it is achieved using the game controls—and then gain some proficiency with it through practice. Second, the player must recognize an appropriate time to use the mechanic and then use it to achieve an end. Third, the player must increase proficiency with the mechanic in order to use it in more complex situations (sometimes in combination with other mechanics) to achieve a subgoal of the game. This kind of elaboration is common in videogames (Gee, 2003) and is usually associated with levels of difficulty.

Becker (2011) identifies four broad categories of learning in videogames (slightly reordered here), and we find it useful to think about these categories in relation to the types of mechanics described above:

1. Things players must learn to achieve the goal(s) of the game. These should be associated with the core and compound mechanics of the game.
2. Things players can learn that may not be required to complete the game. These should be associated with the peripheral mechanics. While it may be tempting for instructional designers to minimize the use of peripheral mechanics because they may not be relevant to the learning goals, they may be used to increase authenticity or to increase motivation by creating a more enjoyable game experience.
3. Things players learn outside the game that may be useful in the game (external learning). These may be associated with part-task practice in the instructional space or with relevant information from other places such as game fan sites.
4. Things players learn by playing the game that are not necessarily useful in playing the game (collateral learning). In *Assassin's Creed Brotherhood* players may choose to read in-game database entries about Renaissance-era Italy, but doing so does not really aid in finishing the game. If an instructional goal of this game were to teach players about important people, places, and events in Renaissance-era Italy, then using this information should be required in order to accomplish goals in the game.

Because game mechanics are the elemental building blocks of games, design decisions should be guided by all six fundamental principles described in the previous section. Mechanics should function as they do in the real world and provide authentic feedback if their use is to transfer outside the game context. Decisions regarding the progression of mechanics usage described above should be informed by the concepts relevant to designing levels of difficulty (e.g., cognitive load, simplifying conditions, etc.). If players are unable to master core mechanics through practice in the game, the scaffolding should provide appropriate assistance in the game or part-task practice until mastery is achieved.

3.3 Rules

In *Rules of Play*, Salen and Zimmerman describe rules as the "deep structure" of a game (2004, p. 120). ***Rules*** *define the possibilities of and constraints on actions in a game, as well as the rewards and penalties for those actions*. Thus they are tightly bound with mechanics, and together these elements make different games both similar (by using common mechanics) and unique (by governing their use in distinctive ways).

Salen and Zimmerman identify three types of rules—operational, constituative, and implicit—but we prefer Parlett's (2005) refinement of these types as operational, foundational, and behavioral. ***Operational rules*** are the rules that players instantiate when they play a game. For board and card games, these are often (but not always) written rules that are enforced by the players. Videogames rarely come with written rules; instead operational rules are enforced by the game itself, enabling more complex rule sets than are practical in non-digital games. ***Foundational rules*** are the underlying logical and mathematical structures upon which the operational rules are based. The other elements of the game, such as the environment, the objects, and the information, are representations of the foundational game state (Schell, 2008). ***Behavioral rules*** are an implicit aspect of entering the magic circle and may be thought of as "good sportsmanship."

When players encounter a mechanic, they have certain expectations based on their prior experiences with that mechanic in other games. Therefore, when creating the rules of a game, designers often rely on precedent established by other games and then tweak their mechanics and rules to fit the particular game being designed. Instructional games may further need to align their rules with outcomes and feedback consistent with the real world to promote transfer of expertise (the principles of authenticity and feedback).

Game balancing *is the art of designing the relationships among all of the elements of a game to promote the desired game experience*. There is no standard process for balancing a game other than the use of playtesting. ***Playtesting*** *is a method used throughout the game design process to systematically test the game elements and their relationships to each other*. Initially playtesting may be done by the game designers, but eventually it should involve only people who have not been involved in creating the game and have never played the game before, while designers observe the gameplay and make notes about players' decisions, questions, difficulties, misunderstandings, and overall experience of the game. Based on findings from playtesting, designers then make modifications to game elements (often mechanics and rules) to address perceived problems and achieve a well-balanced game. Schell (2008) lists twelve common types of balance, a few of which we discuss here:

- *Fairness*: Fairness is achieved when a player feels he has a chance of winning. In a symmetrical game like chess, both players have identical game pieces with the same mechanics and rules. The predictability of the game's outcome increases as the gap between the players' skill levels increases. Some games attempt to balance a disparity between players' abilities by including mechanics that produce random results, such as dice or cards drawn from a deck. However, sometimes asymmetry is desired or necessary, especially if a real-world relationship is being modeled.

- *Challenge vs. Success*: Finding the optimal level of difficulty for a player may be accomplished by either allowing the player to choose the level or by assessing (either continuously or periodically) the player's skill level and dynamically adjusting the difficulty. When a game is too easy, players get bored; when it's too difficult, they get frustrated. In addition to finding the right level of difficulty for a player, designers should provide a range of meaningful challenges that require a variety of abilities and ever-increasing skill (Koster, 2005).
- *Skill vs. Chance*: In general, games for learning should minimize chance unless it is part of the real-world context that is being modeled. For example, Alessi and Trollip (2001) state that chance may be important in situational simulations when human behaviors and attitudes are being modeled.
- *Competition vs. Cooperation*: All games are competitive, whether the players are competing against each other, against themselves, or against the game system. Games that require some cooperation among players can foster communication skills and engage players in forms of distributed thinking (Gee, 2003). In multiplayer role-playing games, players have different roles and associated abilities, and they must all work together to leverage their individual abilities to accomplish the goals of the game.

