The Deteriorating Patient Smartphone App: Towards Serious Game Design

Chapter · January 2016

DOI: 10.1007/978-3-319-08275-2_11

Jeffrey Wiseman
McGill University

Susanne P. Lajoie
McGill University

Chapter 11
The Deteriorating Patient Smartphone App: Towards Serious Game Design

Jeffrey Wiseman, Emmanuel G. Blanchard, and Susanne Lajoie

11.1 Introduction

Hospitals are dangerous and scary places for both patients and health professions learners: Only 18 % of hospitalized patients suffering an unmonitored cardiac arrest survive (Morrison, 2013). Of these patients 60 % show deteriorating vital signs (blood pressure, pulse, respiratory rate, oxygen saturation, level of consciousness, and temperature) for hours to days before the final cardiac arrest (Hillman, 2001; Kause, 2004). Medical students entering their first year of postgraduate training feel unprepared to care for these patients when on call (Labelle, 2012; Smith, 2007). ACLS (Advanced Cardiac Life Support) courses (Morrison, 2013) teach how to resuscitate a patient in cardiac arrest; however, there are few published teaching interventions that focus on the recognition of and response to an acutely deteriorating hospital ward patient *before* a cardiac arrest occurs (Featherstone, 2005).

In this chapter we will summarize current expert frameworks aimed at guiding a clinician's approach to a deteriorating patient situation. We will then describe teaching approaches based on these frameworks. Then we will show how one of these teaching approaches, the Deteriorating Patient Activity (DPA), led to the iterative design of a family of educational technologies. We will describe the latest member of this family, the Deteriorating Patient smartphone app (DPApp), a serious game

J. Wiseman (✉)
McGill University Faculty of Medicine, McGill Centre for Medical Education, Montreal, QC, Canada
e-mail: jeffrey.wiseman@mcgill.ca

E.G. Blanchard
IDÛ Interactive, Inc. Montreal, QC, Canada

S. Lajoie
McGill University Faculty of Education, Department of Educational and Counselling Psychology Montreal, QC, Canada

S. Bridges et al. (eds.), *Educational Technologies in Medical and Health Sciences Education*, Advances in Medical Education 5,
DOI 10.1007/978-3-319-08275-2_11

(SG) designed to support learners' deliberate practice with feedback using smartphone-based deteriorating patient virtual cases. We will present a model of medical SG design that incorporates current literature as well as the new concepts we used in designing the DPApp. Finally, we will illustrate this medical SG design model by presenting some preliminary user feedback on the design of the DPApp graphic user interface.

11.2 Conceptual Frameworks and Educational Methods

Current teaching emphasizes a two-step general approach to a deteriorating (aka unstable or critically ill) patient, known as the primary and secondary surveys (Fisher, 2003; Frost, 2012; Mackenzie & Sutcliffe, 2002; Mohammad, 2014; Neumar, 2010) (Fig. 11.1), which describe a series of actions doctors must take in response to a given patient health state.

During the primary survey, healthcare workers use algorithms as organizing frameworks to prioritize information-gathering and treatment manoeuvres to rapidly detect and treat conditions that can kill a patient in 5–15 min. During the secondary survey, healthcare workers use a slower analytic approach to clinical problem solving (Eva, 2005; Sklar, 2014) that features information-gathering (history-taking, physical examination, choice of additional laboratory and radiology tests) and treatment decisions focused on resolving acute issues. Undergraduate medical students learn and practice even slower complete patient evaluations on patients admitted to wards in stable condition after more experienced physicians have performed primary and secondary surveys when the patient was sicker in the emergency room. The two-way arrows in Fig. 11.1 emphasize that patient states can suddenly and unpredictably change from "stable" to "deteriorating": A stable ward patient can develop a complication or new illness. As a result, undergraduates unfamiliar with primary and secondary surveys mistakenly use a complete data collection approach to critically ill deteriorating ward patients who need a primary survey to quickly recognize and address immediate life threats.

Patients who are critically ill (either already in cardiac arrest or in the process of deteriorating towards an eventual cardiac arrest) present in one of two ways: the patient who is unarousable (no response to voice, touch or pain) and the patient who is arousable (responds to voice, touch, or pain). The unarousable patient is easy to recognize as critically ill and the priority for this situation is to rapidly diagnose and manage the patient who is unarousable because of a cardiac arrest. The arousable patient situation carries different dangers; such patients may not appear to be critically ill to inexperienced healthcare learners who may skip the primary assessment and attempt the more familiar but slow analytic approach of history-taking, thorough physical examination and laboratory/radiology testing that they learned in the first few years of undergraduate medical education on stable patients.

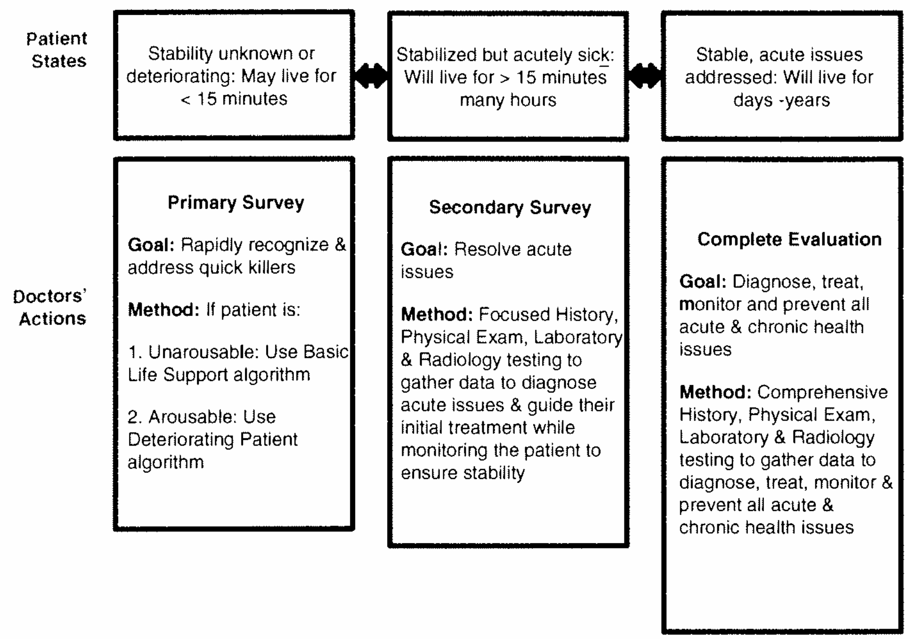

Fig. 11.1 General approach to emergencies: the primary and secondary surveys

There are two overlapping primary survey algorithms used for unarousable adult patients in current teaching:

1. The Basic Life Support (BLS) algorithm (Berg, 2010) described in the top half of Table 11.1 is taught to all undergraduate health learners. It emphasizes rapid recognition of the unarousable patient *in* cardiac arrest and rapid delivery of an electric shock to the heart via electrodes placed on a patient's chest as an emergency treatment to correct the commonest reversible mechanism of a cardiac arrest (also referred to as cardio version).

