Games for Requirements Engineers

Analysis and Directions

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// The requirements engineering (RE) discipline keeps evolving to cope with increasingly complex systems and shorter development cycles. 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. //

RE REMAINS AN important, challenging, and evolving field of software engineering. Advances in RE are driven by rapidly changing, increasingly complex, and emerging systems, such as apps, cyberphysical 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 The existing teaching materials (courses, books, standards, and best practices) are valuable, but they quickly become outdated.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 online. Lecture slides or podcasts, for instance, rely on limited interactions, making them inadequate for today's professionals who demand learning processes that are fast paced, example- and feedback-driven, as well as enjoyable

One possible solution for the RE community is to explore the use of serious games. Serious games have been under investigation across a broad range of disciplines for more than 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. However, their associated costs (of building or purchasing a game, for instance) have received less attention to date. "Serious Games: The Broader Context for Games for Requirements Engineering" provides some additional background on serious games

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to give context 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 it has presented results, such as 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.

Games4RE: A Framework to Characterize Games for RE

Our lightweight framework for analyzing games for RE, Games4RE (see Figure 1), is based on five classic questions: Who is playing? Why are they playing? What does the game help with? How does the game help? Where is the evidence? The questions are highly interdependent as they share a foundation of RE knowledge and serious game development. "The Games4RE Framework Applied: Characterizing the *UserStory* Game" uses Games4RE to illustrate the analysis of the *UserStory* game,[1] a gamified platform for requirements elicitation and specification. The example is intended to help readers understand the practical application of the framework.

Who Is Playing?

This question defines the target audience through their player profile, which can include demographics (e.g., age range), generational expectations (e.g., familiarity with gaming), role (e.g., 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

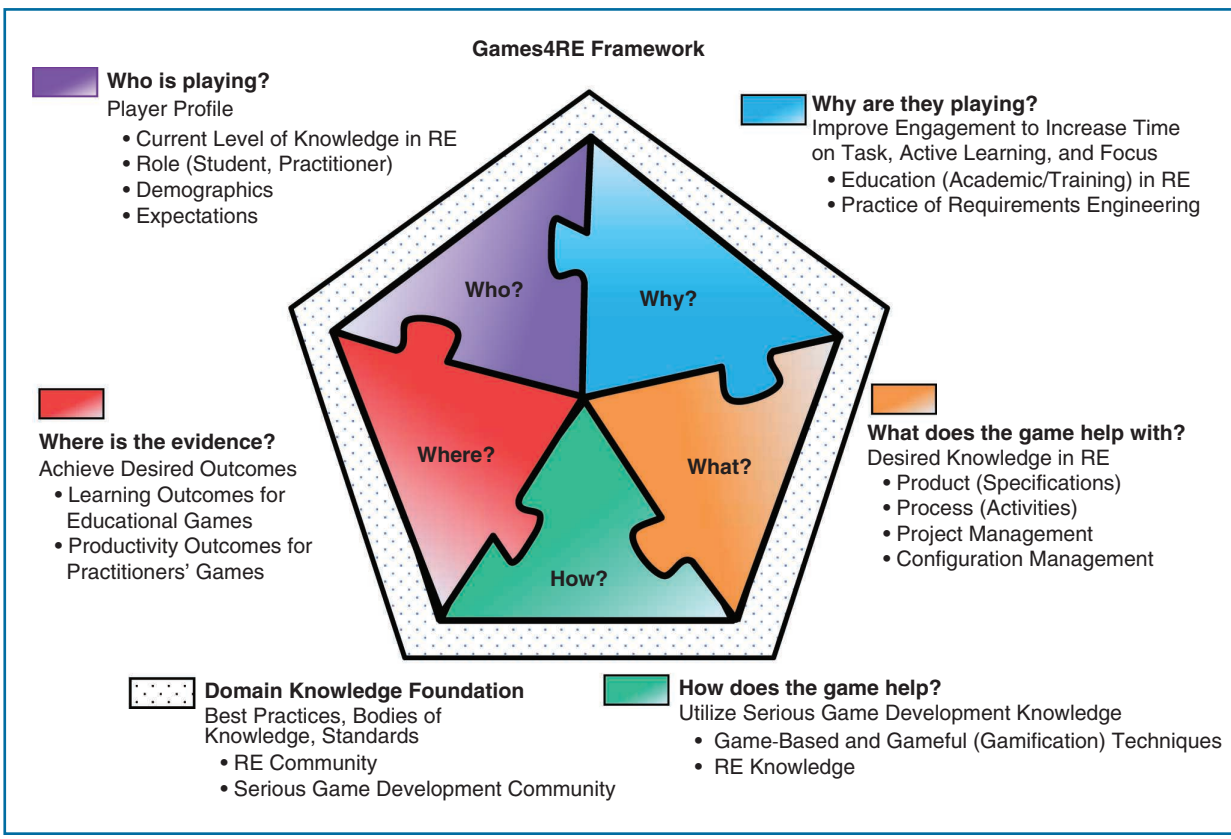

FIGURE 1. Games4RE: A lightweight conceptual framework.