3.4 Players

The ***players*** *are the individuals who choose to enter the magic circle and undergo the experience of a game.* It may at first seem strange to include players as an element of a game. But just as instructional designers endeavor to create learner-centered learning experiences, game designers strive to create player-centered gaming experiences. Games are mediated experiences, and all game design decisions should be directed toward achieving the desired experience for the players. Designers must decide whether a game will be single-player or multi-player, and if the latter, the possible configurations of players. Avedon (1971) refers to these configurations as interaction patterns and describes eight types:

1. Intra-individual: actions involve no other person or object.
2. Extra-individual: actions involve an object but no other person.
3. Aggregate: actions involve other persons but are directed toward objects rather than people.
4. Inter-individual: actions are directed toward another person.
5. Unilateral: actions involve three or more persons but are directed toward only one at a time.
6. Multi-lateral: actions involve three or more persons and are directed toward several or all persons.
7. Intra-group: actions involve cooperation by two or more persons toward a common goal.
8. Inter-group: actions involve competition between two or more intra-groups.

In many games for learning, players take on roles (discussed in more detail in **Narrative** below) and pursue goals by manipulating **avatars** that represent the players in the game environment.

Game dynamics *are the emergent patterns of interplay between mechanics, rules, and players*, and for this reason are not discussed as a separate element. In poker, for example, bluffing is not mentioned in the rules. It is a strategy that emerged as a result of players interacting with the specified mechanics and rules of the game. Hunicke, LeBlanc, and Zubek (2004) proposed the MDA framework (Mechanics, Dynamics, and Aesthetics) as a way of thinking about the relationship between games, designers, and players. *Mechanics* are the designed components; *dynamics* result from players' interactions with mechanics to evoke emotional (aesthetic) experiences in the players. Here again, playtesting is an important method for determining whether players' interactions with game mechanics (and with each other) are resulting in unexpected dynamics and undesired experiences.

3.5 Environment

The ***environment*** *is the setting in which the action of the game takes place and the diegetic objects* (see **Objects** below) *of the game reside*. Most board game environments are either abstract or have a single setting, such as Mr. Boddy's mansion in *Clue*, while videogame environments may have numerous settings, such as the spaceship and locations on several planets in *Mass Effect*. Movement in a game is determined by two primary aspects of the environment. First, the structure of the environment may be **discrete** or **continuous** (or a combination of the two). Using the previous examples, in *Clue* the environment is divided into discrete locations (rooms), and the hallways between rooms are further divided into squares. The player rolls a die and moves her token forward, backward, left, or right (but never diagonally) from square to square, from square to room, or from room to square (or uses a secret passage that connects two rooms). In *Mass Effect*, the environment is divided into much larger discrete locations. Movement between locations (e.g., from planet to planet) is similar to moving from square to square in *Clue*, that is, jumping from one place to another. Movement within those locations is continuous, with the player using a controller to move his avatar to explore the location with few constraints.

The second aspect of the environment that affects movement is dimensionality. An environment may be linear (1D), rectilinear, 2D, or 3D (Björk & Holopainen, 2005). In *Monopoly*, the player's token moves linearly around the board. In a rectilinear environment, movement is constrained to paths between nodes, which is the case in strategy games such as *Risk* where an army may only move into an adjacent region. Movement is limited to two dimensions in a 2D environment such as chess. Many videogames take place in environments with three dimensions (3D) and fluid, continuous movement.

Perspective or point of view in videogames is the vantage from which the player visually perceives the environment. The technological limitations of early videogames restricted perspective and movement to two dimensions, with many offering horizontal and/or vertical screen scrolling to expand the game environment. The adoption of **isometric** perspective, which gives the player a view of three sides of an object with parallel lines that do not converge, added a sense of depth to the game environment (Poole, 2000). Many simulation games and strategy games use either an isometric or a **top-down** perspective, which gives the player the feeling of acting *on* the environment from above rather than *in* the environment. By the early 1990s, personal computer technology was capable of simulating three dimensions, and shooting games like *Wolfenstein 3D* and *Doom* allowed players to maneuver avatars through hallways and rooms from a **first-person** perspective (hence the name *first-person shooter*), albeit with a fairly narrow field of vision. The last perspective we discuss, **third person**, broadens the field of vision by moving out of the avatar's point of view and watching the avatar from a slightly removed position. Many games now refer to this perspective metaphorically as a "camera" that can be moved around the avatar as though it were on a crane (Poole, 2001). Games may also allow the player to switch between first- and third-person views.

While physics is an important aspect of some non-digital games (e.g., billiards, tiddlywinks), many videogames require a ***physics engine**, which is a computer program that handles the rules governing how objects in the environment move and respond to force*. A deeper exploration of design options for game physics is beyond the scope of this paper, but designers should consider the degree of fidelity required to achieve the desired learning outcomes.

Another aspect of the game environment is the rate at which game time passes. Juul notes that the difference between the real world and a game world is reflected in the "duality of *play time* (the time the player takes to play) and *event time* (the time taken in the game world)" (2004, p. 131). Event time in a game may be characterized as real, compressed (speeded up), extended (slowed down), or variable. The rate of event time may vary by event (e.g., eight hours of sleep for the avatar may pass in a few seconds), or event time may be manipulated by the designer to adjust difficulty and challenge for the player.

Design decisions regarding the structure, dimensionality, physics, and time of the game environment, along with the available perspective(s) for the player, are greatly influenced by the instructional goals of the game and the type or genre of game.

