Games for Requirements Engineers: Analysis and Directions

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Abstract

The requirements engineering (RE) discipline keeps evolving to cope with increasingly complex systems and shorter development cycles. This dynamism impacts diverse RE communities, including RE education and RE practice. As the discipline changes, RE educators strive to keep their educational materials up to date, and to deliver a feedback-rich, engaging learner experience for their students. RE practitioners rely on feedback from subject matter experts to help ensure the quality of RE artifacts for an emerging system. However, experts' (instructor, subject matter) availability is scarce. Researchers are exploring the use of serious games in RE to advance the discipline by improving the availability of interactive feedback in engaging environments. Using a lightweight analysis framework, we review the current landscape of games for RE and provide guidance for the practitioner interested in improving their skills using innovative, game-based RE.

Keywords: Requirements engineering, serious games, gamification

Actionable Insights

- Our lightweight framework helps analyze existing games or design new games to support RE education or RE practice.
- Half of our analyzed games (11/21) concern requirements elicitation: a good option to start experimenting with RE games.
- Our framework invites both educators and practitioners to thoroughly assess the employed games' (cost-)effectiveness and to make their findings publicly available.

Motivation

Requirements engineering (RE) remains an important, challenging, and evolving field of software engineering (SE). Advances in RE are driven by rapidly changing, increasingly complex, and emerging systems such as apps, cyber-physical systems, and autonomous software. The RE discipline encompasses broad and in-depth knowledge to create and maintain high-quality requirements for diverse projects.

It is increasingly challenging for RE practitioners to keep up with such changes. The existing teaching materials (courses, books, standards, best practices) are valuable but quickly become outdated; for
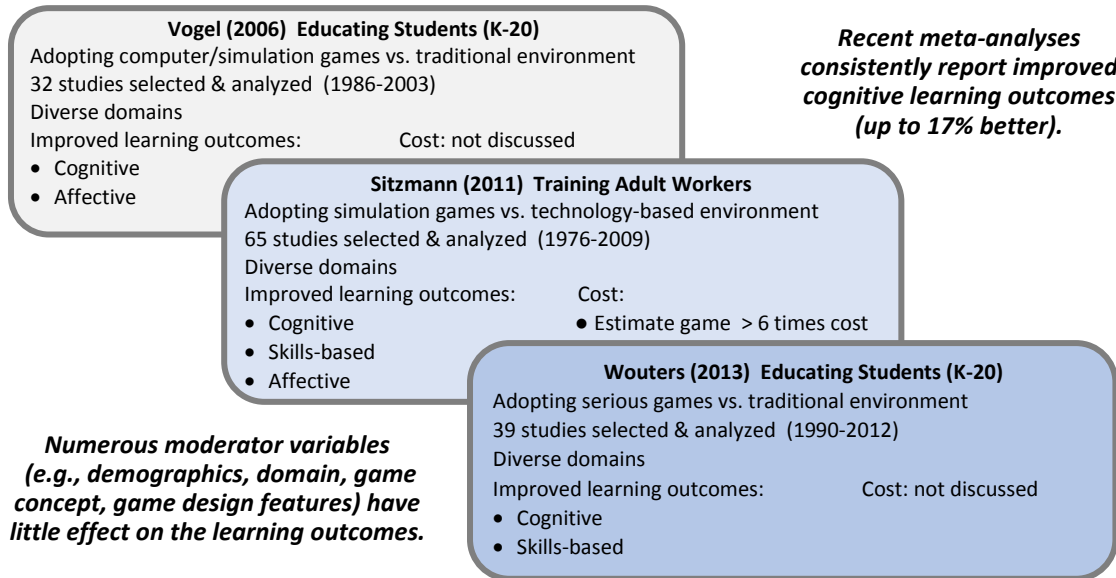
example, there is no book that explains RE in agile development. Furthermore, these materials have practical constraints imposed by learning environments, whether traditional classrooms or on-line. Lecture slides or a podcast, for example, rely on limited interactions, making them inadequate for today's professionals who demand fast-paced, example- and feedback-driven, and enjoyable learning processes.