SERIOUS GAMES: THE BROADER CONTEXT FOR GAMES FOR REQUIREMENTS ENGINEERING

Serious games have a well-established and growing presence across diverse domains (science, engineering, business, psychology, and health care). Their impact has received considerable attention during the last several decades. Meta-analyses of educational games have been reported (see Figure S1) that use statistical methods to test hypotheses on a large collection of studies. These synthesize the results of existing individual studies, resulting in a more

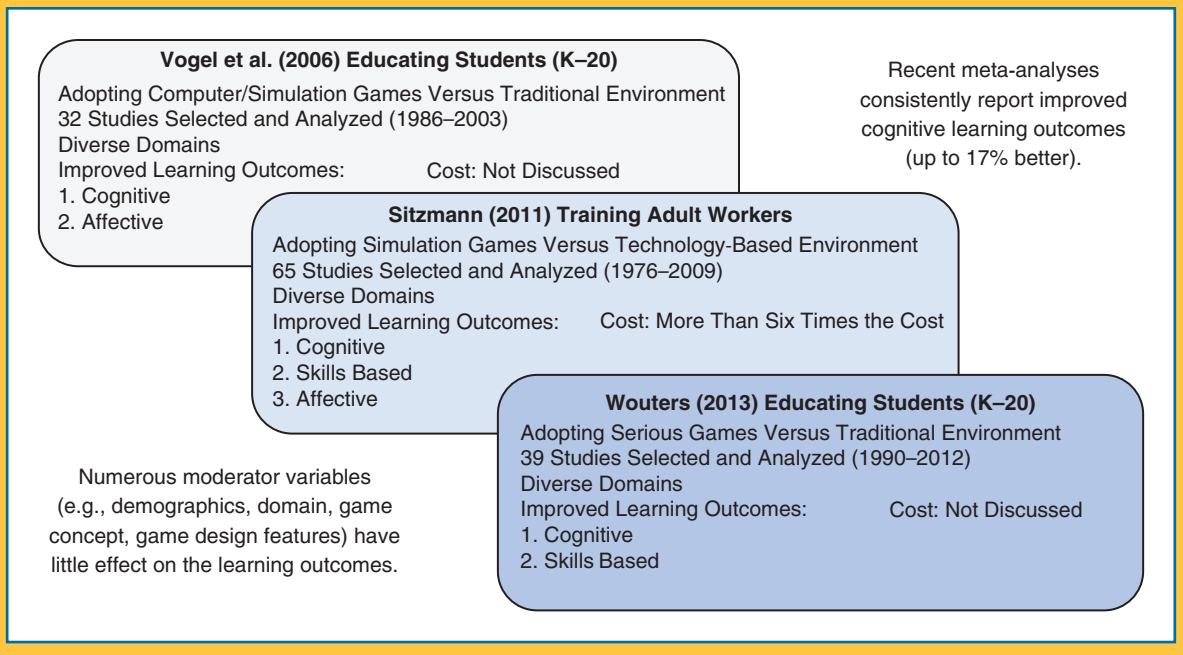

FIGURE S1. Game meta-analyses.

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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 online. RE practitioners may work in different types of organizations, such as industry, government, and education.

What Does the Game Help With?

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

How Does the Game Help?

With this question, techniques are identified from the serious games community that attract and engage players. Initially, a game concept presents high-level descriptions of the genre, world, story line, and user interface (2D or 3D graphics; augmented, virtual, or 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.

SERIOUS GAMES: THE BROADER CONTEXT FOR GAMES FOR REQUIREMENTS ENGINEERING (Cont.)

accurate understanding on the state of the art. Combined, these meta-analyses provide an evolving mosaic of results for the area. The work by Wouters et al.,[S1] for example, extends the results reported earlier by Vogel et al.[S2] and Sitzmann.[S3] Currently, meta-analyses of games for practitioners are lacking.

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 the costs involved to build or buy games. Among the many taxonomies for learning outcomes, Kraiger et al.[12] provide a multidimensional perspective that is well suited for serious games and that includes three categories: cognitive (declarative knowledge), skill based (procedural knowledge), and affective (motivation, effort, self-efficacy, and reactions). The costs of adopting a game, through either building or buying one, received less attention. However, Sitzmann's meta-analysis estimates the relative cost of developing simulation games versus that of technology-based learning material: the cost of developing 1 h of content for a simulation game is more than six times that of making content for technology-based material. Research on this aspect is scarce.