3.6 Objects

***Game objects** are the components of the game system that embody and enable the game mechanics or are affected by the player's use of the game mechanics.* **Diegetic objects** exist in the game setting and, when the game includes an avatar, are accessible to the avatar. In role-playing games, examples include weapons, vehicles, furniture, and agents (non-player characters controlled by the game system). Non-diegetic objects exist outside the game setting and are accessible to the player but not to the avatar, mainly through the virtual (on-screen) interface. These may include menus, heads-up displays (HUDs), and other means of obtaining information about or controlling the game.

Objects have properties (or attributes) with either static or dynamic states (Schell, 2008). For example, a gun may have a static property for the amount of ammunition it can hold and a dynamic property for the amount of ammunition it currently holds. In order to be usable, objects should have affordances (Norman, 1988) that make apparent how the object is used.

3.7 Information

Gameplay is goal-directed and rule-based action within a system. Every action creates a change in the state of the game system. Players' decisions regarding actions are guided by the available information about the game state. Many game objects are conduits for information, which may be presented as text (e.g., a popup window with instructions; a letter from a non-player character), icons (e.g., a weapon icon that indicates which weapon is currently active; a health meter), or visual/aural attributes of objects that serve as cues of state (e.g., a clicking sound to indicate that the chosen door is locked).

Below we discuss five types of information that may be available to the player—information about avatars, objects, events, environment, and system. In general it is helpful to think of the player's access to information as being on an accessible-inaccessible continuum, the exact position depending on a number of factors including authenticity (how much the player would know in the real-world situation being simulated), level of difficulty (withholding information can increase difficulty), and cognitive load (too much information overloads working memory).

- **Information about avatars** includes the role and attribute states of the avatar (e.g., current values for strength, speed, intelligence, etc.), the inventory of available resources and locations, and the avatar's current location.
- **Information about objects** primarily includes attribute states related to game mechanics. For example, a number or a graphic representation might indicate the amount of ammunition in a weapon, which might prompt the player to use the *reload* mechanic or the *switch weapon* mechanic. A special type of information conveyed by objects is perceived affordance, an indication of likely actions that may be taken with an object (Norman, 1988).
- **Information about events** is of two types: feedback and narrative.
    - Feedback is the immediate result and consequences of the use of game mechanics expressed in one or more sensory forms. In videogames, players learn the operational rules of a game by experimenting with game mechanics and interpreting the meaning of the feedback.
    - Narrative information about events includes salient descriptions (or recordings) of past performance in the game, usually key events from levels/missions/quests. It may also include backstory, cut scenes (non-interactive animated sequences that segue between playable sequences), listings of pending missions, reminders of tasks to be completed, and other information related to the unfolding story.
- **Information about the environment** includes maps of known and accessible locations. It also includes sensory cues (e.g., lighting, music) that convey the tone and mood of the environment. A well-designed environment creates in the player a sense of immersion and presence (Tamborini & Skalski, 2006).
- **Information about the system** includes indications of the current game state and the available procedures at the system level, for example, entering and leaving the game space, returning to a previous game state, accessing the instructional overlay, etc.

3.8 Technology

The technologies used in games range from paper and pencil to pewter and molded plastic to joysticks and motion detectors. Schell (2008) distinguished between *decorational* technologies that improve superficial aspects of existing experiences and *foundational* technologies that create the possibility of new experiences. Game designers must learn to recognize the opportunities afforded by technologies as well as their limitations.

***Equipment** consists of the physical pieces required to play the game*. Some games, such as *Twenty Questions,* require no equipment, only players. Board games may include boards, tokens, markers, various sets of cards, and other specialty pieces depending on genre and theme. Video game equipment generally includes some sort of computing device (a *platform*), a screen and speaker(s), and a *physical interface* for interacting with the game system, usually via a *virtual interface* designed to enable the particular mechanics of the game.

Other technology considerations for video games include the network and data storage. A ***network*** is a group of connected devices that, in this case, facilitates multiplayer game experiences. The quality of the connections among the devices impacts the game experience, so games should be designed with bandwidth constraints in mind. In video games, ***data storage*** is used to preserve game state and game history. Data may be stored locally (on the gaming device), portably (on a memory card), or remotely (on a server). For learning games in particular, designers should ensure that relevant performance data are captured and stored for analysis. If the game is designed so that the learning objectives are directly tied to the use of game mechanics, capturing data for these events alone may provide sufficient evidence of mastery.

3.9 Narrative

*A **narrative** is a sequence of events that tells a story*. There is an ongoing debate among game scholars regarding the relationship between narrative and gameplay. In brief, narratologists argue that all games are narratives and are best studied as such, while ludologists contend that even games with strong narrative elements are experienced differently than other forms of narrative—as current rather than past actions—and that the focus of study should be on game rules and mechanics, which enable action (for a more in-depth discussion, see Brathwaite & Schreiber, 2009; Juul, 2001; Salen & Zimmerman, 2004).

From a learning perspective, the use of narrative in games utilizes the power of episodic memory for structuring and storing our *experiences* as narratives (Bruner, 1991). Designing a game with a clear narrative structure, especially a monomythic pattern such as the hero's journey described by Campbell (1968), provides both a familiar frame for experience (an idea of what to expect) and a cognitive frame of reference (schema) to promote recall.