One possible solution the RE community is exploring is the use of serious games. Serious games have been under investigation across a broad range of disciplines for over 30 years; they combine the entertainment value of games (goal-directed, competitive activities within frameworks of agreed rules) with additional objectives such as players acquiring knowledge or skills, receiving guidance and feedback on tasks to perform, or contributing partial solutions to problems. Serious games are intentionally designed to attract, engage, and retain (even addict) players by applying psychology principles. The impact of serious games for educational purposes has received considerable attention: for example, meta-analyses have reported positive impacts on learning outcomes across cognitive, skill-based, and affective categories; their associated costs (e.g., build or purchase a game), however, have received less attention to date. Sidebar 1 provides some additional background on serious games to give context for this work for the reader who is not familiar with the topic.

Games for RE is an emerging area within the broad field of serious games, and has presented results spanning: tools (e.g., commercial and open source games); design techniques for building and testing games; and empirical evaluations including case studies. In this article, we restrict our focus to the games introduced for RE. We present the current landscape by characterizing the games that are currently available for the community. To accomplish this, a lightweight analysis framework that is based on posing classic questions (who, why, what, how, and where) is proposed and applied.

Serious Games: the Broader Context for Games for RE

Serious games have a well-established and growing presence across diverse domains (science, engineering, business, psychology, healthcare, etc.). Their impact has received considerable attention over the last several decades. Meta-analyses of educational games have been reported (see the figure below), which use statistical methods to test hypotheses on large collections of studies. These synthesize the results of existing individual studies, resulting in a more accurate understanding on the state-of-the-art; combined, these meta-analyses provide an evolving mosaic of results for the area. Wouters [13], for example, extends the results reported earlier by Vogel and Sitzmann. Currently, meta-analyses of games for practitioners are lacking.

Vogel (2006) Educating Students (K-20)
Adopting computer/simulation games vs. traditional environment
32 studies selected & analyzed (1986-2003)
Diverse domains
Improved learning outcomes: Cost: not discussed
- Cognitive
- Affective

Recent meta-analyses consistently report improved cognitive learning outcomes (up to 17% better).

Sitzmann (2011) Training Adult Workers
Adopting simulation games vs. technology-based environment
65 studies selected & analyzed (1976-2009)
Diverse domains
Improved learning outcomes: Cost:
- Cognitive   ● Estimate game > 6 times cost
- Skills-based
- Affective

Wouters (2013) Educating Students (K-20)
Adopting serious games vs. traditional environment
39 studies selected & analyzed (1990-2012)
Diverse domains
Improved learning outcomes: Cost: not discussed
- Cognitive
- Skills-based

Numerous moderator variables (e.g., demographics, domain, game concept, game design features) have little effect on the learning outcomes.

Each meta-analysis applies a tailored methodology to select and analyze a collection of game studies. The analyses assess the impacts with respect to learning outcomes and/or the costs involved to build or buy games. Among the many taxonomies for learning outcomes, Kraiger provides a multi-dimensional perspective that is well suited for serious games and includes three categories: cognitive (declarative knowledge), skill-based (procedural knowledge), and affective (motivation, effort, self-efficacy, and reactions) [5]. The costs of adopting a game, either build or buy, received less attention; however Sitzmann's meta-analysis estimates the relative cost of developing a simulation games vs. technology-based learning material: over six times the cost to develop one hour of content. Research on this aspect is scarce.

The meta-analyses report positive impacts of serious games on learning outcomes, both in comparison to traditional and technology-based classroom environments. Many moderating variables have been explored including the demographics of participants, game concept, game design features, game access, and role of the game in a course. In particular, unlimited game access and embedding the game into additional course materials were found to impact positively the learning outcomes.

Sidebar 1: Serious Games – the broader context for Games for RE

Games4RE: A framework to characterize games for RE

Our lightweight framework, Games4RE (refer to Figure 1), for analyzing games for RE is based on five classic questions: *Who* is playing, *Why* are they playing, *What* does the game help with, *How* does the