   The ACLS algorithm (Neumar, 2010) is taught to postgraduate medical learners (junior doctors or residents) and emphasizes advanced drug therapy and cardiac procedures for a patient *in* cardiac arrest who is concomitantly receiving proper BLS. This algorithm is not illustrated here, as it is irrelevant to undergraduate students who cannot yet prescribe advanced drug therapy and cardiac procedures but who can and do provide BLS.

Thus none of the commonly taught Primary Survey algorithms refer to deteriorating ward patient situations *before* a cardiac arrest occurs and only the BLS algorithm is taught at the undergraduate medical student level.

Table 11.1 Algorithms used to guide the primary survey for critically ill patients

If patient is unarousable:	
Basic life support algorithm	Sample data to collect and act on
A: Arousability	Tap patient and shout: "Are you all right"?
B: Breathing	Check to see if the patient is breathing by observing the chest for 5–10 s
C: Carotid pulse CPR Call for help Cardio version ASAP	Carotid pulse: Check for 5–10 s. If no carotid pulse, start CPR: Chest compressions to 2″ depth allowing full recoil at 100/min. Give two breaths by bag and mask for every 30 chest compressions Call for help/activate the emergency response team Use an automatic external defibrillator if one is available or as soon as the emergency response team arrives with one.
If patient is arousable	
Deteriorating patient algorithm	Sample data to collect and act on
A: Airway	Level of consciousness, able to talk, inspiratory wheezing, facial swelling
B: Breathing	Oxygen saturation, respiratory rate, chest movements, tracheal position, lung sounds
C: Circulation Central nervous system Cervical spine	Carotid pulse, blood pressure, heart rate, jugular venous pressure, ECG, bleeding Level of consciousness, pupils, best motor response If trauma context protect until scanned
D: Drugs	Drug bracelets, prescription records, friends, family, and witnesses
E: Electrolytes and endocrine	Serum potassium, calcium, phosphorus, magnesium, bicarbonate, blood gases
F: Fever	Core temperature
G: Glucose	Blood or capillary glucose

11.3 The Deteriorating Patient Activity Simulations

High-fidelity simulations can effectively teach students how to use a primary survey to recognize and stabilize a critically ill patient. However, they are expensive, complicated to set up, often demand that learners take the time to leave the clinical setting to go to a simulation laboratory, can only teach a few learners at a time, and afford limited opportunities for the deliberate practice with feedback which is so important to the development of expertise (Ericsson, 2008).

The DPA is an inexpensive, logistically simple and rapidly deployable family of low-fidelity simulations whose objective is to help students learn how to gain control of unstable clinical scenarios by using a primary survey algorithm developed to specifically address the deteriorating patient before a cardiac arrest occurs. This "ABCDEFG" algorithm, described in the lower half of Table 11.1, consists of a

series of rapid high-priority data gathering actions that are appropriate to undergraduate medical student level and urgent patient management options that are appropriate to postgraduate level but which undergraduate medical students need to understand.

In the original live small group variant of the DPA, the DPAlive (Wiseman & Snell, 2008), the learner takes on the role of "doctor on call" summoned at night to manage a deteriorating ward patient. Students must use the ABCDEFG algorithm to decide what steps to take in treating or stabilizing the situation. Students must know when and who to call for help and how to do an effective "hand-over" (World Health Organization Collaborating Center for Patient Safety Solutions, 2007) defined as communication of essential patient information to more senior colleagues when they arrive at the scene. The tutor takes on and moves between the roles of "patient" with deteriorating clinical signs, "vital sign and event recorder" and "nurse." The DPAlive learning objectives are shown in Table 11.2.

Clinical teachers from various healthcare professions can readily learn how to teach using a DPAlive (McGillion, 2011; Wiseman, 2007) using a simple teaching script (Fig. 11.2). The tutor controls how the situation evolves over time in response to the student's actions or inactions by changing the "patient's" "vital signs," "symptoms" or "physical findings." For example, the clinical teacher can choose to portray the role of a patient screaming in delirium or moaning in pain to further develop learners' skills at following the ABCDEFG's under duress. Alternatively, faced with a floundering or emotionally overwrought student the tutor can choose to provide hints or positive emotional stimuli in the form of encouragement or slowing down the "patient deterioration" or prompt the student to ask for help and consult a supervisor. In the debrief phase, the tutor uses recorded vital signs and events on a

Table 11.2 Deteriorating patient activity learning objectives

Learners completing these learning activities will, with appropriate supervision, be able to:
1. Apply an approach to recognize and stabilize common issues in acutely ill hospitalized patients. This approach includes using the ABCDEFG algorithm to
(a) Screen for and prioritize rapidly fatal but treatable medical conditions when caring for or called to see any hospitalized patient
(b) Recognize the vital sign and clinical patterns that are early harbingers of avoidable cardiac arrest and/or intensive care unit transfer
(c) Simultaneously diagnose, treat, and monitor an acutely ill patient
(d) Use observed changes (deterioration and improvement) in a patient's status as information to modify emergency diagnostic hypotheses and management strategies
(e) Recheck priorities when uncertain what is going on with a sick patient
2. Provide orders for the basic initial management of emergencies commonly encountered in hospitalized patients
3. Call for appropriate help in a timely fashion and apply the above approach while waiting for help to arrive
4. Communicate an appropriate hand-over of an acutely ill patient to another care team member
5. Describe and address the common patient safety events that lead to avoidable intensive care unit admission and death

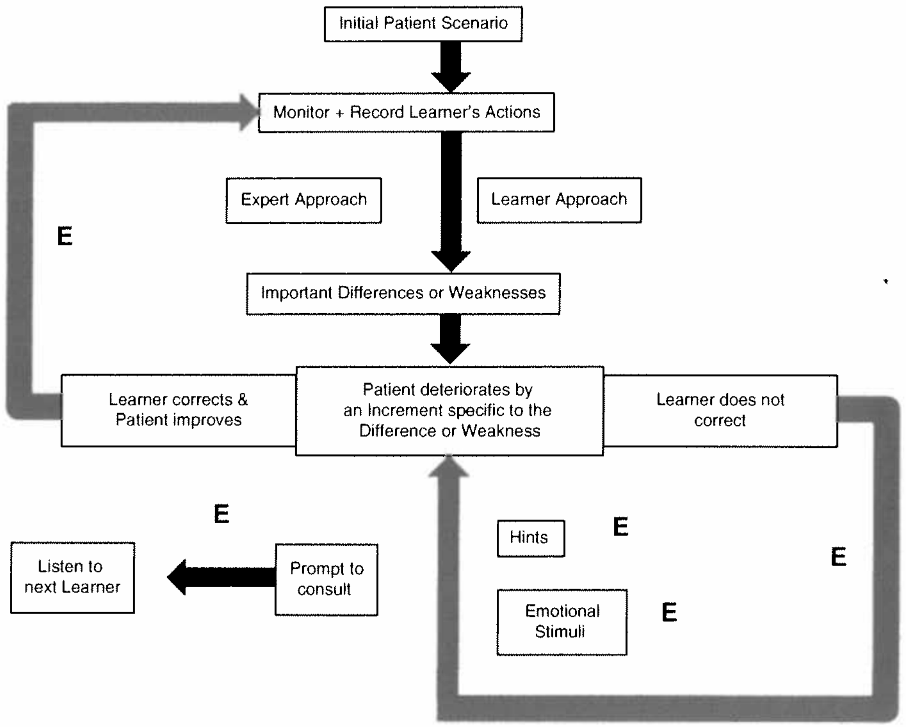

Fig. 11.2 DPAlive teaching script

whiteboard to support students' recall and reflections on their thoughts, decisions, and emotions during the scenario.