The use of narrative in a game may be influenced by game genre. For example, a first-person shooter (FPS) game such as *Halo* may have some narrative trappings like a one-dimensional character and a simple, linear plot held together by cut scenes, but it is primarily focused on developing skills associated with game mechanics; on the other hand, a role-playing game (RPG) such as *Oblivion* is likely to have a customizable avatar and multiple storylines that vary according to the player's actions and choices. But even within a particular genre, narrative may be employed in very different ways. For example, *Grand Theft Auto: San Andreas* and *L.A. Noire* are both action-adventure games. *San Andreas* has missions that are sequenced in a story arc following the main character's efforts to solve his mother's murder, but it also allows the player to freely roam the expansive game environment and engage in seemingly endless activities outside the narrative. *L.A. Noire's* narrative is more tightly structured with more cut scenes to develop the plot, giving it a cinematic feel.

The preceding examples illustrate the fact that game designers have tremendous leeway in deciding how to incorporate narrative into a game. For example, a narrative structure (or *plot*) may be linear, branching, or foldback (with multiple branches that all eventually lead to a single event [Adams, 2010]) and may use devices like flashbacks and cut scenes. Game narratives are often divided into episodes (levels/missions/quests), each with its own buildup of dramatic tension and release.

Games often require the player to assume a *role* within the narrative and to take action in a manner consistent with that role. Shaffer has argued that a player's role in a game for learning should be based on an epistemic frame, which he defines as a set of "skills, knowledge, identities, values, and epistemology that professionals use to think in innovative ways" (2006, p. 12). Clearly this approach is related to the authenticity of a game. One viable option for game designers is to begin by identifying the real-world role, the attributes of its epistemic frame, and the whole set of tasks associated with the role. These constraints can then be used to determine the game mechanics and rules (which the player experiences as causal dynamics within the game) that will enable the player to develop proficiency in thinking and acting in the role. With these key decisions made, the designers can envision a scenario that provides a context for the role and mechanics. As the design process proceeds, decisions regarding the sequencing of tasks and levels of difficulty will influence the emerging narrative structure, and the original fuzzy vision of the game will come into sharper focus.

Game designers should also consider the roles that might be played by non-player characters (NPCs, also known as agents). The most common roles for NPCs are adversaries, teammates, and information sources. As adversaries, NPCs provide obstacles that the player must overcome in order to reach goals. The level of difficulty may be adjusted by changing the number of adversaries or by changing the skill levels of the adversaries. Similarly, NPCs as teammates can also be used to adjust difficulty by having them provide more or less assistance. In some games, the player may make high-level tactical decisions about the placement and actions of NPC teammates in order to carry out offensive/defensive strategies. NPCs (either adversaries or teammates) may also function as information sources, although the player may need to judge the trustworthiness of the NPC.

3.10 Aesthetics

When we talk about the *aesthetics* of games, we are referring to the emotional responses and felt experiences (McCarthy & Wright, 2004) that arise in the player(s) through interaction with/in the game system. Design decisions for all of the other game components create the overall aesthetic experience of the game, so deciding how a player will feel while playing the game is a crucial part of the fuzzy vision early in the design of the game. Hunicke, LeBlanc, and Zubek (2004) proposed a short list of terms for describing the aesthetics of games, including feelings of challenge (game as obstacle course), fellowship (game as social framework), discovery (game as uncharted territory), expression (game as self-discovery), and fantasy (game as make-believe). Naturally, more than one of these feelings may be present at any given time, and all may occur throughout gameplay. If the game follows a narrative, the type and timing of events and their emotional flow may be dictated by the story arc.

Decisions regarding aesthetics are directly influenced by the degree of authenticity required to achieve learning and transfer. The dimensions of authenticity discussed above should be consistent in their levels of realism (or fidelity), where realism ranges from abstract to realistic. Types of realism include physical (feels real), perceptual (seems real), functional (acts real), cognitive (matches mental model), and emotional (evokes reality). In general, novices benefit from initial lower fidelity (to reduce cognitive load and promote automaticity), but as they approach mastery, higher fidelity promotes transfer.

Conclusion

A game is a designed experience comprised of the ten elements described above. Game designers can create the conditions for the desired experience by applying the fundamental principles described in the previous section when designing these elements. Through this process, designers iteratively refine the fuzzy vision of the game. However, as with any medium used for instruction, in serious games special attention must be given to the instructional methods to ensure that players attain the learning objectives. In the next section, we describe in greater detail the elements of the scaffolding and strategies for promoting the desired knowledge, skills, and attitudes.

Section 4
Elements of the Scaffolding

In this section, we elaborate on what the scaffolding should be like for serious games in the Air Force, based primarily on literature about instructional theory. The scaffolding is built into the game, minimizing or eliminating the need for a trainer. As briefly mentioned in Section 2, there are three major types of scaffolding: adjusting, coaching, and instructing.

4.1 Adjusting

Definition. The least intrusive type of scaffolding is adjusting aspects of the game to provide an appropriate level of difficulty for the player. The intent of this kind of scaffolding is to place the player within his or her zone of proximal development (Vygotsky, 1978). It is the least intrusive because it occurs "behind the scenes", leaving the player unaware that any scaffolding has been provided. All adjustments must be removed before the player may master the current level of the game.

Indications. Adjusting should be used when a task or part of a task (episode) is too difficult for a player to learn without support, as long as the adjusting is more efficient to use than either coaching or instructing.