game help, and *Where* is the evidence. The questions are highly interdependent, as they share a foundation of RE knowledge and serious game development. Sidebar 2 illustrates the analysis of the UserStory Game [6], a gamified platform for requirements elicitation and specification, using Games4RE. The example is intended to help readers understand the practical application of the framework.
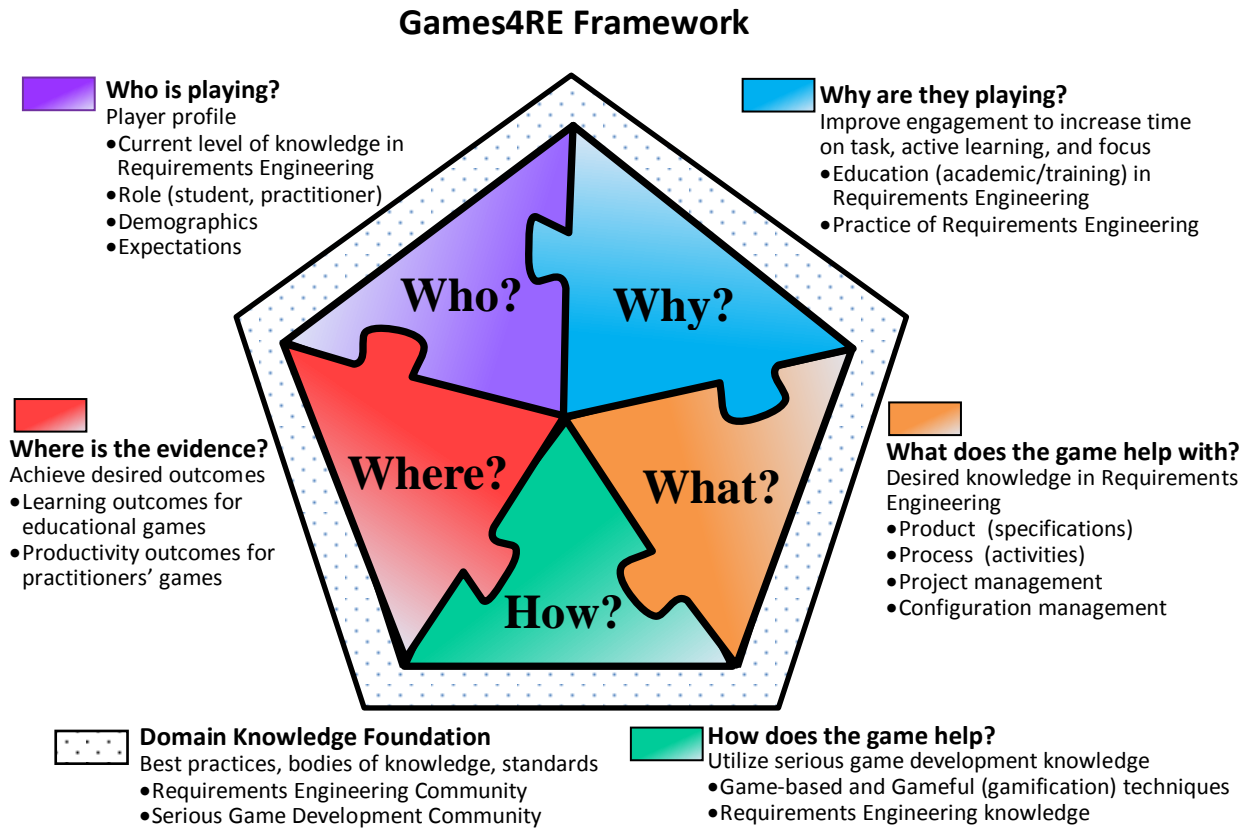
Games4RE Framework

Who is playing?
Player profile
- Current level of knowledge in Requirements Engineering
- Role (student, practitioner)
- Demographics
- Expectations

Why are they playing?
Improve engagement to increase time on task, active learning, and focus
- Education (academic/training) in Requirements Engineering
- Practice of Requirements Engineering

Where is the evidence?
Achieve desired outcomes
- Learning outcomes for educational games
- Productivity outcomes for practitioners' games

What does the game help with?
Desired knowledge in Requirements Engineering
- Product (specifications)
- Process (activities)
- Project management
- Configuration management

Who?   Why?   Where?   What?   How?

