

THE EVOLUTION OF A ROCKS AND MINERALS CHALLENGE GAME DESIGN

Donna Rennar-Potacco¹, Anymir Orellana², & Rita Ramirez-Levine¹

¹William Paterson University; ²Nova Southeastern University

This design case describes design decisions and their impacts during three redesigns of an educational game called the “Rocks and Minerals Challenge.” This game was developed as a laboratory supplement for the rocks and minerals component of a university-based geology course. The game has evolved through three distinct design phases: Design 1, first designed as a challenge module in 2005; Design 2, redesigned as a game in 2012 for compatibility reasons; and Design 3, redesigned in 2015 to enhance instructional effectiveness. Following is a description of the game design factors that were implemented for each of the design phases: learning goals, levels of challenges, scaffolding, user control, feedback, and rules. The timing, rationale and impacts of these design decisions are discussed within the context of recommendations identified by existing educational game research.

Donna Rennar-Potacco is the Director of a science resource center and an adjunct professor in the College of Science and Health at William Paterson University (WPUNJ) for over 20 years. She earned her Ed.D in Instructional Technology and Distance Education from Nova Southeastern University, a Master of Science in Biochemistry and Bachelor of Science in Chemistry from Rutgers University, and a Masters in Business Administration from Fairleigh Dickinson University. Previously, Rennar-Potacco worked in several university research laboratories and held a variety of corporate management positions that included laboratory development and systems auditing. She has authored numerous scholarly publications and presentations in the areas of online learning, technology, academic support, and management.

Copyright © 2020 by the International Journal of Designs for Learning, a publication of the Association of Educational Communications and Technology. (AECT). Permission to make digital or hard copies of portions of this work for personal or classroom use is granted without fee provided that the copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page in print or the first screen in digital media. Copyrights for components of this work owned by others than IJDL or AECT must be honored. Abstracting with credit is permitted.

<https://doi.org/10.14434/ijdl.v11i2.24034>

Anymir Orellana is a Professor in the Abraham S. Fischler College of Education and the School of Criminal Justice, Nova Southeastern University (NSU). She earned a Doctor of Education in Instructional Technology and Distance Education from NSU; a Master of Science in Computer and Information Sciences and Engineering from the University of Florida; and a Bachelor of Science in Informatics Engineering from Universidad Centroccidental “Lisandro Alvarado” (UCLA), Venezuela. Since 2006 she has been teaching online doctoral courses in Spanish and English at NSU in her areas of interest, such as instructional media; instructional technology; distance education; curriculum, teaching, and technology; system analysis and design; and instructional design.

Rita Ramirez-Levine is an Adjunct Professor of Mathematics, Computer Programmer, Webpage Designer, and Assistant Director of the Science Enrichment Center at William Paterson University. She earned her Bachelors of Science in Computer Science and her Masters of Science in Applied Data Analytics from William Paterson University. Her interests are in the areas of programming and mathematics.

OVERVIEW

Game research has identified specific game features that are important in the design of effective educational games. There is much latitude, however, in how the designer uses these elements to accomplish a game’s goal(s) and objective(s).

Game research suggests that instructional game designers should concentrate on design challenges that meet clear learning goals (Charsky, 2010; Gunter, Kenny, & Vick, 2008; Lameris et al., 2017; Van Eck, Shute, & Rieber, 2015) and incorporate adaptive challenges that build upon prerequisite skills (Charsky, 2010; Gunter et al., 2008; Van Eck et al., 2015). Games should also be motivating (Charsky, 2010; Gunter et al., 2008; Van Eck et al., 2015), support learning through feedback and hints (Gunter et al., 2008; Lameris et al., 2017; Van Eck et al., 2015), and provide a framework of rules and choices (Gunter et al., 2008; Lameris et al., 2017).

In this design case, we discuss some of the most salient game features through an examination of the development

of a computer-based educational game for the sciences. The format and theoretical basis of the game has remained constant throughout the development of this game. The design, however, evolved based on lessons we learned during the design process and programming issues. Following, we discuss the game research and instructional design principles that served as a rationale for our design decisions.

THE RATIONALE FOR REDESIGN

Anecdotally, faculty, students, and educators at other educational institutions rated Design 1 (Figure 1) of this program highly. However, the game became non-functional when the webpages' JavaScript stopped supporting browsers using HTML4.

Consequently, Design 2 (Figure 2) involved the transformation of its code to HTML5, which enabled the compatibility of its webpages with different browsers and a broader audience. Additionally, we improved the website's backgrounds, reduced the number of webpages to enable easier editing, and added a summative scoring mechanism to the "Drag N Drop" Game of Level 2.

Although the visual aspects of Design 2 vastly improved with this redesign, feedback indicated that the webpages appeared cluttered and difficult to navigate, compared to the home page of Design 1, prompting the development of Design 3 (Figure 3).

Design 3 continued to use the visual elements of Design 2. However, Design 3 also adopted game elements using the more systematic, comprehensive, and diagnostic approach recommended by Ke (2009) and the Federation of American Scientists (2006).

LEARNING GOALS

Because this was a serious or educational game, our primary goal was to design an effective game that motivated students to learn geological information more effectively. Within this framework, we needed to establish clear learning goals (Killi, 2005; Dickey, 2005); a clear understanding of objectives that could facilitate the completion of these goals; and develop game features that best supported the achievement of objectives (Dondi & Moretti, 2007; Honey & Hilton, 2011). When

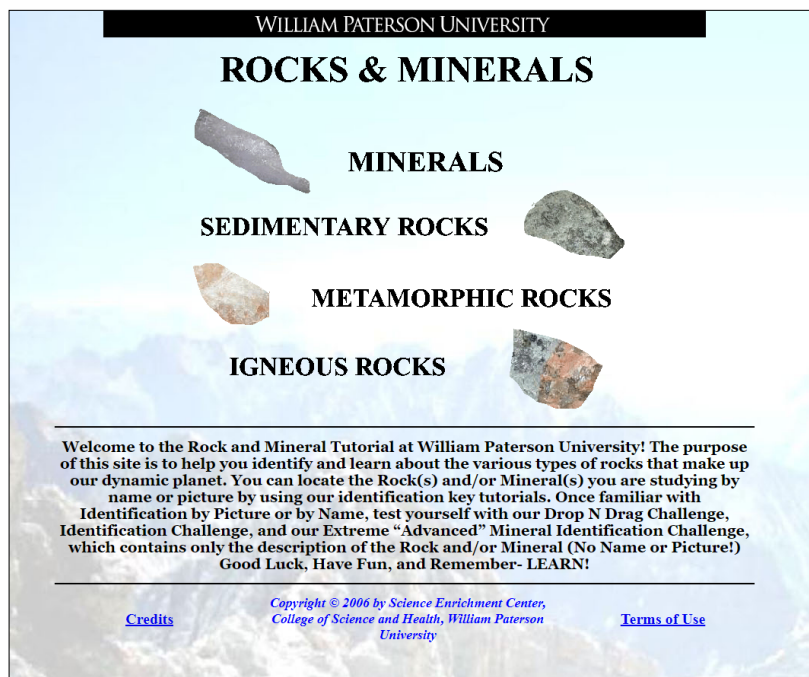


FIGURE 1. Home Page of Design 1. Background re-used with permission.