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

References

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S2. J. J. Vogel, D. S. Vogel, J. Cannon-Bowers, C. A. Bowers, K. Muse, and M. Wright, "Computer gaming and interactive simulations for learning: A meta-analysis," *J. Educational Computing Res.*, vol. 34, pp. 229–243, Apr. 1, 2006. doi: 10.2190/FLHV-K4WA-WPVQ-H0YM.

S3. T. Sitzmann, "A meta-analytic examination of the instructional effectiveness of computer-based simulation games," *Personnel Psychol.*, vol. 64, no. 2, pp. 489–528, May 27, 2011. doi: 10.1111/j.1744-6570.2011.01190.x.

Where Is the Evidence?

While games 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- and posttesting. Finally, the incurred costs (development, training, and operation) are key to determine cost-effectiveness.

Analyzing the Current Landscape

Games for RE have been studied for more than a decade through the design and experimentation of games with students and practitioners. We employed the Games4RE framework to review the current landscape. To identify the games, we started from two cornerstone papers[2,3] and our previous work,[1,4] and we explored further literature through snowballing. After excluding irrelevant papers based on title and abstract, we read the remaining papers and progressively filled in an online data set (http://dx.doi.org/10.17632/c7hhfp5n3d.1) that contains 21 games. Although not exhaustive, our selection represents the spectrum of existing games. Besides including identifying information and a summary, the data set applies our framework's

THE GAMES4RE FRAMEWORK APPLIED: CHARACTERIZING THE *UserStory* GAME

The *UserStory* game is an online gamified platform for requirements elicitation and specification.[1] 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.[S4] The users are engaged by 17 gamification mechanics. As the users progress through the challenges and levels, they compete to earn recognition, badges, and a prize (see Figure S2).

- *Who is playing?* Players are 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' experiences 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.

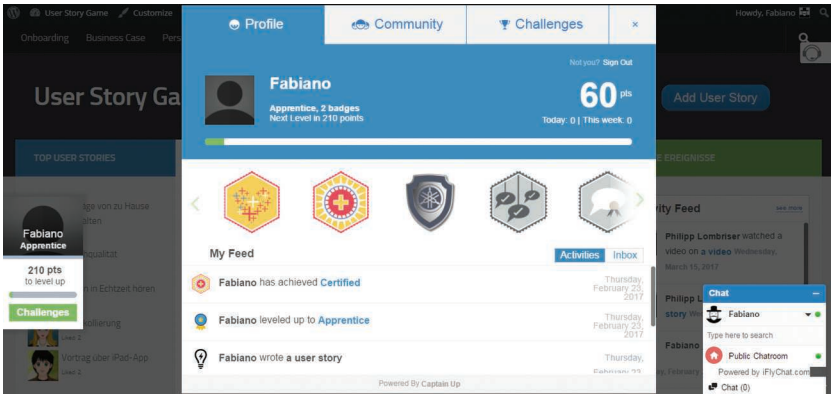

FIGURE S2. An overview of a player's achievements in the *UserStory* game.

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five dimensions (who, why, what, how, and where?).

From the data set, we selected 11 games (Table 1) that offered high-quality game documentation, and we strove to offer a balanced view on the game types (e.g., digital versus physical, serious game versus gamification), the supported RE phase, and their maturity. The 11 games were 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.

Who Is Playing?

Almost all of 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. In contrast, the *Earth Defense* game explains the importance of communication in RE to middle school students who equate computer science

THE GAMES4RE FRAMEWORK APPLIED: CHARACTERIZING THE *UserStory* GAME (Cont.)

- *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, the leaderboard, and a prize. Gameplay progression mechanics support the RE practitioners' journey, beginning with onboarding, followed by challenges to write requirements in a multilevel game organization. The onboarding 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 (see Figure S3). 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 nongamified 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.

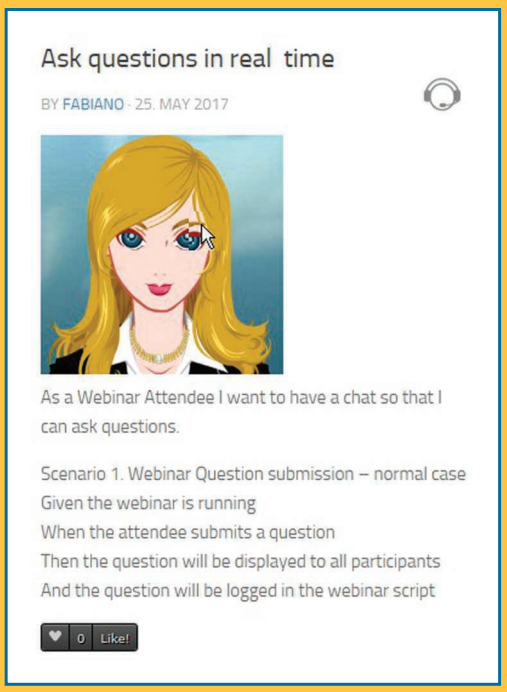

FIGURE S3. The onboarding feature: an avatar presents a business case as a story.