Domain Knowledge Foundation
Best practices, bodies of knowledge, standards
- Requirements Engineering Community
- Serious Game Development Community

How does the game help?
Utilize serious game development knowledge
- Game-based and Gameful (gamification) techniques
- Requirements Engineering knowledge

Figure 1. Games4RE: A Lightweight Conceptual Framework

Who is playing? Defines the target audience through their player profile, which can include demographics (e.g., age range), generational expectations (e.g., familiarity with gaming), role (student, practitioner), and current level of expertise in RE concepts or skills (e.g., expert with use cases).

Why are they playing? The two top-level goals, which we identified while reviewing the current landscape, are learning about RE (assisting RE education and training) and supporting RE practice (helping perform RE). Academic education takes place in high schools, colleges, and universities; training is delivered via in-house, commercial, and continuing education courses offered in classrooms or on-line. RE practitioners may work in different types of organizations such as industry, government, and education.

What does the game help with? Relates the game scope with the level of expertise in RE concepts or skills that the game is expected to deliver or to support. Given the breadth and depth of knowledge in RE, it is not feasible to develop one single game that encompasses the whole domain.

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How does the game help? Identifies the techniques from the serious games community that attract and engage players. Initially, a game concept presents high-level descriptions of the genre, world, storyline, and user interface (2D/3D graphics, augmented/virtual/mixed reality). This concept is refined by specifying the game mechanics and how they support teaching and conducting RE. The pedagogical foundation is constructivism, which embraces active, problem-based learning and scaffolding.

Where is the evidence? While *g*ames for RE education are assessed on the achievement of their learning outcomes, games for RE practice are evaluated on how well they support effective RE tasks and high-quality RE artifacts. Furthermore, player engagement should be analyzed. The evidence can be gathered via diverse methods including action research, case studies, and experiments. The instruments to retrieve the evidence range from player perception to expert opinions and pre-/post-testing. Finally, the incurred costs (development, training, operation, etc.) are key to determine cost-effectiveness.

The UserStory game is an on-line, gamified platform for requirements elicitation and specification. It aims to improve the performance of RE practitioners in terms of productivity, quality, and creativity. It employs well-established scenario-based RE languages: user stories and acceptance criteria [7]. 17 gamification mechanics engage the users; as the users progress through the challenges and levels, they compete to earn recognition, badges, and a prize.

Who is playing? RE practitioners who elicit and specify stakeholders' needs for a project. A good foundation of RE techniques and soft skills is required. While the RE practitioners' experience can range from junior to senior, the role of Game Master is filled by an expert.

Why are they playing? The platform supports eliciting requirements of higher quality, quantity, and creativity. As the practitioners create user stories and scenarios, they apply the learned knowledge. The game also serves as a mentoring environment via interactive help from the Game Master and colleagues.

What does the game help with? UserStory helps elicit and specify requirements with scenario-based RE languages. The user stories include what feature to implement, what stakeholder benefits from the feature, and the delivered value. The acceptance criteria scenarios define test cases for the user stories, and include a precondition, the scenario's triggering event, and the expected outcomes.
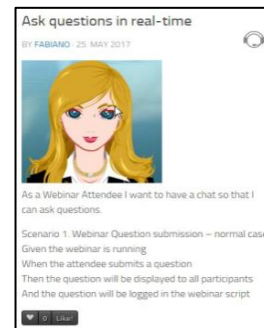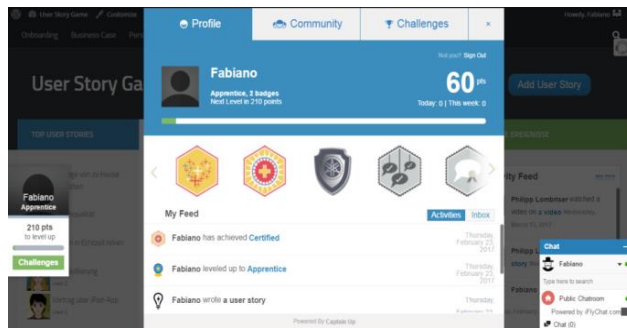
How does the game help? *Achievement recognition* is evoked via points, badges, leaderboard, and a prize. *Game play progression* mechanics support the RE practitioners' journey, beginning with on-boarding, followed by challenges to write requirements in a multi-level game organization. The on-boarding feature presents a business case as a story with an animated video, and advancement through the game is supported by a progress bar and a timed quiz. *Emotional response* is triggered via an activity feed for practitioners to monitor user activity, a like/comment option to garner feedback on the requirements, and appealing artwork.