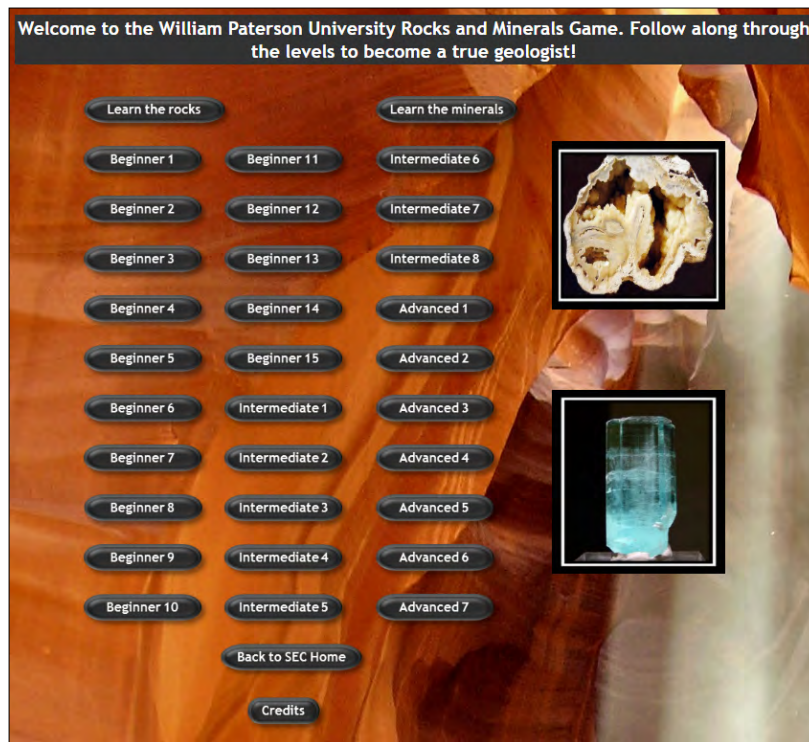


FIGURE 2. Home Page of Design 2. Background is "The Antelope Canyon in Arizona" by Lucas Löffler, retrieved from https://commons.wikimedia.org/wiki/File:USA_Antelope-Canyon.jpg Released into the public domain, Creative Commons. Rock image is "Agate.jpg" by Dave Dyet, retrieved from https://commons.wikimedia.org/wiki/File:01761_Agate.jpg Released into the public domain, Creative Commons. Mineral images is Aigue-marine by Vassil, retrieved from https://commons.wikimedia.org/wiki/File:Aigue-marine_Pakistan_180308.jpg Released into the public domain, Creative Commons

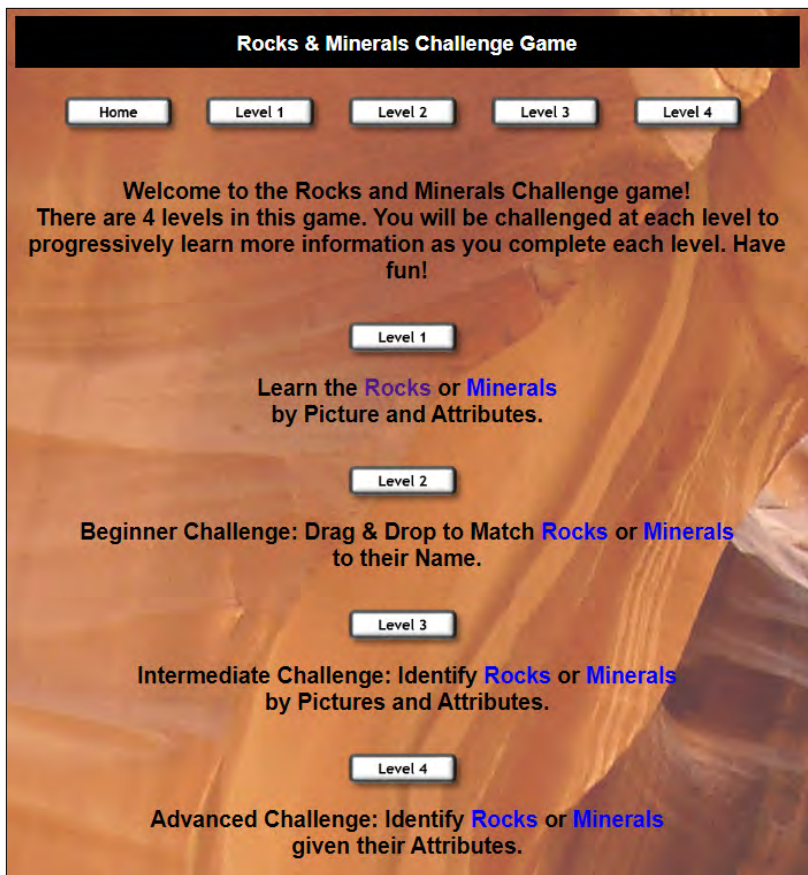


FIGURE 3. Home Page of Design 3.

goals are clear, the player is more aware of what he or she is learning and how to apply the instruction (Federation of American Scientists, 2006). Goals that align the tasks of the game with intended educational outcomes (Prensky, 2011; Quellmalz, Timms, & Schneider, 2009; Wilson et al., 2009) also help prevent the inclusion of extraneous information that can distract from the learning process (Clark & Mayer, 2011) and facilitate the design of assessments that measure the effectiveness of the game (Hays, 2005; Quellmalz, et al., 2009).

The content goal established for the Rocks and Minerals Challenge (RMC) was to help students identify rocks and minerals involved in the earth's formation through characteristics observed and tested in the laboratory. This goal helped us determine the learning objectives, instructional strategy, and design of the game at each level to facilitate the strategic scaffolding of information.

Working with a subject matter expert (SME) throughout the instructional design process is recommended for effective design, especially when establishing the goals and the need for instruction (Dick, Carey, & Carey, 2015). In addition to providing the program's goal and objectives, our SME verified the accuracy of the RMC's content and helped us establish standards for feedback and scoring.

LEVELS OF CHALLENGES

The completion of challenges has been the top-ranking motivation for game playing in higher education (Hainey, Connolly, Stansfield, & Boyle, 2011). Challenges in an educational game typically provide the gamer with the opportunities to acquire the skills and knowledge needed for more complex challenges (Mayer & Johnson, 2010), motivate game usage, and enhance learning potential (Wilson et al., 2009).

Good games also adjust challenges and give feedback in such a way that different players feel the game is challenging but doable and that their effort is paying off (Gee, 2005). This can be done with positive feedback in the form of hints, scores, points, prompts, and levels that help sustain engagement (Lim et al., 2013) and motivate continued game play (Jones & Issroff, 2005; Killi, 2005; Sanchez, 2011).

All three designs included challenges scaffolded in levels labeled 1, 2, 3, and 4. Level 1 is an informational resource page. Levels 2, 3, and 4 contain unique games that help students learn information needed to reach each objective. Within each level, students have access to content that is organized by geological category and subcategory. Between levels, the level of difficulty increases. That is, Level 2 of the "Drag N Drop" challenge teaches the easiest objective; Level 4's challenge is the most difficult.

Although the organizational logic used in Design 1 and 2 was consistent, reaction to Design 2 (Figure 4) was negative. Feedback revealed that the content per page was overwhelming.