Kinds. The major kinds of adjusting include:

- *providing easier cases* first or adjusting the difficulty of cases up or down to place the player in his or her zone of proximal development,
- *providing artificial prompts* or cues for the player's performance (ones not present in an authentic case), though these should be removed from cases in which the player will be summatively assessed, and
- *performing parts* of the task for the player.

Access. There are three major mechanisms for deciding when to use adjusting. One is *universal*, in which all players receive the scaffolding at a particular point in the game. The second is *triggered*, in which the decision is based on certain player actions, primarily ones reflecting inadequacies in the player's performance. The third is *requested*, in which each player can request an adjustment in the level of difficulty to match the player's zone of proximal development.

4.2 Coaching

Definition. Coaching is defined here as a type of scaffolding that provides cognitive and/or emotional support to the player, and also preferably a human element that is performed by the player's virtual mentor. It primarily entails providing information or tips to the player, though it can include providing a short demonstration of a skill. More extensive demonstrations and practice with feedback go beyond coaching and are considered instructing. To enhance authenticity, coaching usually requires freezing time in the game, as in a "time-out" in sports scrimmages.

Indications. Like adjusting, coaching should be used when a task or part of a task (episode) is too difficult for a player to learn without support, as long as the coaching is more efficient to use than either adjusting or instructing. It is typically used when the player needs only a little help. Larger amounts of help are typically best provided through adjusting and/or instructing.

Kinds. Coaching can take the form of providing *information*, providing a *hint* or tip, or providing an *understanding*. The latter two kinds of coaching can take either an inquisitory or an expository form. The *inquisitory form* occurs as questions to the player that help the player to discover an appropriate hint or understanding, as occurs in a Socratic dialogue. The *expository form* occurs as statements or visuals that provide the hint or stimulate the understanding.

Timing. Coaching is most often provided or requested before or during a performance episode. It can also be provided after a performance in the form of a debriefing or reflection on action to learn from the experience. If the situation allows, this can be without freezing time in the game. Otherwise, it entails freezing time, in which case the virtual mentor is typically used.

Access. There are three major mechanisms for deciding when to use coaching. One is *universal*, which, if the authentic situation allows, is offered by the player's superior within the game scenario to prepare the player for a new situation before the action starts, or even during the action. Otherwise, it may be offered by the player's virtual mentor before or during the action. The second is *triggered*, in which its use is based on certain events (usually a mistake made by the player). The third is *requested*, in which the player asks for it when he or she feels the need for a little help to perform a part of his/her role. When universal coaching is authentic to the task, it can be done without freezing time in the game. Otherwise, it may often require freezing time. Triggered and requested coaching commonly require freezing time to provide the coaching, due to the inauthenticity of providing coaching in the middle of a performance. For requested coaching, the player asks a question of the virtual mentor or asks for clarification or elaboration, so the system must be able to understand and respond appropriately, or a menu-driven system must be in place for making requests for coaching.

4.3 Instructing

Definition. Instructing is a kind of support for learning that provides the player with appropriate activities as well as information to promote learning. Because it is not an authentic part of the performance environment, time must be frozen. All instruction should be just-in-time (JIT), meaning that it only teaches KSAs that the player will use in the next episode of the task upon unfreezing time in the game.

Indications. Instructing should be used whenever a significant amount of learning effort is required. This may include a significant amount of information to be memorized, a difficult understanding to be acquired, or a difficult skill to be acquired, including appropriate levels of transfer and automatization.

Access. The decision to provide instruction can be made in four ways. First, the computer system may be programmed to *universally* provide instruction to all players in that role for a selected set of KSAs. Second, the decision can be *triggered* by repeated failure of the player to demonstrate a KSA. Third, the player can *request* instruction if the player recognizes that a significant amount of learning is required to perform the current (or next) episode in the task. Finally, the virtual mentor could *suggest* pausing for some instruction but leave the decision up to the player.

Formats. There is a variety of formats in which the instruction can occur, each of which exists on a continuum. One continuum is *part-task selection*, which concerns whether the system diagnoses each player's needs regarding instruction on one extreme or just teaches all the part-tasks to all players in a given role on the other extreme. A midpoint on this continuum is for the instruction on each part-task to start with medium-difficulty practice (with feedback) using a computer-adaptive testing algorithm, and then provide richer instruction as needed. A second continuum for format is *use of a virtual mentor*, which ranges from extensive use of virtual mentor at all stages of the instruction to no use of a virtual mentor for any stages of it.

Strategies for instruction and assessment. The nature of the instruction and assessment differs primarily on the basis of the kind of learning involved. Kinds of learning that have the greatest impact on selection of instructional and assessment strategies include memorizing information, applying skills (including higher-order thinking skills), understanding causal relationships, understanding natural processes, understanding conceptual relationships, and believing in a certain attitude or set of values.

4.3.1 Strategies for memorization

Strategies for teaching and assessing this kind of learning include primary, secondary, and control strategies.

Primary strategies. The primary strategies for instruction are to *present* what is to be memorized and to *practice* recalling or recognizing it (depending on the post-instructional requirements). The practice also serves as the assessment (or certification of proficiency) when the player meets the criterion (e.g., the information is successfully recalled or recognized 10 consecutive times unaided, as an accuracy criterion, or the speed of response averages 1.0 seconds or less for an automaticity criterion).