Steps marked by an E for "Emotions" in Fig. 11.2 represent points in the case where teachers can greatly increase or decrease learners' stress for optimal realism and learning. This manipulation of student stress levels is supported by studies of the variable effects of amount and types of stress on learning in rodents (Salehi, 2010) and in humans in nonmedical (Smeets, 2009) and medical domains (Leblanc, 2009). A major advantage of the DPAlive is the speed with which medical educators can use their "mental database of cases" (Eva, 2004) to rapidly generate additional DPAlive cases that can focus on learners' weaknesses and provide a range of cases over different contexts. Drawbacks of the DPAlive are that teachers must be physically present to provide students with deliberate practice with feedback and it is difficult for one tutor to manage a group of more than a few learners at a time.

Learners attempting to solve DPAlive cases who were given electronic prompts to refer to the ABCDEFG algorithm and collaboratively discuss their DPAlive case solutions using networked electronic whiteboards performed better on the DPAlive than those that did not (Lu, 2010). This study and extensive (unpublished) tutor

experience with the DPAlive showed that learners commonly found the ABCDEFG algorithm simple to memorize but not simple to apply during DPAlive scenarios because:

1. Learners had difficulty understanding that a patient's vital signs as they evolve over time provide not only diagnostic hints for quick killers but also feedback on a doctor's or a healthcare team's performance.
2. The ABCDEFG algorithm must be used stepwise in only one direction—always starting with "A" then proceeding in order to F because initial disease presentations can be misleading. One must repeat the ABCDEFG algorithm recursively until the patient's vital signs have stabilized or normalized. Many learners do not recycle the ABCDEFG algorithm if vital signs deteriorate again and instead attempt the much slower processes of analytic reasoning.
3. Learners' emotional responses to the stress of emergencies when immediate help and resources are unavailable add to their extrinsic and germane cognitive loads (Fraser, 2012; Young, 2014) and interfere with their ability to apply a Primary Survey recursively.
4. Many learners do not use changes in vital signs over time as feedback that the patient will soon die and delay calling for help. Where they do seek assistance, as more healthcare workers arrive to help, the learner must then change from working individually to integrating staff into a growing and changing interprofessional team. Learners need to be able to integrate information from the ABCDEFG process into their communication of essential information or hand-offs to other team members (Cohen, 2012).
5. Learners confound the BLS algorithm with the DPA ABCDEFG algorithm.

These observations led to the development of a more explicit DPA expert mental model aimed at guiding learners to use the ABCDEFG algorithm recursively and showing how the ABCDEFG approach relates to the cardiac arrest BLS algorithm (Fig. 11.3). The vital signs are an important part of the high-priority data to collect and act on in the BLS and ABCDEFG algorithms. For instance, both the BLS and ABCDEFG algorithms mandate determination and monitoring of the patient's level of alertness and consciousness. As can be seen in Table 11.1 both the BLS and ABCDEFG algorithms prioritize respiratory rate and carotid pulse or heart rate.

A *web-based DPA* (Blanchard, 2012a, 2012b) (DPAweb) was created as an online deteriorating patient that learners could repeat as often as needed. One of the authors, a senior medical educator, acted out the patient role in a sequence of short videos that formed the online patient representation. Interestingly, learners in informal conversations with the case designers even years later have spontaneously described feeling "scared" at having to treat a "patient" whom they personally knew. These emotional reactions to technology have been predicted by the media equation theory which hypothesizes that users respond socially and emotionally to technology it as if it were "real life" (Reeves & Nass, 1996) especially when prompt reactions are stimulated (Lee, 2008). Other learners commented on how much the DPAweb resembled a video game and wanted to know how well they performed compared to others and when more cases were coming out. This is not surprising

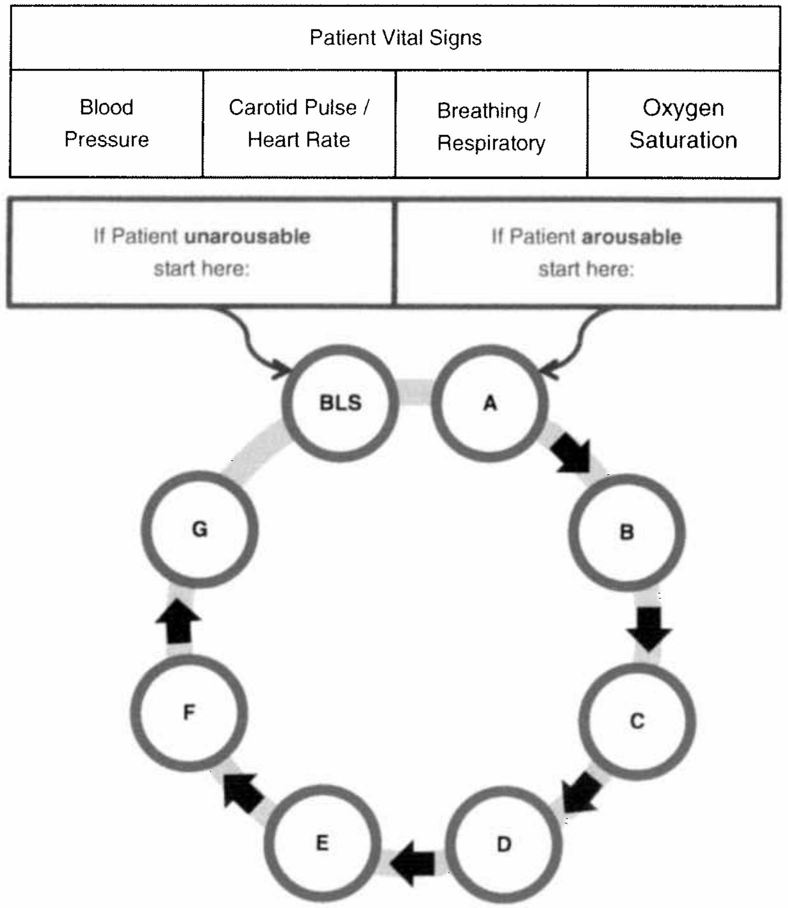

Fig. 11.3 Actions in the BLS + ABCDEFG algorithms must be applied recursively until patient vital signs are normal

considering the current generation of medical students, most of whom are fluent in the use of social media and many of whom play or are open to playing digital games (Kron, Gjerde, Sen, & Fetters, 2010). The DPAweb pilot demonstrated that it is possible to create a technology-based delivery mechanism for the DPA that is as engaging and challenging to learners as the DPAlive and could support deliberate practice without a live tutor present. Neither the DPAlive nor the DPAweb versions of the DPA resolved the problems of providing large groups of learners with:

1. Many different DPA cases of varying level of difficulty.
2. Feedback during the run phase and the debriefing phase of the simulation to that is sensitive to learners' emotions and cognitive levels and that is not dependent upon the synchronous presence of a live tutor.