In response, we simplified the format of Design 3 (Figure 5) and organized it similar to Design 1's home page (Figure 6), which had been very popular with users.

SCAFFOLDING

We scaffolded challenges in the RMC by introducing students to new concepts at each level, making connections between these concepts within levels, and building upon these concepts at higher levels. This logic followed the literature, which suggests that designers carefully organize challenges in a game according to levels of increasing complexity and decreasing support. Embedding the academic content in a game using this logic enables the player-learner

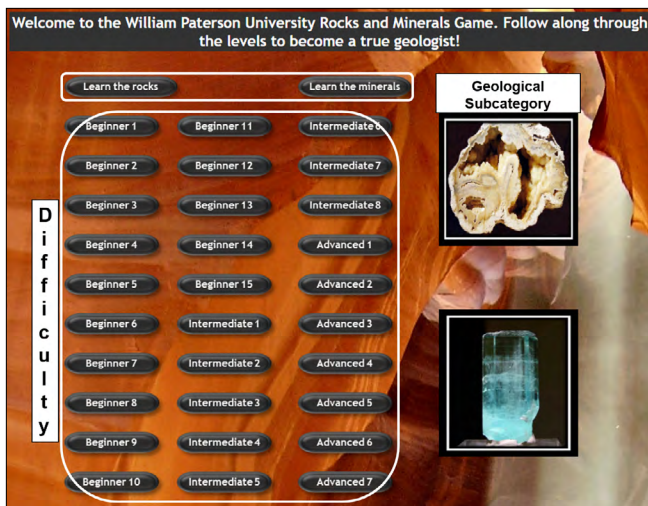


FIGURE 4. Design 2's Levels of Challenge organized by Geological Subcategory and Difficulty.

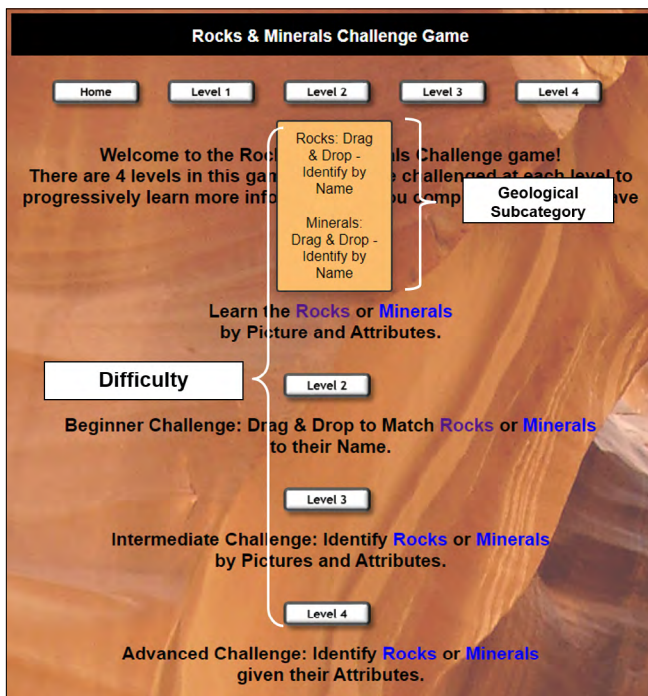


FIGURE 5. Design 3's Levels of Challenge organized by Geological Subcategory and Difficulty.

to apply, synthesize, and/or create new knowledge on a higher level through a systematic recall of previous content knowledge (McClarty et al., 2012). This structure maximizes the educational challenge (Dai & Wind, 2011; Wilson et al., 2009).

Researchers suggest that scaffolding reduces the complexity of the task (Mayer, Mautone, & Prothero, 2002) and provides support during learning (O'Neil, Wainess, & Baker, 2005) by reducing the extraneous cognitive load of the learning content through design and the promotion of schemata

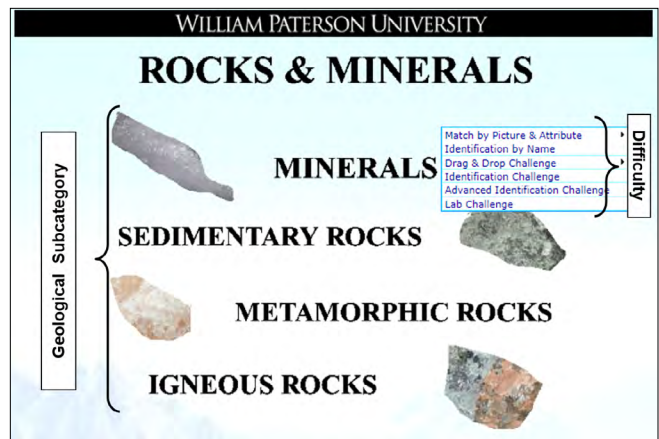


FIGURE 6. Design 1's Levels of Challenge organized by Geological Subcategory and Difficulty.

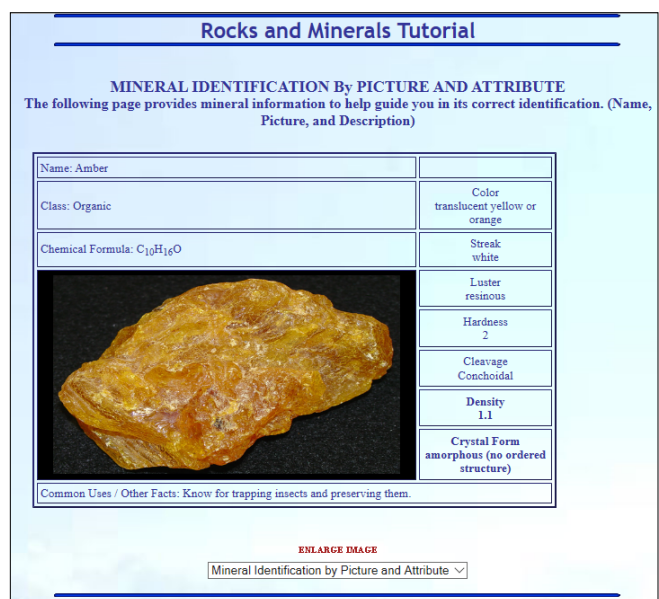


FIGURE 7. Level 1 of Design 1 provided the information students should learn after Level 4 (the specimen page) individually for each rock or mineral.

development. Concomitantly, Clark, Tanner-Smith, and Killingsworth (2014) found that digital games using higher levels of scaffolding were associated with higher relative learning outcomes than lower levels of scaffolding.

Scaffolding also enables players to control the difficulty of gameplay, accommodating users with different levels of expertise (Bedwell, Pavlas, Heyne, Lazzara, & Salas, 2012; Gee, 2005; Sweetser & Wyeth, 2005; Van Eck et al., 2015; Wilson et al., 2009) and promoting high levels of motivation (Bedwell et al., 2012; Honey & Hilton, 2011; Killi, 2005; Wilson et al., 2009). Novices can take a long time at early levels at a lower difficulty level in order to avoid frustration, while skilled players can move through initial levels quickly, avoiding boredom (Van Eck, 2007).