Secondary strategies. The secondary strategies are increasingly important as the information becomes more difficult to remember. They include: *repetition* for both the presentation and the practice; *chunking*, which entails dividing up large amounts of information into manageable chunks (usually 7 plus or minus 2 items) and requiring mastery on one chunk before moving to the next chunk; *spacing*, which entails providing for passage of some time between consecutive practice or test of any given piece of information; *prompting*, which entails providing hints (e.g., "begins with 'p'") when the player has difficulty remembering an item; *mnemonics* (rhymes, songs, acronyms, images, etc.) when helpful, either provided by the instruction or developed by the player, and prompting can provide hints for remembering the mnemonic; and *review*, which entails periodically testing the player on an item from an earlier chunk (the review pool) and including it in the active item pool if the player could not remember it. The more difficult the remember-level task is, the more secondary strategies are useful to support learning.

Control strategies. The two main control strategies are system control and player control. Decisions about whether to receive presentation or practice often begin under system control with one round of presentation for a chunk, and then typically revert to player control for decisions about whether or not to repeat the presentation. Amount of repetition of practice is generally under system control, based on a criterion for number of consecutive correct responses and/or speed of responses for an item that is appropriately spaced. When the criterion is met, the item is put into the "review pool" and periodically placed back into the "active pool" for review in subsequent chunks. Decisions about item selection within a chunk are typically done randomly by the system, unless order of items is a natural part of the remembering task in the real world. Decisions about the size of the chunks are typically made by the system, adjusting the chunk size based on the player's current and past performance with chunks of various sizes, complexities, and levels of familiarity. Decisions about spacing are made by the system, based on historical data about optimal spacing for review of mastered items. Typically, the spacing of review gradually increases (farther apart) over time for a given item, unless the player fails a review, in which case its spacing decreases (its frequency of review increases). Decisions about prompting are typically under both system and player control. The system usually provides a prompt if the player takes a long time to respond, but the player may also be allowed to request a prompt at any time. Of course, prompted practice does not count toward mastery of the item. Mnemonics can be under system control, either provided automatically to all players or offered only when a player has difficulty remembering, or the player may be prompted and aided to generate a mnemonic of his or her own; or mnemonics can be under player control, with the player able to request a mnemonic or generate a mnemonic of their own unprompted and unaided. Decisions about review are typically made by the system, as discussed earlier.

4.3.2 Strategies for skills

Strategies for teaching and assessing this kind of learning also include primary, secondary, and control strategies.

Primary strategies. The primary strategies for instruction are to tell the player how to do it (*generality*), show the player how to do it (*demonstration*), and provide opportunities for the player to do it (*practice*), with immediate *feedback*. For assessment, the primary strategy is unaided practice to a criterion for mastery.

Secondary strategies. These strategies are increasingly helpful with increasingly difficult skills, but not necessary for easy skills. Generalities can be enhanced with attention-focusing devices (such as highlighting in textual messages, emphasis in audio messages, and zoom in video messages, to name a few), alternative representations (such as paraphrasing, visuals, and audio), and a prototypical demonstration simultaneous with a presentation (explanation). Demonstrations and feedback can also be enhanced with attention-focusing devices and alternative representations (including motion/video). Demonstrations and practice can be enhanced with easy-to-difficult sequences of items and with item divergence (making the items as different as possible from each other, within the full domain of items encountered in the real world (or at least the types of items encountered at this level of the game). Finally, practice can be enhanced with prompting and by requiring overlearning, the latter being accomplished with a criterion for speed of performance in addition to a criterion for accuracy. Again, the more difficult the skill, the more secondary strategies are needed to support learning.

Control strategies. Typically, the system has control over whether to use an inductive or deductive approach to acquisition of the skill. The inductive approach tends to result in better understanding and retention of the skill, whereas the deductive approach tends to be more efficient. The inductive approach also enhances inductive reasoning and skills. This decision can be universal for all players based on the requirements of the task (system control), or it can be tailored to the learning style of each player (system control), or it can be placed under player control. The inductive approach can begin with either demonstrations or practice, depending on the player’s tolerance for failure. The deductive approach typically begins with simultaneous generality and demonstration (system control), though the player can be given control over this decision. After the initial instruction (inductive or deductive), the player is typically given control over what primary strategy component to use next (another example, another practice item, or review of the generality), whether to receive attention-focusing devices or alternative representations, what difficulty level to receive next for demonstrations and practice. However, the system could exercise some control over these decisions, based either on the player’s learning style or the desire to expose the player to multiple ways of learning, or if the player is not making wise player-control decisions. Decisions for prompting are generally made by the player, but the system might intervene with a prompt if the player takes too long to perform. Finally, the decision to do overlearning is generally under system control, along with the criterion for speed of performance.

4.3.3 Strategies for causal understanding

Strategies for teaching and assessing this kind of learning also include primary, secondary, and control strategies, but in addition they include performance strategies.

Primary strategies. The primary strategies for instruction are related to acquisition and application of the causal relationship(s). Acquisition is promoted by telling the player what the causal relationships are (*generality*) and showing the player what they are (*demonstration*). Application is promoted by providing opportunities for the player to use the causal relationships (*practice*), with immediate *feedback*. The primary strategy for assessment is unaided practice to a criterion for mastery.

Secondary strategies. The generality can be either expository or confirmatory (discovery), but either way, a prototypical demonstration of the causal relationship should be provided. The demonstrations can be either passive or active (involving exploration or manipulation of either the causes or the effects). The immediate feedback can be either natural or artificial; it can be simply confirmatory, provide a hint, or provide a full-blown explanation; and it can be informational and/or motivational. The generality, demonstrations, and feedback can have attention-focusing devices and alternative representations. The demonstrations and practice can be in an easy-to-difficult sequence or not, depending on the difficulty of the causal understanding. The practice may also require overlearning for automaticity.