Where is the evidence? A controlled experiment with practitioners compared UserStory and a non-gamified version; despite the similar engagement (measured via validated scales), RE performance was significantly higher with UserStory (requirements quantity, quality, and creativity). UserStory is a platform built on Wordpress, and it can therefore be reused in new projects by customizing the video that presents the case.

Sidebar 2: The Games4RE Framework Applied: Characterizing the UserStory Game [6]

Analyzing the current landscape

Games for RE have been studied for over a decade through the design and experimentation of games with students and practitioners. We employ the Games4RE framework to review the current landscape.

To identify the games, we started from two cornerstone papers [11, 14] and our previous work [6, 12], and the first author explored further literature through snowballing. After excluding irrelevant papers based on title and abstract, both authors read the remaining papers and progressively filled in an online dataset (http://dx.doi.org/10.17632/c7hhfp5n3d.1) that contains twenty-one games. Although not

exhaustive, our selection represents the spectrum of existing games. Besides including identifying information and a summary, the dataset applies our framework's five dimensions (who, why, what, how, where).

From the dataset, we have selected eleven games (Table 1) that offered high-quality game documentation, and we strived to offer a balanced view on the game types (digital vs. physical, serious game vs. gamification, etc.), the supported RE phase, and their maturity. The eleven games have been organized into two groups to improve the readability of the table. The first group is for games that support RE learning; the second is for games that support RE in practice.

Table 1: Selected subset of the online dataset of games that support RE education and RE practice

Games for Learning about the RE Discipline
Physical role-playing games
UTS-RE. Simulation of projects in undergraduate or graduate University courses with role playing and swapping [14] **RE-Wiki.** A variant of UTS-RE including a Wiki as digital communication means [8]
Physical tabletop games
RE-O-Poly. A board game inspired by Monopoly for teaching (education, training) best practices of RE [11] **GBRE-Suite.** A suite of board games for training on different aspects of RE [1]
Digital games
SW-Quantum. A browser game for teaching (education, training) about the risks of communicating unclear requirements [4] **RCAG.** A 3D simulation game for a University course on requirements elicitation and analysis, featuring NPCs [3] **Earth defense.** A game for middle school students on interviewing in requirements elicitation [10]
Games for Supporting the RE Practice
Physical tabletop games
HATCH. A card game that supports the elicitation and prioritization of social engineering security requirements [2] **Jigsaw puzzle.** A tabletop game with a visual metaphor to foster co-responsibility about conflict handling [9]
Digital games
REfine. A digital gamified elicitation platform with rewards for useful stakeholders [12] **UserStory Game.** A game on BDD-based requirements elicitation with diversified game elements [6]

Who is playing?

Almost all the surveyed games are intended for people with little or no background RE knowledge. A prominent target audience consists of higher education students. An example is the UTS-RE playful simulation approach for teaching RE to (under)graduate students at the University of Technology Sydney in Australia. Similarly, *RCAG* helps teach elicitation and was tested in tertiary education institutions in the United Kingdom. Differently, the *Earth defense* game explains the importance of communication in RE to middle school students who equate computer science with programming. Some games address industry practitioners; for example, the *GBRE-Suite* catalogue of games aims to heighten learner engagement during RE training. Finally, some games support stakeholders during RE projects; for example, the *REfine* gamified platform enables any stakeholders to express their requirements, while the *Jigsaw puzzle* makes stakeholders aware of requirements conflicts.

Fewer works cater to experienced requirements engineers. The *UserStory* game (Sidebar 2) is a gamified platform that aims to increase the elicitation performance of requirements engineers. *HATCH* helps elicit social engineering security requirements and targets a variety of company employees including security engineers, IT administrators, and administration staff.

Why are they playing?

Table 1 differentiates educational games from games for supporting RE practice. Most games for higher education and training (*RCAG*, *UTS-RE*, *GBRE-Suite*) follow a constructivist learning approach that situates the players in an authentic environment where deep learning happens by delivering an active experience. Games for lower education or the general audience foster awareness on what is RE (*Earth defense*) and the role of communication (*SW-Quantum*). The different motivation for playing affects the game design and the depth of the contents, as we show in the following sections.