Rocks and Minerals Tutorial

Rock Identification by Picture and Attribute

Familiar with what the Rock looks like but not on what it is all about? That's okay. Click on the picture below that corresponds to the rock you would like to study.

The following page provides Rock information to help guide you in its correct identification. (Name, Picture, and

Description		Alternate Specimen(s)	
Name: Marble		Fichter, Lynn S. James Madison University	
Classification: Metamorphic		Texture/Color: non-foliated; most often cream	
		Minerals Composition: calcite (possibly dolomite)	
		Metamorphic Grade: low to high	
About this rock: Calcite and dolomite crystals usually visible.		Parent Rock: limestone (possibly dolomite)	
ENLARGE IMAGE			
			
Menu			

FIGURE 8. Level 1 of Design 2 provided the information students should learn by Level 4 through a Rocks and Minerals summary page that gave students access to each specimen's summary page (center page).

The need to simplify students' ability to control navigation within and between scaffolded levels influenced the prominent placement of our levels (Figures 4, 5, & 6) and our design of Level 1, which provided students with a summary of the content taught through all three game designs. Students who used Level 1 in Design 1 (Figure 7), however, had to search through multiple links to find alternative specimens.

In contrast, for Designs 2 (Figure 8) and 3 (Figure 9) of Level 1, we strategically placed the specimen image in the table frame of the rock/mineral (Figure 8) description to facilitate students' retrieval of the information and reduce linking. For Design 3, we also chunked specimens by Category and

Subcategory to improve the design's pedagogical utility (Figure 9).

USER CONTROL

User control is an important feature of a game that refers to the amount of control a learner has over content or gameplay (Bedwell et al., 2012). Control can lead to more positive attitudes (Wilson et al., 2009) and higher cognitive outcomes (Vogel et al., 2006). User control also provides the player with the ability to influence elements within their learning environments, navigate through content, pace their progress (Wilson et al., 2009), and observe the consequences of their choices (Hainey et al., 2011). Dickey (2005) posits that choice is central to the design of gameplay through its ability

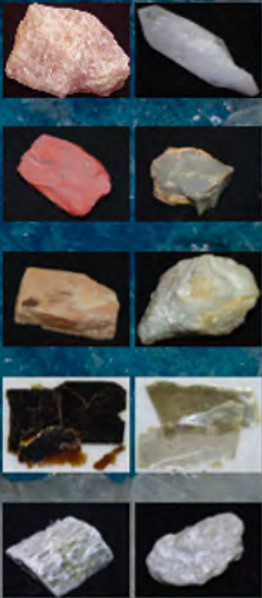
The Rocks & Minerals Challenge Game


Home Level 1 Level 2 Level 3 Level 4

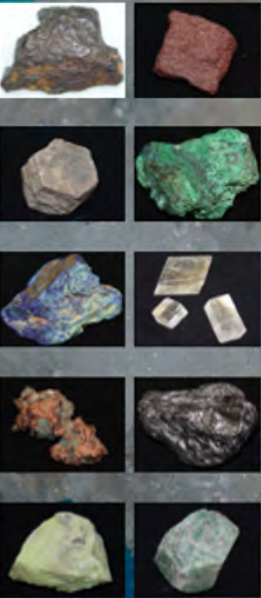
Mineral Identification by Picture and Attribute

Explorers! Before you begin your journey, you need to recognize these geological specimens.
Begin by selecting one of the specimens pictured.

Inosilicates, Neosilicates, Sorosilicates

Silicates


Name: Rose Quartz	Alternate Specimen(s) Fichter, Lynn S. James Madison University
Class: SILICATES Group: Tektosilicates (framework silicates)	Color pink
Chemical Formula: SiO ₂	Streak white
	Luster glassy
	Hardness 7
	Cleavage (Conchoidal Fracture)
	Density 2.6
Crystal Form Trigonal/Hexagonal	
Common Uses / Other Facts: A variety of quartz with a distinctive pink color created by the presence of small amounts of manganese or titanium. Massive and milky in appearance.	

Oxides, Hydroxides, Carbonates


Sulfides and Sulfates
Halides
Organic


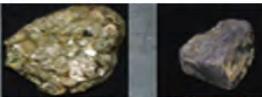





FIGURE 9. Level 1 of Design 3 chunked information into subcategories, as well as providing easy access to each specimen's summary page. Background is by Frans de Wit, retrieved from <https://www.flickr.com/photos/fransdewit/3856989990/in/photostream/> Attribution-NonCommercial-NoDerivs 2.0 Generic (CC BY-NC-ND 2.0)

to both personalize the experience and affect gameplay. Choice also provides the gamer with the ability to change the level of difficulty so that the learner can make mistakes without real consequences (Sanchez, 2011) and allows users to control their exposure to information according to their level of expertise, improving learner motivation (Lameras et al., 2017).

We implemented the feature of choice, or user control, in all three designs of the RMC by providing students with

multiple levels of challenges and by scaffolding the content in levels. In Designs 1 and 3, the learner was able to navigate using drop-down menus and tabs. In Design 2, the learner used tabs. Although tabs provided easier access, excessive tab use, such as that used in Design 2, appeared to overwhelm our users with information. By Design 3, the pros and cons of each method of navigation were deliberated based on the objective of the level, structure of the game, design of the page, ease of navigation, reduction of unnecessary redundancy, and the programming.

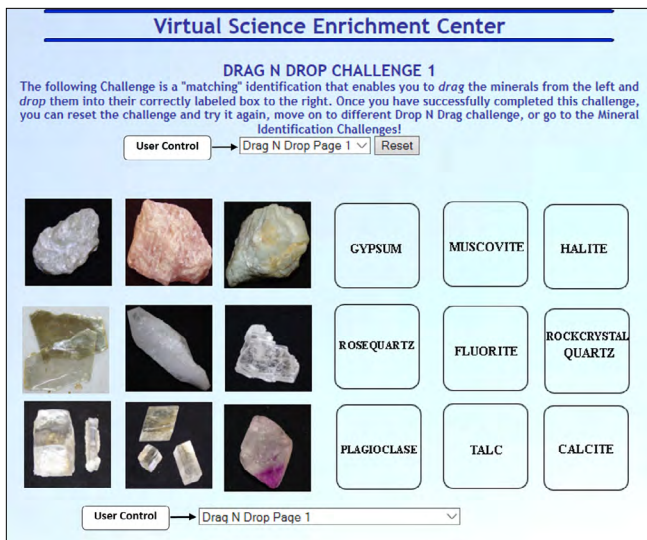


FIGURE 10. Level 2 of Design 1's "Drag N Drop" Challenge with two means of navigation.