Performance strategies. The basic elements of causal understanding are causes and effects, often in chains and with multiple causes and multiple effects, making for complex causal models. These causal models can be used in three different ways – explanation, prediction, and solution – meaning that the kind of performance shown in the demonstrations and required in the practice can be any of those three types of performance. For *explanation*, an effect is given and the player is asked to explain what caused it. For *prediction*, a causal event is given and the player is asked to predict what will happen as a result. For *solution*, a desired effect (goal) is given, and the player is asked to implement the necessary causes to bring it about. The kind(s) of performance used in the demonstrations and practice should be consistent with those required by the game and the subsequent real-world task. One other aspect of using causal understanding to perform a task is that it requires learning a *performance routine* or strategy for doing that kind of performance using the causal understanding. The performance routine is typically more heuristic than procedural. This performance routine should be explicitly taught using a generality, demonstrations, and practice with feedback.

Control strategies. The system typically decides on the type(s) of performance to be taught, based on the real-world task. Depending on the difficulty of the performance routine, after it is introduced to the player (with generality and demonstration) under system control, it is often placed under player control for further access when needed, but wrong-answer feedback typically includes the performance routine under system control. Since deep understanding is particularly important for causal understanding, the decision to use the discovery form of the generality is typically under system control (universal), as is the decision to use active rather than passive demonstration (manipulation or exploration). In contrast, the decision as to whether and when to see the generality, demonstrations, and practice are typically under player control. Attention-focusing and alternative representations are often under system control (universal) at first, then placed under player control. Difficulty level is under system control by default (adapted to player performance), but the player may also request items of a different difficulty level. Finally, the decision to do overlearning is generally under system control, along with the criterion for speed of performance, to match real-world needs.

4.3.4 Strategies for process understanding

Strategies for teaching and assessing this kind of learning also include primary, secondary, performance, and control strategies, and they are very similar to those for causal understanding. Therefore, the following focuses on the differences.

Performance strategies. The basic element of process understanding is a natural sequence of events. Sequences performed by humans are not included, for they are a kind of skill. An example is the phases in the life cycle of a flowering plant: a seed sprouts into a seedling, a seedling grows into a mature plant, the mature plant develops a flower, and the flower forms seeds. The kind of performance shown in the demonstrations and required in the practice is *description*, which entails describing the events and their sequence. Such descriptions may include the entire natural process, or they may be as small as describing what immediately preceded or follows a given event (phase) in the process. The kind(s) of performance used in the demonstrations and practice should be consistent with those required by the game and the subsequent real-world task. A *performance routine* is often important for using this kind of understanding in the performance of an episode of the task and may therefore also need to be explicitly taught using a generality, demonstrations, and practice with feedback.

Primary strategies. The primary strategies for instruction are to tell the player what the events in the natural process are (*generality*), show the player what they are (*demonstration*), and provide opportunities for the player to use the natural process (*practice*), with immediate *feedback*. The primary strategy for assessment is unaided practice until a criterion for mastery is reached.

Secondary strategies. These strategies are the same as for causal understanding, except that the need for overlearning is less common.

Control strategies. These strategies are also the same as for causal understanding.

4.3.5 Strategies for conceptual understanding

Strategies for teaching and assessing this kind of learning also include primary, secondary, and control strategies, but they are heavily influenced by the desired dimensions of understanding (or conceptual relationships).

Dimensions of understanding. Conceptual understanding is primarily a matter of understanding the relationships among concepts. Different kinds of relationships constitute different dimensions of understanding. The major types of relationships include: superordinate, coordinate, and subordinate (in which the concepts may be either parts or kinds of each other), analogical, and experiential. Many other types exist but are less common. The types of relationships (dimensions of understanding) taught in the instruction should be consistent with those required by the game and the subsequent real-world task.

Primary strategies. The primary strategies for instruction are to portray the relationship (*description*) and to provide opportunities for the player to use the conceptual relationship (*application*), with immediate *feedback*. Demonstrations or examples do not exist as they do for skills, causal understanding, and process understanding. The primary strategy for assessment is unaided application until a criterion for mastery is reached. Different kinds of relationships require different kinds of descriptions and applications. The primary strategy for the superordinate relationship is *context* for a concept. For example, one dimension of understanding the concept "atom" is understanding that it is a component of all matter (the parts-superordinate relationship). The primary strategy for the coordinate relationship is *comparison and contrast* with its coordinate concepts. For example, one dimension of understanding the concept "revolutionary war" is understanding how it is similar to and different from a civil war (the kinds-coordinate relationship). The primary strategy for the subordinate relationship is *analysis* of that concept's parts or kinds. For example, one dimension of understanding the concept "F-16 airplane" is analyzing its major parts (e.g., weapon system, propulsion system, navigation system). The primary strategy for the analogical relationship is *analogy*, which entails identifying similarities between the concept and a similar concept outside of the area of interest, along with the limitations of the analogy (differences between the two concepts). For example, one dimension of understanding the concept "electrical resistor" is learning about its similarities to a valve or faucet in a water system. The primary strategy for the experiential relationship is *instantiation* of the concept – providing a concrete instance of it. This is perhaps the most fundamental of all dimensions of understanding, for it alone can prevent circularity of definitions. All the other relationships are among generalities or definitions of the concepts. This alone taps into one's experiential database to provide the most basic understanding. In cases where the player has no preexisting experience with instances of a concept, it is necessary to introduce such experience. Otherwise, it is only necessary to relate the concept to the player's prior experience. Both are forms of instantiation. These are perhaps the most common dimensions of understanding, but they are by no means all of them. The important point is that each dimension of conceptual understanding (or type of relationship between concepts) requires a different primary instructional strategy, and that strategy can entail description and/or application (e.g., describe an analogy to the player or have the player describe the analogy).