Reference

S4. D. North, "Behavior modification: The evolution of behavior-driven development," *Better Softw.*, vol. 26, pp. 26–31, Mar. 2006.

with programming. Some games address industry practitioners. For example, the *GBRE-Suite* catalog of games aims to heighten learner engagement during RE training. Finally, some games support stakeholders during RE projects. For instance, the *REfine* gamified platform enables any stakeholders to express their requirements, while the jigsaw puzzle[11] makes stakeholders aware of requirements conflicts. Fewer works cater to experienced requirements engineers. The *UserStory* game (as seen in "The Games4RE Framework Applied: Characterizing the *UserStory* Game") is a gamified platform that intends 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 that support RE practice. Most games for higher education and training (*RCAG*, *UTS-RE*,

Table 1. A selected subset of the online data set 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[3]
RE-Wiki: A variant of UTS-RE including a wiki as digital communication means[5]
Physical tabletop games
RE-O-Poly: A board game inspired by Monopoly for teaching (education, training) best practices of RE[2]
GBRE-Suite: A suite of board games for training on different aspects of RE[6]
Digital games
SW-Quantum: A browser game for teaching (education and training) about the risks of communicating unclear requirements[7]
RCAG: A 3D simulation game for a university course on requirements elicitation and analysis, featuring nonplayer characters[8]
Earth Defense: A game for middle school students on interviewing in requirements elicitation[9]
Games for supporting the RE practice
Physical tabletop games
HATCH: A card game that supports the elicitation and prioritization of social engineering security requirements[10]
Jigsaw puzzle: A tabletop game with a visual metaphor to foster co-responsibility about conflict handling[11]
Digital games
REfine: A digital gamified elicitation platform with rewards for useful stakeholders[4]
UserStory: A game on behavior-driven-development-based requirements elicitation with diversified game elements[1]

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 eliciting 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 the classification of Kraiger et al.,[12] 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, such as the following.

- 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 it adopts full-fledged games instead of playful role-playing.
- *SW-Quantum* has less depth, and it strives 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 data set (including *REfine* and *UserStory*, as shown 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's purpose, genre, and design choices. *UTS-RE* relies on the playful simulation of RE projects to boost student engagement, and it makes use of the role-reversal game mechanic: students were changing roles every week, thereby being exposed to a variety of situations. The jigsaw puzzle uses a playful metaphor to foster coownership and coresponsibility 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 nonplaying 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 it also features endorsing others' ideas, and it 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 that welcomes the players, a story that unfolds as the game progresses, and missions that give players concrete goals to strive for.

> Before selecting a game for RE practice, it is essential to carefully assess the maturity of the available games.

Where Is the Evidence?

The type and strength of evidence about the games' (cost)-effectiveness varies considerably. Out of the 21 games in the data set, five are not evaluated, while the others use one or more instruments, such as player perception (seven), the opinion or observation of instructors or experts (11), pre- and posttests (two), and performance on RE practice (two). The prevalent research methods are action research (seven), experimentation (six), and case studies (three).

In line with the evidence about serious games (see "Serious Games: The Broader Context for Games for Requirements Engineering"), 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 among learners in continuing or higher 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 nongamified 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 the jigsaw puzzle measures the number of conflicts.

Some game mechanics proved to be effective for specific tasks. An unfolding story line and an onboarding program were especially appreciated in *UserStory*. Weekly role reversal was highly engaging for the student (*UTS-RE*), but it 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 jigsaw puzzle metaphor helped create a relaxed and collaborative environment in conflict management.

> We recommend identifying the intended purpose and tracing it to game design elements as high-priority tasks, ensuring that the gameplay and purpose are well integrated.

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.[3] A panel of experts judging the *REfine* platform argued that the produced requirements are not detailed enough for the product backlog and that 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 Versus 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 are practitioners. Therefore, before selecting a game for RE practice, it is essential to carefully assess the maturity of the available games.

Is RE Only Elicitation?

Elicitation is the most-covered RE phase, with different degrees of depth. Some games foster awareness (*SW-Quantum*[7]), while others help teach complex tasks, such as the extraction of consistent and truthful requirements (*RCAG*[8] and *Earth Defense*[9]). 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 the return on investment.

Purpose Centricity

We recommend identifying the intended purpose and tracing it to game design elements as high-priority tasks, ensuring that the gameplay 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.

Although games for RE have been studied for more than a decade, the research maturity of the domain remains quite low. Our analysis reveals two primary 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 gameplay 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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