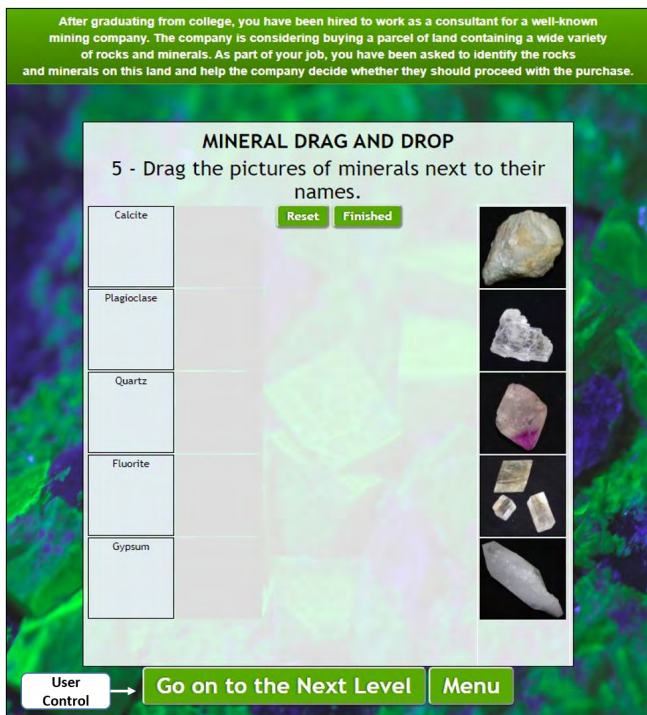


FIGURE 11. Level 2 of Design 2's "Drag N Drop" Challenge with one means of navigation. Background is "Autunite sous UV (France).jpg" by Parent Géry, retrieved from [https://commons.wikimedia.org/wiki/File:Autunite_sous_UV_\(France\).jpg](https://commons.wikimedia.org/wiki/File:Autunite_sous_UV_(France).jpg) Released into the public domain, Creative Commons

An example of changes in user control that transpired through development was the "Drag N Drop" challenge. Level 2 of Design 1 (Figure 10) provided users with two means of navigation and user control, compared to one means in Design 2 (Figure 11). In contrast, Design 3 (Figure 12) of the same level provided three means of navigation, providing users with more ways to control their gameplay.

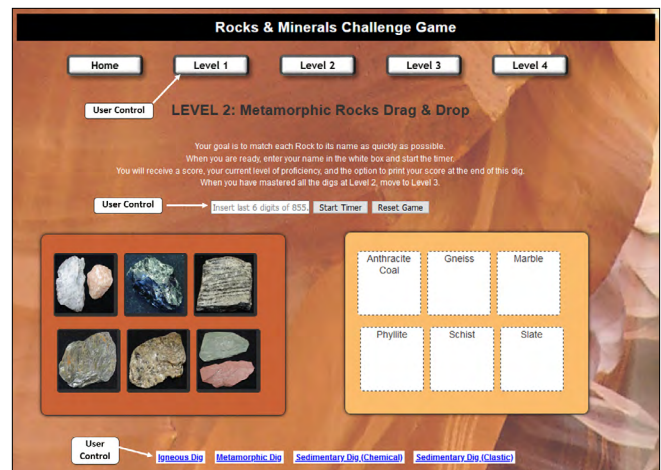


FIGURE 12. Level 2 of Design 3's "Drag N Drop" Challenge with three means of navigation. Released into the public domain, Creative Commons.

All three designs provided access to the other pages, but Design 3 made access and control easier and more transparent.

FEEDBACK

According to Wouters, Van Nimwegen, Van Oostendorp, and Van Der Spek's (2013) meta-analysis, serious games are more effective when they are accompanied by supplemental instructional methods that prompt players to articulate new knowledge and integrate it with their prior knowledge. Supportive feedback and scaffolding supplemented by hints, prompts, partial solutions, and pervasive feedback motivate learners to continue gameplay (Jones & Issroff, 2005; Killi, 2005; Sanchez, 2011), enable players to self-regulate their progress (Killi, 2005; Van Eck, 2007; Federation of American Scientists, 2006), and enhances learning (Clark & Mayer, 2011; Honey & Hilton, 2011; Hattie, 2009). Frequent feedback also allows the learner to recognize his or her achievement, anticipate the consequences of his or her actions, and adapt to the situation by applying a new strategy if needed (Sanchez, 2011).

We provided feedback in all three designs. However, the frequency, type, and degree of feedback provided in each challenge varied. Level 2 feedback was consistent in all three designs through a "Drag N Drop" challenge (Figures 10, 11 & 12), which was a memorization drill that trained students to identify rocks or minerals by name. Toward that end, images incorrectly matched to their name would return to their original location in the image table while images correctly matched remained on its name. The close linking of a learner's action with feedback and the provision of feedback as an action instead of text enabled learners to be aware of their progress in accord with the recommendation of Liang, Lee, and Chou (2010).

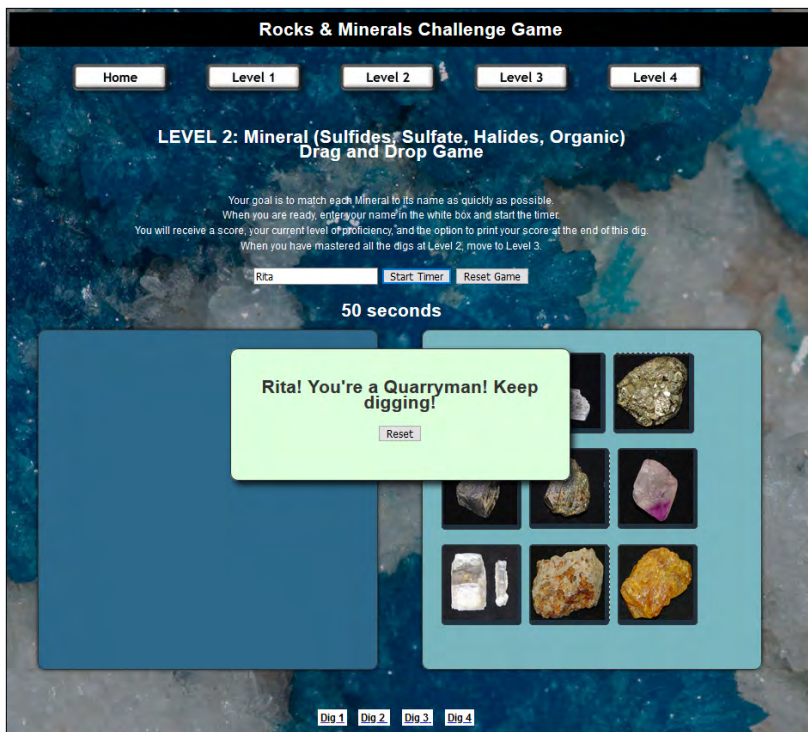


FIGURE 13. Time-based, Evaluative Score of Design 3's Level 2.



FIGURE 14. Level 3 of Design 1 provided feedback through a drop-down, word-bank hint.

In addition to this feedback, students in Design 3's Level 2 (Figure 13) received a completion time linked to evaluative feedback since rapid response games appear to be well suited for skills that must become automated through extensive drill and practice (Clark & Mayer, 2011). The performance rubric used to provide this feedback was developed with the assistance and agreement of several SMEs. Players who received low scores were "Pebble Puppies" and encouraged to repeat the challenge. Players who received average scores were "Quarrymen" and encouraged to continue practicing. Players who received high scores were "Rock Hounds" and encouraged to challenge themselves at a higher level or attempt a similar challenge in an alternative rock or mineral category.

We provided feedback in Design 1, Level 3's, "Mineral/Rock Identification Challenge" (Figure 14), through a drop-down word bank hint designed to support students' efforts and a pop-up tab with the text "Good job" to reward correct answers. Design 2, Level 3's (Figure 15), "Intermediate Challenge" added an evaluative score, a correct/incorrect text box, and the specimen's image as a reward for correct answers in addition to the word bank hint.