11.4 What Is a Serious Game?

Games are activities with rules

> in which a player works, through interaction with an environment towards a goal. In the process, a player conquers challenges in an attempt to achieve the specified goal without any certainty that it will be attained (de Ribaupierre, 2014, p. 18).

The game environment, also referred to as the "game space," can take on varying representations such as decks of cards, boards, a playing field and computer-based videos (Blanchard, 2012a, 2012b). *Simulations* are "simplified, dynamic and accurate models of reality" (Sauve, 2011). When a game incorporates models of reality into its design, it becomes a *Simulation Game* (Sauve, 2011), with some authors reserving the use of the word "game" for activities that feature competition, rewards and rules (Akl, 2010). *Gamification* is a careful and considered application of game-based mechanics, aesthetics and game thinking to promote learning, engage people and motivate action through problem solving using all the elements of games that are appropriate (Kapp, 2012).

A *Serious Game* (*SG*) is a "gamified experience" (Kapp, 2012) using some type of interactive technology or tool that was designed with education as its primary goal and with engagement and entertainment as secondary goals (Gee et al., 2014).

The *attributes of a good game* are seen as analogous to the *attributes of good instruction* (Gee, 2007; McLuhan, Fiore, & Agel, 1967) and include:

- Compelling and relevant stories or problems
- Clear rules and goals
- Feedback
- An interactive learning environment
- Challenge such that "each level dances around the outer limits of a player's abilities, seeking at every point to be just doable" (Shute, Rieber, & Van Eck, 2011)
- Support or scaffolding adapted to players' zones of proximal development (Vygotsky, 1978)
- Player control over the game experience
- Uncertainty as to the eventual outcome
- Use of multiple sensory modalities

Similarly the steps involved in designing good games and good instruction are highly analogous: *Game design* consists of iterative cycles of planning, prototyping, play testing, evaluation and refinement "because the play of a game will always surprise its creators" (Salen Tekinbas & Zimmerman, 2003). *Instructional design* commonly follows the iterative (Hirumi & Stapleton, 2008) phases of the "ADDIE" generic instructional design model (Branch, 2014) consisting of analysis, design, development, implementation and evaluation. Both instructional and game design worlds use simple, incomplete but rapidly deployable and testable versions of an educational intervention (or game) offered to learners (or game players) with the express purpose of garnering their feedback to inform subsequent improved versions of the educational intervention or game.

A review of SGs in largely nonmedical educational contexts (Romero, 2014) identified good SG attributes that overlap with the above list but emphasized support of learner debrief and collaboration as the most important SG attributes and fidelity and fantasy as the least important SG attributes. The scenario or case-based subtype of SGs (Westera, Nadolski, Hummel, & Wopereis, 2008) are particularly well aligned with the case-based tradition of medical practice and education. Desirable attributes of a case-based SG include:

- A game environment that mimics the ambiguity and conflicting information of real-world environments.
- Learning activities demanding complex problem solving and adoption of professional roles and social relationships.
- Use of expert strategies as a reference to control complexity and to generate relevant feedback during the game (Westera et al., 2008).

From a medical instructional design perspective (Amundsen, 2004; Kern, 1998), one would add to Westera's attributes the degree to which a case-based SG:

- Is aligned (Biggs, 1996) with elements of the educational and professional practice systems it is intended to serve
- Serves an educational function that cannot be met by simpler, cheaper and more readily available educational approaches
- Can be adjusted to learner level and in response to learner and teacher feedback
- Supports formative and summative assessment of learners
- Supports the development of teaching expertise
- Supports the development of learners' and teachers' educational communities of practice (Wenger, 1998)

Systematic reviews of the literature on the effectiveness of SG's in medical education for knowledge outcomes are inconclusive. Few studies included any kind of outcome evaluation or controls for the gaming intervention for either medical student's knowledge (Akl, 2010) or for postgraduate health professionals' patient outcomes or care processes (Akl, 2013).

11.5 Medical Serious Game Design

Djaouti's (2011a, 2011b) extensive review of multiple game design approaches found no dominant framework to guide the design of a SG. Like many other authors, he emphasized the importance of alignment of educational theory, instructional design and game design to the effectiveness of a SG but offered no practical guidance on exactly how to go about doing this.

Westera et al.'s (2008) case-based SG design framework simplifies gaming design language by recommending that educators consider three game technology elements:

1. Game space: This contains components like game locations, ways of navigating between different locations as well as game objects, which could be tools, knowledge resources or other live or virtual subjects. All of these elements would create an initial case representation whose narrative would then emerge or be further elaborated in response to the actions of the learner or other subjects.
2. Game dynamics: This consists of game states, a description of the game space at a given point in time during the game and the game logic or "If: Then" rules that govern whether and how game states evolve either in response to players' different actions or autonomously.
3. Game complexity. There are three ways of managing the complexity of the SG design that are highly relevant to educational designers:
   (a) Structure design: Because of the sequential nature of case-based SGs, one can simplify SG structures yet maintain the complex realism of gameplay by providing players with a wider number of simultaneous options (trees with more leaves relative to branches) rather than a deeper chain of sequential options (trees with more branches relative to leaves).
   (b) Feedback design: It is simpler and more effective to give players an overall sense of how they are doing and how they can improve rather than giving microfeedback on every step or action they take during the SG.
   (c) Representation design: Authentic content is far more important to an SG than beautiful graphics. In SGs it is the educational case itself that should stimulate tension and engagement.

Arnab et al.'s (2014) Learning Mechanics-Game Mechanics (LM-GM) SG model proposes analyzing the pedagogical potential of a SG by mapping its general learning mechanisms (LMs) onto its general game mechanisms (GMs) in an attempt to identify Serious Game Mechanisms (SGMs). According to Arnab et al. an SGM is defined as:

> the design decision that concretely realizes the transition of a learning practice/goal into a mechanical element of gameplay for the sole purpose of play and fun. SGM's act as the game elements /aspects linking pedagogical practices (represented through learning mechanics) to concrete game mechanics directly linked to a player's actions (p. 3).

The LM-GM model has the advantage of explicitly identifying the points in an SG where gameplay and pedagogy "intertwine" as SGM's but the disadvantage of not being able to describe how to prospectively design a SG using SGM's.

Lim et al. (2014) further developed the notion of SGMs for SG design by arguing that the narratives SG players encounter, create and share should have a central role in SG game design. Again, this fits well with medical education's tradition of case-based learning (Thistlethwaite, 2012) and practice. However, these authors did not define what they mean by "pedagogical outcomes." Such an unelaborated term might suggest that a SGM's only educational effect would be on learning outcomes to the exclusion of effects on evaluation, feedback, contexts or other elements of an educational system.

There are even fewer frameworks to guide the design of smartphone-based SGs. The "M-COPE" framework for mobile learning (Dennen, 2014) prompts designers to consider issues such as the added value of using mobile technology (M); the environmental conditions (C) that may affect learners' use of mobile technology; the intended and unintended learning outcomes (O) from mobile technology use; the pedagogical theory (P) justifying and matched to the use of mobile technology and the ethics (E) of mobile technology use.

In summary, an effective narrative SG (NSG) is the result of a judicious combination of design approaches from diverse disciplines. However, from a medical education perspective, we next argue that there is one final design component to consider before settling on a final model of NSG design, emotion.