The games that support RE practice focus on specific needs, including the elicitation of social engineering security requirements (*HATCH*), increasing the participation and motivation of the stakeholders in elicitation through the use of gamified platforms (*REfine*, *UserStory*), and fostering co-ownership about the identification and resolution of conflicts (*Jigsaw puzzle*).

What does the game help with?

The RE education games help users master RE concepts including phases, activities, methods and techniques. Following Kraiger's classification [5], the learning outcomes can be *cognitive* such as concepts and facts, *skill-based* such as the ability to follow procedures, and *affective* such as motivation.

The current games span multiple cognitive outcomes, for example:

- The role-playing in *UTS-RE* covers the whole RE spectrum: elicitation, analysis, specification, validation, and management. Well-defined techniques are exercised, such as a given specification language that the instructor taught in class.
- *GBRE-Suite* has similar cognitive outcomes to *UTS-RE*, but adopts full-fledged games instead of playful role-playing.
- *SW-Quantum* has less depth and aims to create learner awareness of the importance of communicating requirements.
- *RCAG* aims not only to teach concepts and procedures of elicitation and analysis, but also to make the players apply *skills* by assigning tasks to virtual team members.

The games for RE practice can be compared by the RE tasks they support. Seven games in our dataset (including *REfine* and *UserStory* in Table 1) focus on the elicitation phase and differ by the employed game elements and the language for writing requirements. For example, *UserStory* employs behavior-driven development via user stories and acceptance tests. Other games go beyond elicitation: the *Jigsaw puzzle* motivates stakeholders to actively participate in the identification and resolution of requirements conflicts by explaining the potentially negative effects of not doing so.

How does the game help?

Various game elements and mechanics are used to engage the players, depending on the game purpose, its genre, and the game design choices.

UTS-RE relies on the *playful simulation* of RE projects to boost student engagement, and makes use of the *role reversal* game mechanic: students were changing role every week, thereby getting exposed to a variety of situations. The *Jigsaw puzzle* uses a *playful metaphor* to foster co-ownership and co-responsibility about requirements conflicts.

Some approaches are inspired by renowned board games. For example, *RE-O-Poly* builds on *Monopoly*, and the players have to resolve conflicts and determine priorities for selected projects that the players themselves acquire during the game.

Established game mechanics can be reused. *RCAG* poses challenges about elicitation and project management by constraining the possible behavior (*limited time*, resources and *budget*), and by stimulating player immersion via *verbal interaction with non-playing characters*. *SW-Quantum* explains the importance of communicating requirements with the right people at the right time by confronting the player with *challenging decisions*. Under *time pressure*, the player has to quickly choose between analyzing the requirements further and passing imperfect requirements on to the following phase.

Existing platforms for gamified requirements elicitation explore different mechanics. *REfine* uses the *Points-Badges-Leaderboard* triad to rank the most active stakeholders, but also features *endorsing* others' ideas, and provides *real-life rewards* by inviting the most useful stakeholders to the focus group that decides on the next software release. *UserStory* utilizes 17 game elements that cater to heterogeneous analysts; among those, it features an *onboarding program* to welcome the players, a *story* that unfolds as the game progresses, and *missions* that give players concrete goals to strive for.

Where is the evidence?

The type and strength of evidence about the games' (cost)-effectiveness varies considerably. Out of the 21 games in the dataset, five are not evaluated, while the others use one or more instruments such as player perception (7), the opinion or observation of instructors or experts (11), pre- and post-tests (2), and performance on RE practice (2). The prevalent research methods are action research (7), experimentation (6), and case studies (3).

In line with the evidence about serious games (see Sidebar 1), most studies report high player engagement. However, the predominant collection method consists of player perception, often collected via questionnaires that are likely to suffer from response bias. An unexpected result concerns *UserStory*, where gamification leads to high but not increased engagement.

Concerning learning effectiveness, *RE-O-Poly*'s main strength is learning reinforcement: the learning gain was highest when the player possessed a solid background RE knowledge. *RCAG* offers an in-depth comparison between learners higher and further education, showing increased knowledge in both cases, but a significantly higher effect for higher education students.