Secondary strategies. The description can be either expository or confirmatory (discovery through applications). The application can be for a single dimension or for the entire spectrum of understanding desired and can be separate or integrated into a task. The immediate feedback can be simply confirmatory, provide a hint, or provide a full-blown paraphrased description; and it can be informational and/or motivational. The descriptions and feedback can have attention-focusing devices and alternative representations.

Control strategies. The system typically decides on the dimension(s) of understanding to be taught, based on the real-world task. The decision on whether or not to use the discovery form of the generality is typically under system control (universal), depending on the difficulty and importance of the understanding. When the discovery form is used, the retention rate is typically better, though time-to-mastery tends to be a bit longer. In contrast, the decision to see the generality again is typically under player control. Attention-focusing and alternative representations are often under system control (universal) at first, then placed under player control. The number of applications is system controlled, depending on the criterion for proficiency.

4.3.6 Strategies for attitudes and values

Strategies for teaching and assessing this kind of learning also include primary and secondary strategies, but not control strategies.

Primary strategies. Attitudes and values have three major components: cognitive, affective, and psychomotor (or behavioral). Each requires a different primary strategy. The cognitive component requires *persuasion* through cognitive reasoning. The affective component requires *operant conditioning* to develop positive feelings about the attitude or values. This can be done vicariously through social modeling, such as observing a person with whom one can easily empathize in a film. The psychomotor component requires *demonstrations and practice with feedback* to develop the appropriate behaviors.

Secondary strategies. Since attitudes and values typically exist on a continuum, all three components should be moved to a new position on the continuum as close to simultaneously as possible, where it should be consolidated before making another move along the continuum. This process continues until the desired point on the continuum is reached.

For each of these types of learning that is needed for the player to succeed in the present or upcoming episode of the game, certification of proficiency is required before the player is allowed back into the game. Test of proficiency is fully integrated with the instruction, so that the practice or application also serves as assessment. Accuracy is the primary criterion for all kinds of learning, and it is typically measured as *x* performances correct in a row, or *x* out of the last *y* performances correct. For kinds of learning that should be automatized, the certification also depends on reaching a criterion for speed of performance, such as sufficient speed for *x* performances in a row or for *x* of the last *y*. Alternatively, the player could be given another task that requires strategic thinking while having to perform the automatized task, but speed of performance is still a factor.

Time is then unfrozen in the game, and the player uses the KSAs just acquired to perform the next episode of the game. If it is a multi-player game, then the player may have to wait for the other players to finish their certifications.

Section 5
Gaps in our Knowledge

In this section, we identify some gaps in our knowledge that prevent us from realizing the vision of game-based training offered in this report, and we provide recommendations for addressing those gaps.

The biggest gaps in knowledge relate to the design specifications for a system of technological tools for realizing this vision of the use of serious games in Air Force training. Therefore, the most important recommendation is to develop and continually improve a fully integrated system of tools for 1) the learning and assessment environment, 2) the development and evaluation environment, and 3) the management and security environment.

We propose that the best use of research funds will be to develop such a fully integrated system of tools and continuously conduct design-based research on that system. The reasons are that:

a) it will provide an authentic environment for conducting research,
b) it will improve practice simultaneously with knowledge about that practice,
c) it will focus on research-to-improve rather than research-to-prove (providing a much higher ROI), and
d) it will allow research and development of an entirely different approach to assessing ROI, one that allows the "investments" to be on a much smaller, more fine-grained level, as opposed to the current approach which essentially entails replacing one large training system with another at great expense and great difficulty in estimating "returns" in advance of the investments.

Therefore, the highest research priority is the design and development of a prototype that meets the specifications presented in Sections 2-4 of this report. During the proposed project, we suggest that it is important to address the following research questions for the design of the learning and assessment environment, the development and evaluation environment, and the management and security environment.

Learning and Assessment Environment

What kinds of pre- and post-game experiences will be most helpful for the players?

- How should the game be introduced?
- How should the players be debriefed after the game?

How should the players be able to collaborate in the game from different computers?

- What forms of communication should the system support?

How should the scaffolding be integrated with the game?

- What should happen if some players on a team are ready to return to the game before others?

What should the system architecture be to plug the games and scaffolding into?

- Modular, interoperable, APIs, customizable, open resource, open source?
- To what extent is the architecture used by BrainHoney the most promising existing one?

How should gameplay data related to learning and performance be captured, stored, and analyzed?

Development and Evaluation Environment

How should tools be designed to facilitate game design and development?
How should tools be designed to facilitate instructional-overlay design and development?
How should tools be designed to facilitate formative evaluation and improvement of the games and scaffolding?

- How should ROI be assessed on each small improvement identified in the formative evaluation?

What should the system architecture be to plug these tools into?

Management and Security Environment

How should tools be designed to keep track of what competencies each player has mastered?
How should tools be designed to help plan what game each airman should play next?
How should tools be designed to help ensure security of confidential information on each player?
What should the system architecture be to plug these tools into?

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