11.6 The Role of Emotions in Narrative Medical SG Design

The role of emotions in healthcare professionals' education is relatively unexplored (McConnell, 2012). The emotional detachment and objectivity of the rational biomedical model of illness remains a dominant part of medical practice (Nettleton, 2008) especially during emergency situations (Powell, 2014) where emotionally distraught team members can negatively affect the performance of an entire team during medical crises (Piquette, 2009).

Learners' stress during simulated medical crisis scenarios variably affects their learning depending on scenario emotional content, debriefing timing and technique (DeMaria, 2013). Some but not all medical students prefer the challenge of additional emotional elements in standardized patient scenarios for communication skills (Lefroy, 2011). Residents are much more likely to cognitively appraise resuscitation scenarios as a threat rather than as a challenge when they contain scripted emotional stimuli (Harvey, 2010).

Control-value theory (Pekrun & Perry, 2014) predicts how emotions influence learning and can inform NSG design: Medical students experience achievement emotions that depend on their perceptions of the degree of control of scenario outcomes and value to their future practice. Previously experienced achievement emotions can also change learners' perceptions of control and value of future scenarios. NSGs can be designed to positively influence medical learners' perceptions of control and value and their subsequent achievement emotions (Artino, 2012; Graesser & D'Mello, 2014) by ensuring that features include:

1. Task demands appropriate to learners' capabilities
   Flow is a feeling many describe when they are engaged in and totally concentrated on a pleasantly challenging activity that is just within reach of their skills and/or knowledge (Csikszentmihalyi, 1991). The sensation of flow, which is associated with optimal learning, requires a balance between learners' skills and task challenge in order to avoid emotions like boredom (high skill, low challenge) and frustration (low skill, high challenge). This balance can be maintained for learners attempting very difficult challenges by scaffolding them in their zones of proximal development—that is by providing help in the form of hints, feedback and support by live or online tutors or peers (Kiili, Lainemab, de Freitasc, & Arnabc, 2014; Vygotsky, 1978).
2. Authentic cases and thinking activities that are highly relevant to learners' future careers.
3. Case narratives that change in response to users' actions.
4. Timely and explicit feedback.

5. Choice of cases of different levels of difficulty.
6. A learning environment where errors are explicitly seen and treated as learning opportunities.
7. Debriefing that welcomes, normalizes and responds to learners' expressions of emotion and difficulty.

This section has summarized work that would inform the emotional component of NSG design. In the following sections we will describe a model of narrative medical SG (NMSG) design that includes planning for learners' achievement emotions and then show how this model informs the development of the DPApp.

11.7 Model of Narrative Medical SG Design

Based upon the above concepts, an effective approach to NSGM creation would align design elements of instruction, emotions, games and technology around a central core of narrative design over time (Fig. 11.4). Areas where design elements converge either as a "node" at a particular point in the time of the patient narrative or along a period of narrative time as a "weave" will be demonstrated in the following paragraphs. Nodes and weaves represent points where all aspects of SG design work together synergistically.

11.8 The Deteriorating Patient App "Nodes and Weaves"

Table 11.3 shows a "walk through" of one deliberate practice session with the DPApp in relation to the different screen shots (Fig. 11.5) learners would encounter in each phase. In the following paragraphs we will describe how, for each

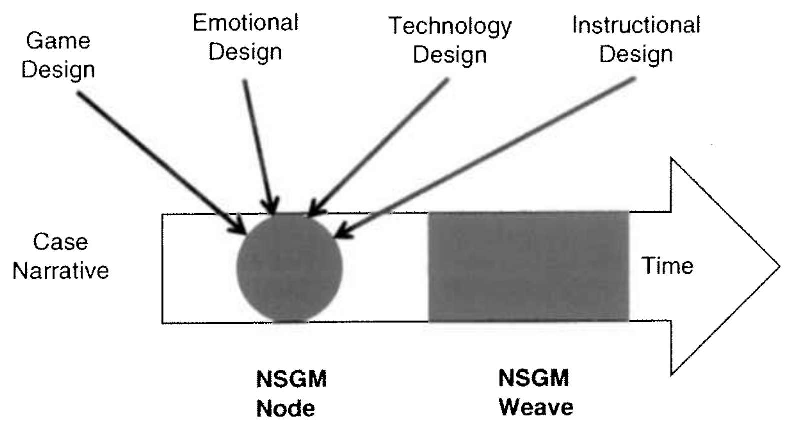

Fig. 11.4 Narrative medical serious game design model showing convergence of multiple design decisions for a given point in time of the case narrative

Table 11.3 Deteriorating patient app (DPApp) walkthrough

Instructional and emotional design elements	Narrative design elements	Game and technology design elements: DPApp smartphone screen views			
Node 1	Orientation	A			
Node 2	Beginning	A	B	C (ABCDEFG prioritized cyclic menu)	C (HxPxLabRadTreatment unprioritized dropdown menu)
Weave 1	Middle	A	B	C	D
Node 3	End/debrief	A	F		