We redesigned Design 3, Level 3's (Figure 16), "Search and Find" to be more visually aesthetic. We also used a simpler pedagogical design that asked students to connect specimen images from Level 2 to characteristics, rather than the characteristics with the specimen's name. Feedback in this design is through coloration of the buttons: red is incorrect and green is correct. Additionally, at the end of the challenge, a results page provides a score and the option for students to repeat that or an alternative challenge.

Level 4 is the most advanced level of the RMC, requiring students to apply the information learned in earlier levels. We eliminated the hints provided in Level 3 from Level 4 of Design 1 (Figure 17) but added an image of the specimen's picture for feedback and reward for correct answers.

We also eliminated Level 3's hints from Design 2's Level 4 (Figure 18). However, according to users, the presentation of questions in Design 2 was overwhelming, reducing user motivation to enter this challenge. Level 4 of Design 3

of this level is a complete redesign of Design 2 that is currently in process.

RULES

According to Dondlinger's (2007) review of educational video game design, in addition to objectives and goals, the rules of play are a significant element of effective video game design. Rules provide context to game design that can be operationalized as constraints that limit the actions a gamer can and cannot take. The flexibility of the rule structure determines the extent that learners can explore, test hypotheses, and find alternative ways of fulfilling goals. Specific, well-defined rules and guidelines also provide the player with feedback on their progress toward achieving the goals. Mayer and Johnson (2010) suggest that a rule-based environment that is responsive helps the player gain an understanding of the game.

Rules in the RMC were intrinsic to the design in that a player would be unable to complete higher-level challenges unless they had acquired the knowledge of previous challenges. We provided this rule structure to students through clear instructions and recommendations intended to help them understand the goals of each challenge.

REFLECTION AND RECOMMENDATIONS

The redesigns discussed in this paper showed the need for careful planning of the instructional design with team members before development. We developed Design 1 as a study aid for geology students before educational gameplay and mobile access was popular. The design was based on the "Learning for Use" (LfU) model (Edelson, 2001), which is a general framework developed to help web designers develop content-intensive, inquiry-based science learning activities and incorporate the principles of motivation, knowledge construction and knowledge refinement. Design 1 was popular with students, but more of a study ancillary than a game

The predominant motivation for the redesign of Design 1 was its incompatibility with HTML5. During this reprogramming, we also incorporated more game features and upgraded our visuals to motivate increased student usage. This process took two years due to our limited funding and

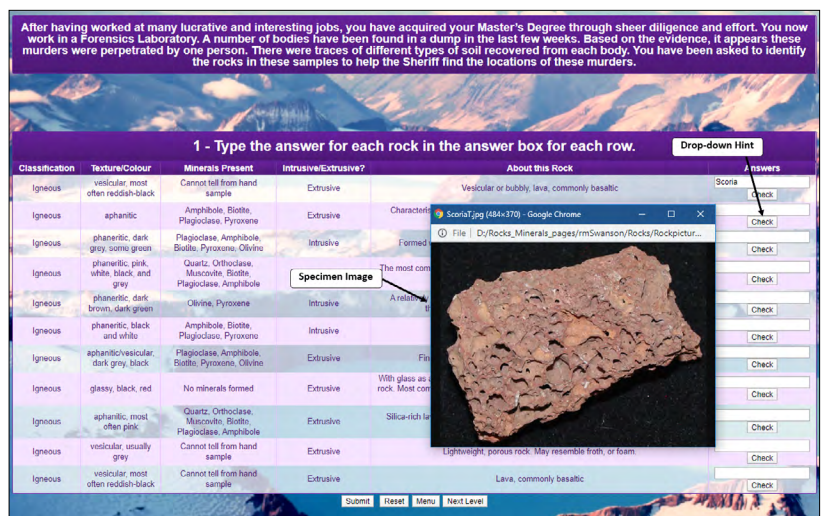


FIGURE 15. Level 3 of Design 2 provided feedback with the appearance of the specimen's picture and a drop-down, word-bank hint. Background is "Katmai Crater 1980.jpg" by Captain Budd Christman, NOAA Corps, retrieved from https://commons.wikimedia.org/wiki/File:Katmai_Crater_1980.jpg Released into the public domain, Creative Commons.

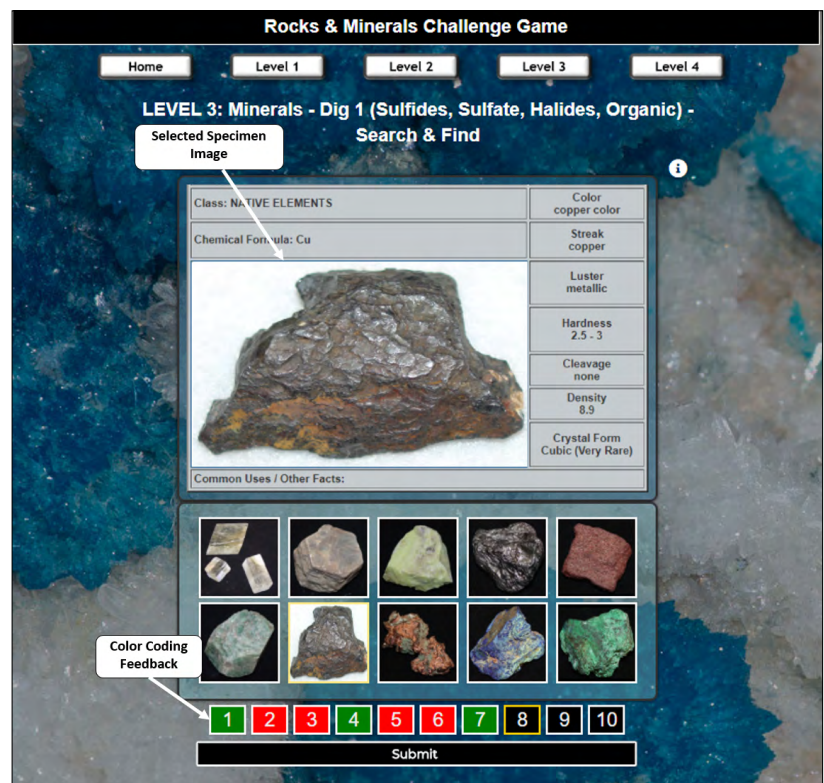


FIGURE 16. Level 3 of Design 3 provides feedback through the coloration of the buttons below the challenge and a results page.

skeleton staff. The user reaction to Design 2 was negative. On reflection, programming decisions made in Design 2 compromised design principles.

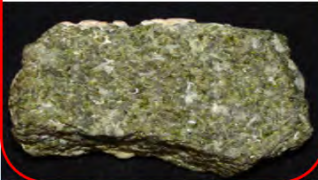
The conflict between programming wants versus instructional design principles was also evident during Design 3.

Rocks and Minerals
 ADVANCED MINERAL IDENTIFICATION
 Test your true knowledge of Minerals with a Challenge. Identify the name of the Mineral with a Picture, and NO HINTS! (Good Luck, this Challenge is a diamond!)