Positive results exist about task effectiveness: *UserStory* shows significant improvements compared to a non-gamified version of the platform in terms of the generated requirements (number, quality, and creativity). Other games measure only the quantity of outcomes but without comparing to a baseline; for example, HATCH counts the number of social engineering threats, while *Jigsaw* measures the number of conflicts.

Some game mechanics proved to be effective for specific tasks. An unfolding storyline and an onboarding program were especially appreciated in *UserStory*. Weekly role reversal was highly engaging for the student (*UTS-RE*), but led to inconsistent information being provided to analysts (*RE-Wiki*). In *Earth Defense*, the ability of nonplaying characters to deceive engaged learners taught them the complexity of interviewing. In *GBRE-Suite*, the rewards were positively rated, while overly complex rules were an obstacle. The puzzle metaphor of *Jigsaw* helped create a relaxed and collaborative environment in conflict management.

Very few papers discuss cost and other practical issues. Among them, *UTS-RE* reports significant costs for setting up the game, which are mitigated by the expected game reuse in future course editions. A panel of experts judging the *REfine* platform argued that the produced requirements are not detailed enough for the product backlog, and additional expert analysis is required.

Lessons learned in education and practice

Our review reveals guidance for those educators and practitioners who aim to adopt games for teaching RE and for improving the RE practices in their organization.

Education vs. practice. Educational games have been studied much more than games for RE practice. A possible reason is that students are easier to reach for researchers than practitioners. Therefore, before selecting a game for RE practice, it is essential to carefully assess the maturity of the available games.

RE = Elicitation? Elicitation is the most covered RE phase with different degrees of depth. Some games foster awareness (*SW-Quantum*), while others help teach complex tasks such as the extraction of consistent and truthful requirements (*RCAG*, *Earth defense*). In comparison, other RE activities (specification, analysis, validation, and management) have received little attention to date.

(Cost)-effectiveness. We have generally positive evidence concerning the effectiveness of games for RE. Immersion in the game world and fun are often advocated as key reasons for employing serious games, and experiences with the reviewed games show a positive opinion by the learners on the use of a game. However, very little is known about the cost-benefit ratio. Although generic mechanisms such as product lines and customization help, only adoption in industry can address return on investment.

Purpose-centricity. We recommend identifying the intended purpose and tracing it to game design elements as high priority tasks, ensuring the game play and purpose are well integrated. This is essential to ensure both the effectiveness and engagement value of the game. Unfortunately, the literature in the field does not shed much light on the techniques used to address this concern.

The way ahead for research

Although games for RE have been studied for over a decade, the research maturity of the domain remains quite low. Our analysis reveals two main, open issues in the domain.

Research methodology. Most of the games are analyzed through qualitative evaluations of the perceived usefulness and enjoyment. More rigorous experimentation is needed that goes beyond perceived effectiveness (subject to social desirability bias) and that assesses the actual effectiveness for the task at hand against alternative treatments, with many subjects, and under different conditions. Similarly, future studies should strive to ease the work of other researchers by ensuring *recoverability* (for interpretative, action research) or *replicability* (for experimentation). Researchers should assist practitioners in studying the return on investment of the games. The active participation of researchers is essential both to ensure *rigor* in the conduct of the studies and to gain evidence on the *actual* impact.

Better RE for games. Most games make use of basic game design patterns. Virtual and augmented reality may increase learner immersion in an authentic experience. Learning analytics could provide tailored learning experiences, inspired by the successes in online learning. Professional game designers should be involved to heighten player engagement: many games are based on good concepts that are not realized to their full potential. The documentation of the games, both in terms of game play and RE content, varies drastically across the articles, thereby making their comparison challenging. We recommend defining a template based on the Games4RE framework to help improve this situation; such a template could be adopted by researchers and practitioners for building or choosing games for RE.

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Tweets

1. Requirements analysis may be a boring task, right? Have you ever considered using some game?
2. If you are about to design or buy a game for requirements engineering, make an informed choice through the Games4RE analysis framework!
3. Over half of our analyzed games for requirements engineering concern the elicitation phase
4. Games for requirements engineering are effective, but are they cost-effective? To find out, read [Paper URL]