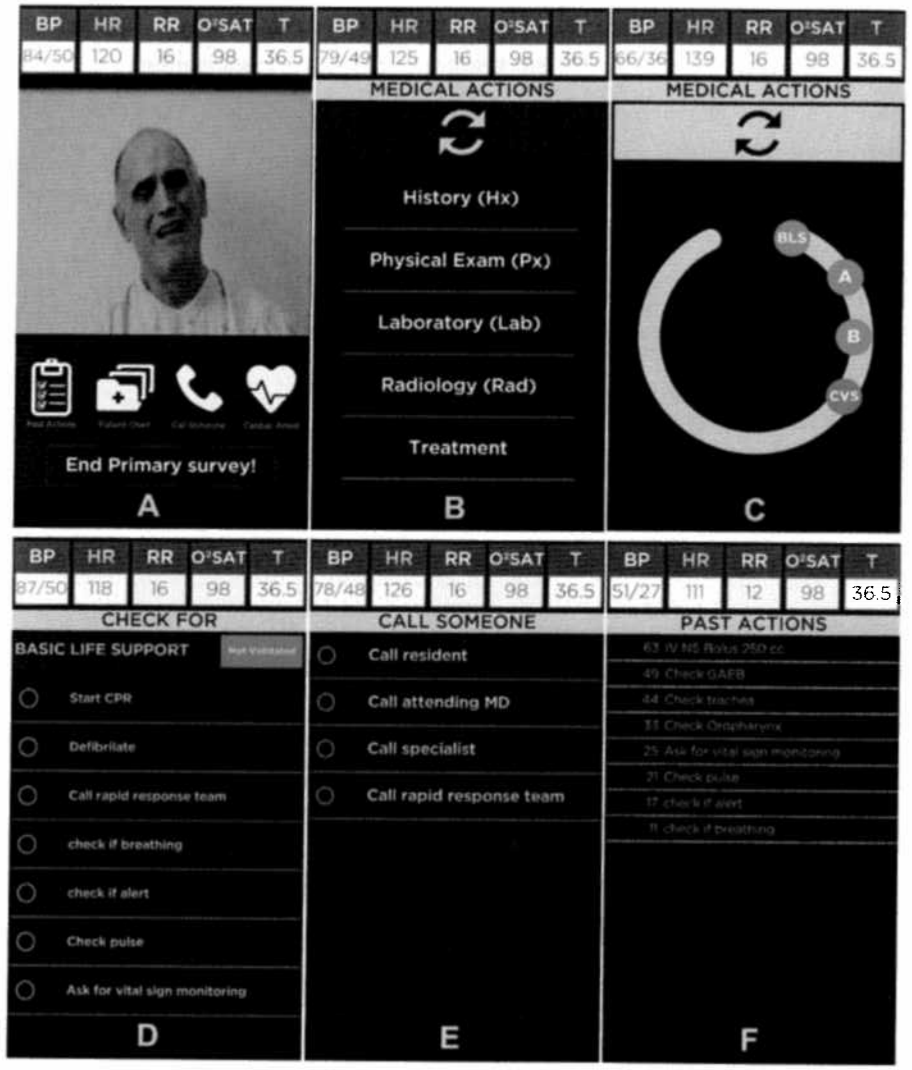

Fig. 11.5 DPApp smartphone screen views

narrative design element, game and technology design elements were created to fit that narrative element as well as work with the instructional and emotional design elements as three nodes and one weave that are embedded within the DPApp case narrative.

11.8.1 Node 1: Orientation

Game/Technology Design Elements: In this phase a live tutor ensures that learners understand the game space, how to toggle between and use different app screen views and input buttons and that each smartphone functions properly.

Instructional and Emotional Design Elements: The orientation minimizes extraneous cognitive load and negative achievement emotions imposed by the DPApp itself. The learning objectives, rules and goals of the DPApp case are identical and thus aligned with those of prior DPAlive sessions.

11.8.2 Node 2: Narrative Beginning

Game/Technology Design Elements: After signing in learners select the case they want to practice on and encounter the initial scenario in the "Patient Chart" section:

> You are called at 2 AM to see Mr. W. a 68 year old male who feels terrible, is confused and is covered with sweat. His initial vital signs are normal. He was admitted 4 days ago for treatment of a community-acquired pneumonia. His past medical history includes atrial fibrillation, hypertension, and diabetes. His current medications include intravenous Ceftriaxone and Doxycycline, oral Diltiazem, Metformin, and Coumadin and subcutaneous Insulin. He has no known allergies.

Learners can then toggle between three different screen views (See screen views A, B, and C in Fig. 11.5).

Screen view A shows the patient's initial vital signs, a looped video of the patient in the initial state and buttons at the bottom of the screen that permit learners to see a record of their Past Actions and Collected Data (taking the learner to screen F), a button to Call Someone for help (taking the learner to screen E) and a button to call a Cardiac Arrest team. As time goes by, the vital signs and patient video change for better or for worse, depending on learners' actions.

Screen view B shows the vital signs and a choice of any of six actions learners can choose: The cyclic ABCDEFG algorithm symbol button (two arrows forming a cycle) and History, Physical examination, Laboratory tests, Radiology tests, and Treatment option buttons respectively from top to bottom. Learners who choose the cyclic ABCDEFG algorithm symbol button are taken to screen view C. Learners who choose the History, Physical Examination, laboratory, or Radiology symbol buttons are taken to drop-down menus (not displayed here) that permit them to choose whatever additional unprioritized data they think is needed.

Screen view C shows the cyclic ABCDEFG algorithm. When learners select a button within screen view C the learner is then taken to another screen view that prompts the learner to choose high-priority data and actions corresponding to that part of the cyclic algorithm. For instance, selecting the "BLS" button takes learners to screen view D. Learners must complete the entire cycle in order—the software will not allow a learner to skip B and go from A to C for instance. Once the algorithm has been completed, learners can go through it again as needed by the patient's status as indicated by the video and/or patient vital signs.

Instructional and Emotional Design Elements: Learners assume a highly desirable future professional "on call" role. This authentic scenario is complex, ambiguous and challenging, as it is initially unclear why this patient with multiple health issues feels terrible and (in the video) looks and acts unwell. Learners are confronted with a realistic situation in which there is a lot of data to gather and decisions to make for a patient who may very well die in the time it takes for more experienced help to arrive.

11.8.3 Weave 1: Narrative Middle

Game/Technology Design Elements: As long as learners search for irrelevant information and prescribe irrelevant treatments, the "if-then" game dynamic makes the patient vital signs progressively worsen over 10 min with simultaneous successive 2 min long patient video loops showing a moaning confused patient who becomes more somnolent and eventually comatose and then suffers a cardiac arrest. Learners who choose relevant treatments will see the vital signs improve and the patient video loop portray a successively more alert and less sick patient. Learners who use the ABCDEFG algorithm will collect relevant information and prescribe relevant treatments much more efficiently than those who do not as the search space for all of the patient data one could collect is huge. Designing a wide choice of options rather than deep chains of sequential options makes the game complex for learners but easier to programme.

Instructional and Emotional Design Elements: The narrative, displayed using multiple sensory modalities and interactively constructed by learners, becomes more compelling and challenging as the patient deteriorates or improves in response to learners' actions, supporting learners' perceptions of control and value and demanding that learners use an expert (ABCDEFG) strategy to manage case complexity or encounter realistic consequences of not using the ABCDEFG strategy. Scaffolding from a live tutor (and from future versions of the DPApp) will keep learners in their zones of proximal development and a state of flow.

11.8.4 Node 3: Narrative End/Debrief

Game/Technology Design Elements: The session ends when the patient "dies" or if learners press the End Primary survey! Button (meaning they think that they have successfully stabilized the patient) in screen view A. At the end of the case the

learner is taken to screen view F which displays a learner's past actions or a plot of time on the vertical axis with patient vital signs and corresponding learner past actions taken on the horizontal axis. This personalized leaderboard helps learners and tutors visualize what was done well or not well and when.

Instructional and Emotional Design Elements: Screen view F presents the data needed to support a live debrief of both learner actions in relation to the ABCDEFG expert framework and learner emotions experienced during the case. Learners discover how easily one can forget to stick to the expert ABCDEFG framework and get lost in minor details when faced with the emotional heat of deteriorating vital signs and an ill-appearing patient.

11.9 Conclusions

The node and weave model of NMSG design portrays the most difficult and time consuming part of SG design, that of making decisions on instructional, emotional, technology and game designs coordinate in explicit subservience to educational goals.

Once the current version of the DPApp performs as designed based on additional user testing we will then be in a position to create additional cases with differing levels of difficulty, a scoring system, adaptive feedback based on learners' commonest errors and difficulties, a case builder for learners and educators to create and try out each others' cases, and an online environment where learners and teachers can debrief their case solutions synchronously or asynchronously.

McLuhan wrote, "Anyone who tries to make a distinction between education and entertainment doesn't know the first thing about either" (McLuhan et al., 1967). If so, then those who know about education—learners and teachers—already know a few things about both. The most effective "playing field" for conceiving and testing an SG is the live teaching environment where it is intended to function.

References

Akl, E. A. (2010). The effect of educational games on medical students learning outcomes: A systematic review: BEME guide no 14. *Medical Teacher, 32*, 16–27.

Akl, E. A. (2013). Educational games for health professionals (review). *Cochrane Database of Systematic Reviews, 3*, 1–49.