Reset Submit

Do not put spaces between words when answering

This page says
Correct



Class: SILICATES Subclass: Sorosilicates	Color dark green
Chemical Formula: $Ca_2(Fe^{+3}, Al)_3(SiO_4)_3(OH)$	Streak white
	Luster glassy or pearly
	Hardness 6 - 7
	Cleavage 1 direction
	Density 3.4 - 3.5
	Crystal Form Monoclinic
Common Uses / Other Facts:	

FIGURE 17. Level 4 of Design 1 showing the appearance of a specimen image in response to correct answers.

After working in the industry for years, you went back to school for your doctorate. Before you are given this degree, you will have to take a written exam. This test will help you prepare. There are no hints. Continue to retake this test until you are sure you will do well on your exam.

7 - Type the answer for each rock in the answerbox for each row.

Classification	Mineral Composition	Texture and Properties	How did it form?	About this Rock	Answers
Sedimentary	Carbonate	very fine, pebbly	transfers, sea-side	has a bluish-grey color	
Sedimentary	Carbonate	very fine, pebbly	Deposited in deep marine environments	Very pure limestone that may contain only small amounts of silt or mud. Forms from the shells of plankton, marine animals, and marine plants.	
Sedimentary	Hellite	massive, colorless	Evaporites, and sea	Stacks up within of the in the shallow sodium chloride	
Sedimentary	Carbonate	layered appearance	Deposition in hot springs	Consisting of almost pure calcium carbonate. Fossil material is virtually absent. Very irregularly layered	
Sedimentary	depends on the composition of the rock fragments	coarse angular clasts	deposited close to the source	Volcanic varieties of this rock are common around Pacific and Andean volcanoes. This rock is essentially limited to clastic	
Sedimentary	Carbonate	shells and shell fragments cemented together	Formed on a beach	Named after the small clam shells, of which it is mostly composed	
Sedimentary	None, or amorphous silica	very fine, pebbly	Deep Marine environment	Composed of shells of a particular algae.	
Sedimentary	Clays, Micas	very fine	Deposited in deep water	Fine grained, and splits easily along bedding planes. The fossils found in this rock are often sweep or marine animals or plants.	
Sedimentary	depends on the composition of the rock fragments	medium angular clasts, well-sorted	Deposited rapidly in a desert area	Feldspar can contribute as much as a third of the rock. Rock fragments are common	
Sedimentary	Carbonate	fragment	Formed in a marine environment	Any limestone in which fossils are easily identified	
Sedimentary	Carbonate	no individual crystals visible (micro-crystalline, dark grey)	Formed in a warm, shallow marine environment	Forms by re-crystallization of dolomitic sediment. This type of rock may be classified as shale, siltstone, except that organic matter makes it dark and gives it the property of 'bleaching' when struck with steel or another rock.	
Sedimentary	Carbonate	small spheres of calcite	Formed in a warm, shallow marine environment	Oolites are spherical or ovoidal structures built of layers. The rounded oolites are easy to see with the naked eye.	
Sedimentary	depends on the composition of the rock fragments	locally rounded clasts	Deposited in a shallow or near-shore environment	Forms where there is sufficient energy to move large fragments of material. This includes beaches and river systems (barochans).	
Sedimentary	Quartz, sometimes with calcite cement	medium rounded clasts (sand)	Deposited in water, near shore	Has a range of colours, and may have a layered, wood-like grain to it.	
Sedimentary	depends on the composition of the rock fragments	medium triangular clasts, well-sorted, slightly grey	Deposited rapidly in a desert area	Feldspar can contribute as much as a third of the rock. Rock fragments are common	
Sedimentary	Carbonate	very fine particles, clasts, well-sorted	Deposited rapidly	It related to sandstone, but less clay and finer particles	
Sedimentary	Carbonate	very fine crystals	deposited in a shallow environment	Irregularly-deposited, and has been used as a fossil for writing, or stone for paving	

Finished Reset Menu Next Level

FIGURE 18. Level 4 of Design 2 with white boxes for response submissions. Background is "Monument Valley 1. JPG" by Josep Renalias, retrieved from https://commons.wikimedia.org/wiki/File:Monument_Valley_1.JPG Creative Commons Attribution-Share Alike 3.0 Unported license.

Programmers attempted to make changes to the program, inadvertently affecting the instructional design and pedagogy. By Design 3, however, we learned to minimize these occurrences by sharing the logic of the design by posting a work plan that detailed programming activities, responsible parties, and benchmarks; and tracking progress regularly.

A side benefit of this program's development was the growth demonstrated by our programmers, who were computer science students. The game gave them a platform to experiment, research, learn, and develop a portfolio. Corporations recruited each of these students as soon as they graduated.

FUTURE DIRECTION

It became evident during our literature search that there is a need for scientifically rigorous studies that identify the impact of design features on the instructional effectiveness of games and guide future design (e.g., Clark, Yates, Early, & Moulton, 2010; Deleeuw & Mayer, 2011; Hannifin & Vermillion, 2008; O'Neil & Perez, 2008; Tobias, Fletcher, Dai, & Wind, 2011). Hence, we are currently investigating the efficacy of unique game attributes implemented in Levels 2, 3, and 4 in the context of relevant theoretical constructs. Once we complete these investigations and share the results with the gaming community, we will make the RMC game available through the internet to students of geology and their instructors as an open educational resource.

ACKNOWLEDGEMENT

Thank you to Dr. Karen Swansen, our SME, for providing her academic expertise.

REFERENCES

- Bedwell, W. L., Pavlas, D., Heyne, K., Lazzara, E. H., & Salas, E. (2012). Toward a taxonomy linking game attributes to learning: An empirical study. *Simulation & Gaming, 43*(6), 729-760. <https://doi.org/10.1177/1046878112439444>
- Charsky, D. (2010). From edutainment to serious games: A change in the use of game characteristics. *Games and culture, 5*(2), 177-198. <https://doi.org/10.1177/1555412009354727>
- Clark, R. C., & Mayer, R. E. (2011). *E-Learning and the science of instruction*. New York, NY: Wiley.
- Clark, D., Tanner-Smith, E., Killingsworth, S. (2014). *Digital Games, Design and Learning: A Systematic Review and Meta-Analysis (Executive Summary)*. Menlo Park, CA: SRI International.
- Clark, R. E., Yates, K., Early, S., & Moulton, K. (2010). An analysis of the failure of electronic media and discovery-based learning: Evidence for the performance benefits of guided training methods. In K. H. Silber & R. Foshay (Eds.), *Handbook of training and improving workplace performance: Vol. 1. Instructional design and training delivery* (pp. 263- 297). Somerset, NJ: Wiley.