Amundsen, C. S. (2004). Analysis of course content. In A. Saroyan & C. Amundsen (Eds.), *Rethinking teaching in higher education: From a course design workshop to a faculty development framework* (pp. 34–51). Sterling, VA: Stylus. Chapter 3.

Arnab, S. L., Lim, T., Carvalho, M. B., Bellotti, F., de Freitas, S., Louchart, S., … De Gloria, A. (2014). Mapping learning and game mechanics for serious games analysis. *British Journal of Educational Technology, 46*(2), 391–411.

Artino, A. R. (2012). Control-value theory: Using achievement emotions to improve understanding of motivation, learning and performance in medical education: AMEE guide no. 64. *Medical Teacher, 34*(3), e148–e160.

Berg, R. A. (2010). Part 5: Adult basic life support: 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care. *Circulation, 122*, S685–S705.

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education, 32*, 347–364.

Blanchard, E. G. (2012). A realistic digital deteriorating patient to foster emergency decision-making skills in medical students. In *IEEE 12th international conference on Advanced Learning Technologies* (pp. 74–76). Rome, Italy: IEEE.

Blanchard, E. G. (2012b). Learning with games. In N. M. Seel (Ed.), *Encyclopedia of the sciences of learning* (pp. 2019–2024). Berlin, Germany: Springer.

Branch, R. M. (2014). Instructional design models. In M. J. Spector (Ed.), *Handbook of research on educational communications and technology* (4th ed., pp. 77–87). New York, NY: Springer.

Cohen, M. D. (2012). A handoff is not a telegram: An understanding of the patient is co-constructed. *Critical Care, 16*(1), 303–309.

Csikszentmihalyi, M. (1991). *Flow: The psychology of optimal experience*. New York, NY: Harper Perennial.

de Ribaupierre, S. K. (2014). Healthcare training enhancement through virtual reality and serious games. In M. E. Ma, L. C. Jain, & P. Anderson (Eds.), *Virtual, augmented reality and serious games for healthcare 1* (pp. 9–27). Berlin, Germany: Springer.

DeMaria, J. S. (2013). The use of stress to enrich the simulated environment. In A. Levine, J. S. DeMaria, A. D. Schwartz, & A. J. Sim (Eds.), *The comprehensive textbook of healthcare simulation* (pp. 65–72). New York, NY: Springer.

Dennen, V. P. (2014). Intentionally mobile pedagogy: The M-COPE framework for mobile learning in higher education. *Technology, Pedagogy and Education, 23*(3), 397–419.

Djaouti, D. A.-P. (2011a). Classifying serious games: The G/P/S model. In P. Felicia (Ed.), *Handbook of research on improving learning and motivation through educational games: Multidisciplinary approaches* (pp. 118–136). Hershey, PA: IGI Global.

Djaouti, D. (2011). *Serious game design: Considerations theoriques et techniques sur la creation de jeux video a vocation utilitaire*. Universite de Toulouse, Mathematiques Informatique Telecommunications. Toulouse, France: Universite Toulouse III Paul Sabatier.

Ericsson, K. A. (2008). Deliberate practice and acquisition of expert performance: A general overview. *Academic Emergency Medicine, 15*, 988–994.

Eva, K. W. (2004). What every teacher needs to know about clinical reasoning. *Medical Education, 39*, 98–106.

Featherstone, P. E. (2005). Impact of a one-day inter-professional course (ALERT) on attitudes and confidence in managing critically ill adult patients. *Resuscitation, 65*(3), 329–336.

Fisher, R. (2003). Traumatology and orthopedics. In M. Dobson (Ed.), *Surgical care at the district hospital* (pp. 16-1–16-8). Geneva, Switzerland: World Health Organization.

Fraser, K. M. (2012). Emotion, cognitive load and learning outcomes during simulation training. *Medical Education, 46*, 1055–1062.

Frost, P. J. (2012). Early management of acutely ill ward patients. *BMJ, 345*, e5677–e5685.

Gee, J. P. (2007). *Good videogames + good learning: Collected essays on videogames, learning and literacy*. New York, NY: Peter Lang.

Gee, D. C., Chu, M. W., Blimke, S., Rockwell, G., Gouglas, S., Holmes, D., & Lucky, S. (2014). Assessing serious games: The GRAND assessment framework. *Digital Studies/Le Champ Numerique, 4*, 1–14.

Graesser, A. C., & D'Mello, S. K. (2014). Emotions in advanced learning technologies. In R.-G. Pekrun & L. Linnenbrink-Garcia (Eds.), *International handbook of emotions and education* (pp. 473–493). New York, NY: Routledge.

Harvey, A. N. (2010). Threat and challenge: Cognitive appraisal and stress responses in simulated trauma resuscitations. *Medical Education, 44*, 587–594.

Hillman, K. M. (2001). Antecedents to hospital deaths. *Internal Medicine Journal, 31*(6), 343–348.

Hirumi, A., & Stapleton, C. (2008). Applying pedagogy during game development to enhance game-based learning. In C. T. Miller (Ed.), *Games: Purpose and potential in education* (pp. 127–162). New York, NY: Springer.

Kapp, K. M. (2012). *The gamification of learning and instruction: Game-based methods and strategies for training and education*. San Francisco, CA: Pfeiffer.

Kause, J. S. (2004). A comparison of antecedents to cardiac arrests, deaths and emergency intensive care admissions in Australia and New Zealand and the United Kingdom—The ACADEMIA study. *Resuscitation, 62*, 275–282.

Kern, D. E. (1998). *Curriculum development for medical education: A six step approach*. Baltimore, MD: John Hopkins University Press.

Kiili, K. L., Lainemab, T., de Freitasc, S., & Arnabc, S. (2014). Flow framework for analyzing the quality of educational games. *Entertainment Computing, 5*, 367–377.

Kron, F., Gjerde, F. W., Sen, A., & Fetters, M. D. (2010). Medical student attitudes toward video games and related media technologies in medical education. *BMC Medical Education, 10*, 1–11.

Labelle, M. (2012, April 17). *How critical is teaching critical care: A needs analysis in undergraduate medical education*. Retrieved July 1, 2014, from https.www.proreg.ca/events/ccme/archive_2012/schedule_abs.php?id=83855.

Leblanc, V. (2009). The effects of acute stress on performance: Implication for health professions education. *Academic Medicine, 84*(10 Suppl), S25–S33.

Lee, K. M. (2008). Media equation theory. In W. Donsbach (Ed.), *International encyclopedia of communication*. Retrieved November 20, 2014, from http://www.communicationencyclopedia.com/subscriber/tocnode.html?id=g9781405131995_chunk_g978140513199518_ss35-1.

Lefroy, J. B. (2011). Some like it hot: Medical student views on choosing the emotional level of a simulation. *Medical Education, 45*, 354–361.

Lim, T. L., Louchart, S., Suttie, N., Hauge, J. B., Stanescu, I. A., Ortiz, I. M. … Berta, R. (2014). Narrative serious game mechanics (NSGM)—Insights into the narrative-pedagogical mechanism. In S. Gobel, & J. Wiemeyer (Ed.), *Games for training, education, health and sports: Proceedings of 4th international conference on Serious Games, GameDays 2014, Darmstadt, Germany, April 1–5, 2014* (pp. 23–34). Darmstadt, Germany: Springer.

Lu, J. L. (2010). Scaffolding problem-based learning with CSCL tools. *International Journal of Computer-Supported Collaborative Learning, 3*, 283–298.

Mackenzie, R., & Sutcliffe, R. C. (2002). Immediate assessment and management of acute medical emergencies. *Journal of the Royal Army Medical Corps, 148*, 276–287.

McConnell, M. M. (2012). The role of emotion in the learning and transfer of clinical skills and knowledge. *Medical Education, 87*, 1316–1322.

McGillion, M. D. (2011). The postoperative pain assessment skills pilot trial. *Pain Research & Management, 16*(6), 433–439.

McLuhan, M., Fiore, Q., & Agel, J. (1967). *The medium is the massage*. London, England: Penguin.

Mohammad, A. B.-Z. (2014). Educational and clinical impact of advanced trauma life support (ATLS) course: A systematic review. *World Journal of Surgery, 38*, 322–329.

Morrison, L. J. (2013). Strategies for improving survival after in-hospital cardiac arrest in the United States: 2013 consensus recommendations: A consensus statement from the American Heart Association. *Circulation, 127*, 1538–1563.

Nettleton, S. B. (2008). How do you feel doctor? An analysis of emotional aspects of routine professional medical work. *Social Theory and Health, 6*, 18–36.

Neumar, R. W. (2010). 2010 American Heart Association guidelines for cardiopulmonary resuscitation and emergency cardiovascular care science. Part B. Adult advanced cardiovascular life support. *Circulation, 122*, S729–S767.

Pekrun, R., & Perry, R. P. (2014). Control-value theory of achievement emotions. In R.-G. Pekrun & L. Linnenbrink-Garcia (Eds.), *International handbook of emotions in education* (pp. 120–141). Hoboken, NJ: Taylor & Francis.

Piquette, D. R. (2009). Stressful intensive care unit medical crises: How individual responses impact on team performance. *Critical Care Medicine, 37*(4), 1251–1255.
Powell, M. G. (2014). Shaped by shock: Staff on the emergency department "shop floor". *Anthropology in Action, 2*, 14–22.
Reeves, B., & Nass, C. (1996). *The media equation: How people treat computers, television and new media like real people and places*. New York, NY: Cambridge University Press.
Romero, M. U. (2014, September). Can serious games contribute to developing and sustaining 21st century skills? *Games and Culture*.
Salehi, B. C. (2010). Learning under stress: The inverted u-shaped function revisited. *Learning & Memory, 17*, 522–530.
Salen Tekinbas, K., & Zimmerman, E. (2003). *Rules of play: Game design fundamentals*. Cambridge, MA: MIT Press.
Sauve, L. R. (2011). Games, simulations and simulation games for learning: Definitions and distinctions. In M. Khosrow-Pour (Ed.), *Gaming and simulations: Concepts, methodologies, tools and applications* (pp. 168–194). Hershey, PA: Information Resources Management Association.
Shute, V. J., Rieber, L. P., & Van Eck, R. (2011). Games...and...learning. In R. A. Reiser & J. V. Dempsey (Eds.), *Trends and issues in instructional design and technology* (3rd ed., pp. 321–332). Upper Saddle River, NJ: Pearson Education.
Sklar, D. (2014). How do we think? Can we learn to think better? *Academic Medicine, 82*(2), 191–193.
Smeets, T. W. (2009). Stress selectively and lastingly promotes learning of context-related high arousing information. *Pyschoneuroendocrinology, 34*, 1152–1161.
Smith, C. M. (2007). Undergraduate training in the care of the acutely ill patient: A literature review. *Intensive Care Medicine, 35*(5), 901–907.
Thistlethwaite, J. E. (2012). The effectiveness of case-based learning in health professional education. A BEME systematic review: BEME guide no. 23. *Medical Teacher, 34*, e421–e444.
Vygotsky, L. S. (1978). *The mind in society: The development of higher mental processes*. Cambridge, MA: Harvard University Press.
Wenger, E. (1998). *Communities of practice: Learning, meaning and identity*. Edinburgh, Scotland: Cambridge University Press.
Westera, W. N., Nadolski, R. J., Hummel, H. G. K., & Wopereis, I. G. J. H. (2008). Serious games for higher education: A framework for reducing design complexity. *Journal of Computer Assisted Learning, 24*, 420–432.
Wiseman, J. G. (2007). The "deteriorating patient" simulation: A pedagogical strategy for teaching dynamic clinical reasoning in practice. In *Practice makes perfect: Education of health professionals in community, clinical and simulated settings* (p. 11). Vancouver: BC, Canada: Academic Health Council.
Wiseman, J., & Snell, L. (2008). The deteriorating patient: A realistic but "lo tech" simulation of emergency decision-making. *The Clinical Teacher, 5*(2), 93–97.
World Health Organization Collaborating Center for Patient Safety Solutions (2007). *Communication during patient hand-overs*. Retrieved January 20, 2015, from http://www.who.int/patientsafety/solutions/patientsafety/PS-Solution3.pdf?ua=1.
Young, J. Q. (2014). Cognitive load theory: Implications for medical education: AMEE guide no. 86. *Medical Teacher, 36*, 371–384.

Chapter 12
Mobile Just-in-Time Situated Learning Resources for Surgical Clerkships

Robert B. Trelease

12.1 Introduction: Curriculum and Context

With the continuing evolution of global Undergraduate Medical Education (UME) curricula over the last few decades, there has been a widespread integration, compression, and distillation of instructional time for early, traditional basic science courses and anatomy (Drake, McBride, Lachman, & Pawlina, 2009; Heylings, 2002) preceding the onset of on-service clinical training (e.g., clerkships/clarkships, externships, and pre-internships). Anatomy learning is an integral part of and crucial to clinical understanding, diagnosis, and treatment of diseases and disorders as encountered in surgery (Cottam, 1999; Older, 2004), radiology and imaging (Orsbon, Kaiser, & Ross, 2014), and obstetrics and gynecology (Heisler, 2011; Jurjus et al., 2014). Thus, reduction in basic sciences learning time has placed increasing emphasis on the acquisition, review (revision), and reinforcement of clinically relevant basic anatomical concepts in clinical training contexts (Lazarus, Chinchilli, Leong, & Kauffman, 2012; Yammine, 2014).

The task of facilitating structured learning during medical student clinical clerkships faces the challenges of eking out significant dedicated time for basic for science learning amidst the compelling ad-hoc service demands of daily hospital and clinic activities. This is a particular concern for surgical clerkships, wherein students must acquire and reinforce a clinically relevant diversity of detailed structural knowledge for specific diagnoses, diseases, and procedures many months after

R.B. Trelease (✉)
Department of Pathology and Laboratory Medicine and Instructional Design and Technology Unit, Dean's Office, David Geffen School of Medicine, University of California Los Angeles, Los Angeles 90095, CA, USA
e-mail: trelease@ucla.edu

S. Bridges et al. (eds.), *Educational Technologies in Medical and Health Sciences Education*, Advances in Medical Education 5,
DOI 10.1007/978-3-319-08275-2_12