- Dai, D.Y., & Wind, A.P. (2011). Computer games and opportunity to learn: Implications for teaching students from low socioeconomic backgrounds. In: Tobias, S., Fletcher, J.D. (Eds.) *Computer Games and Instruction*, pp. 477–500. Information Age, Charlotte.
- DeLeeuw, K. E., & Mayer, R. E. (2011). Cognitive consequences of making computer-based learning activities more game-like. *Computers in Human Behavior*, 27(5). <https://doi.org/10.1016/j.chb.2011.05.008>
- Dick, W., Carey, L., & Carey, J. O. (2015). *The systematic design of instruction* (8th ed.). Upper Saddle River, NJ: Pearson.
- Dickey, M. D. (2005). Engaging by design: How engagement strategies in popular computer and video games can inform instructional design. *Educational Technology Research and Development*, 53(2), 67-83. <https://doi.org/10.1007/bf02504866>
- Dondi, C., & Moretti, M. (2007). A methodological proposal for learning games selection and quality assessment. *British Journal of Educational Technology*, 38(3), 502-512. <https://doi.org/10.1111/j.1467-8535.2007.00713.x>
- Dondlinger, M. J. (2007). Educational video game design: A review of the literature. *Journal of applied educational technology*, 4(1), 21-31.
- Edelson, D. C., (2001). Learning-for-Use: A Framework for the Design of Technology-Supported Inquiry Activities. *Journal of Research in Science Teaching*, 38(3), 355-385. [https://doi.org/10.1002/1098-2736\(200103\)38:3<355::aid-tea1010>3.3.co;2-d](https://doi.org/10.1002/1098-2736(200103)38:3<355::aid-tea1010>3.3.co;2-d)
- Federation of American Scientists. (2006). *Summit on educational games: Harnessing the power of video games for learning*.
- Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-Learning*, 2, 5-16. <https://doi.org/10.2304/elea.2005.2.1.5>
- Gunter, G. A., Kenny, R. F., & Vick, E. H. (2008). Taking educational games seriously: using the RETAIN model to design endogenous fantasy into standalone educational games. *Educational Technology Research and Development*, 56(5-6), 511-537. <https://doi.org/10.1007/s11423-007-9073-2>
- Hainey, T., Connolly, T., Stansfield, M., & Boyle, E. (2011). The differences in motivations of online game players and offline game players: A combined analysis of three studies at higher education level. *Computers & Education*, 57(4), 2197-2211. <https://doi.org/10.1016/j.compedu.2011.06.001>
- Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. New York, NY: Routledge
- Hays, R. T. (2005). *The effectiveness of instructional games: A literature review and discussion*. Technical Report 2005–004. Orlando, FL: Naval Air Warfare Center Training Systems Division.
- Honey, M. A., & Hilton, M. (2011). (2011). *Learning science through computer games and simulations*. Committee on Science Learning: Computer Games, Simulations, and Education. National Research Council (NRC). Washington, DC: The National Academies Press.
- Jones, A., & Issroff, K. (2005). Learning technologies: Affective and social issues in computer-supported collaborative learning. *Computers & Education*, 44(4), 395-408. <https://doi.org/10.1016/j.compedu.2004.04.004>
- Ke, F. (2009). A qualitative meta-analysis of computer games as learning tools. *Handbook of research on effective electronic gaming in education*, 1, 1-32. <https://doi.org/10.4018/978-1-59904-808-6.ch001>
- Killi, K. (2005). Digital game-based learning: Towards an experiential gaming model. *The Internet and higher education*, 8(1), 13-24. <https://doi.org/10.1016/j.iheduc.2004.12.001>
- Lameras, P., Arnab, S., Dunwell, I., Stewart, C., Clarke, S., & Petridis, P. (2017). Essential features of serious games design in higher education: Linking learning attributes to game mechanics. *British Journal of Educational Technology*, 48(4), 972-994. <https://doi.org/10.1111/bjet.12467>
- Liang, C., Lee, Y. Z., & Chou, W. S. (2010). The Design Consideration for Game-Based Learning. *Educational Technology*, 50(2), 25-28. www.jstor.org/stable/44429774
- Lim, T., Louchart, S., Suttie, N., Richie, J. M., Aylett, R. S., & Stănescu, I. A. (2013). Strategies for effective digital games development and implementation. In Y. Baek & N. Whitton (Eds), *Cases on digital game-based learning: methods, models, and strategies*, IGI global (pp. 168-198). Hersey, PA: Information Science
- Mayer, R. E., & Johnson, C. I. (2010). Adding instructional features that promote learning in a game-like environment. *Journal of Educational Computing Research*, 42(3), 241–265. <https://doi.org/10.2190/ec.42.3.a>
- Mayer, R. E., Mautone, P., & Prothero, W. (2002). Pictorial aids for learning by doing in a multimedia geology simulation game. *Journal of Educational Psychology*, 94(1), 171-185. <https://doi.org/10.1037//0022-0663.94.1.171>
- McClarty, K. L., Orr, A., Frey, P. M., Dolan, R. P., Vassileva, V., & McVay, A. (2012). A literature review of gaming in education. *Gaming in education*, 1-35.
- O’Neil, H. F., Wainess, R., & Baker, E. L. (2005). Classification of learning outcomes: evidence from the computer games literature. *Curriculum Journal*, 16(4), 455-474. <https://doi.org/10.1080/09585170500384529>
- O’Neil, H. F., & Perez, R.S. (2008). *Computer games and team and individual learning*. Oxford, UK:Elsevier.
- Prensky, M. (2011). Comments on research comparing games to other instructional methods. In S. Tobias & J. D. Fletcher (Eds.), *Computer games and instruction* (pp. 251-280). Charlotte, NC: Information Age Publishing.
- Quellmalz, E. S., Timms, M. J., & Schneider, S. A. (2009, October). *Assessment of student learning in science simulations and games*. Paper presented at the National Research Council workshop on gaming and simulations, Washington, D. C.
- Sanchez E. (2011). *Key criteria for Game Design: A Framework*. Rapport du Meet project, European Commission.
- Sweetser, P., & Wyeth, P. (2005). GameFlow: a model for evaluating player enjoyment in games. *Computers in Entertainment (CIE)*, 3(3), 3-3. <https://doi.org/10.1145/1077246.1077253>
- Tobias, S., Fletcher, J. D., Dai, D. Y., & Wind, A. P. (2011). Review of research on computer games. In S. Tobias & J. D. Fletcher (Eds.), *Computer Games and Learning* (pp. 127–222). Charlotte, NC: Information Age Publishing

Van Eck, R. (2007). Six ideas in search of a discipline. In B. E. Shelton & D. Wiley (Eds.), *The design and use of simulation computer games in education* (pp. 31–60). Rotterdam, The Netherlands: Sense Publishers.

Van Eck, R. N., Shute, V. J. & Rieber, L. P. (2015). Leveling up: Game design research and practice for instructional designers. In R. Reiser & J. Dempsey (Eds.), *Trends and issues in instructional design and technology* (4th ed.). Upper Saddle River, NJ: Pearson Education, Inc.

Vogel, J. J., Vogel, D. S., Cannon-Bowers, J., Bowers, C. A., Muse, K., & Wright, M. (2006). Computer gaming and interactive simulations for learning: A meta-analysis. *Journal of Educational Computing Research*, 34(3), 229-243. <https://doi.org/10.2190/flhv-k4wa-wpvq-h0ym>

Wilson, K. A., Bedwell, W. L., Lazzara, E. H., Salas, E., Burke, C. S., Estock, J. L., ... & Conkey, C. (2009). Relationships between game attributes and learning outcomes: Review and research proposals. *Simulation & Gaming*, 40(2), 217-266. <https://doi.org/10.1177/1046878108321866>

Wouters, P., Van Nimwegen, C., Van Oostendorp, H., & Van Der Spek, E. D. (2013). A meta-analysis of the cognitive and motivational effects of serious games. *Journal of Educational Psychology* (4th Edition), 105(2), 249–265.