

BakeRE: A Serious Educational Game on the Specification and Analysis of User Stories

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Abstract—Learning requirements engineering (RE) notations is a tedious task for most people, because this learning activity is all but engaging. As an alternative to traditional educational methods, we propose BAKERE, a serious educational game for RE. The game focuses on specific learning objectives: the specification and analysis of requirements with user stories. BAKERE is the first game proposed to address these learning objectives. It is a multilevel puzzle game that can complement courses (traditional or on-line), such as a general software engineering or a specialized RE course. The player assembles user stories for a specific system by combining building blocks (roles, actions, benefits) from a predefined collection. As the player progresses through the levels, the difficulty increases. At the end of each level, learning feedback is provided to the player. Besides describing the game and its learning objectives, we present the game design process and outline in-progress research that aims to extend BAKERE through its embedding within an RE course.

Index Terms—requirements engineering, serious games, user stories, QUS framework

I. INTRODUCTION

Serious educational games (SEGs) are interdisciplinary systems that embrace concepts that span game development, pedagogy, and domain-specific subject matter. SEGs are widely recognized to provide numerous benefits, including improved student participation, time on task, timely assessment and feedback, and ultimately the achievement of learning outcomes [1]. Such games have been proposed for many domains [2], including requirements engineering (RE) [3].

Game development concepts address the “fun” nature of a SEG, and serve to attract, engage, and retain players [4]. They include the genre, number of players, and levels to establish a high-level framework for a game (e.g., a single player, multilevel, puzzle game). The distinguishing characteristics of a game are driven by decisions on the theme, narrative, game play challenges and progression, mechanics, economy, and so on. Digital games utilize aesthetically pleasing 2D/3D graphics and music/sound effects to enhance the game play experience.

The “serious” nature of SEGs is addressed with the pedagogical foundations and the domain-specific subject matter [5]. The pedagogical foundations include theories from educational psychology (e.g., cognitive, social constructivist theories [6]) and taxonomies (e.g., revised Bloom’s [7]). The learning theories provide rigorous educational foundations that include problem-based learning, peer learning, assessment and feedback, and classification of lower- to higher-order thinking

skills. The learning objectives reflect a subset of the domain-specific subject matter. For example, the learning objectives in an RE game may include the traditional elicitation, specification, analysis, validation, and management activities [8].

Recently, a survey of RE game and gamification proposals [3], [9] has identified and analyzed 21 RE games. The games are a mix of digital and tabletop card games that address a range of RE educational topics. Four of the games span the established RE activities, either within one game [10], [11] or over a set of games [12], [13]. Other games are more narrowly focused. For example, nine of the games focus on elicitation, four focus on soft skills (e.g., communication, negotiation, conflict management), and two focus on project management topics (e.g., effort estimation). With respect to specification notations, a game on i^* is available [14]; user stories [15] have received some attention from an engineering perspective in the UserStory game [16] and from a project management perspective in the Planning Poker [17] game.

The UserStory game is an on-line, gamified platform for requirements elicitation and specification. It aims to improve the productivity, quality, and creativity of RE practitioners while using well-established scenario-based RE languages: user stories and acceptance criteria. The game adopts 17 mechanics; as the players progress through the challenges and levels, they compete to earn recognition, badges, and a prize.

The Planning Poker game is a tabletop card game for practitioners that focuses on effort estimation for requirements captured in user stories. The project management and negotiation game play has been inspired by the card game Poker.

Currently, there are no SEGs for RE available to help learn about the specification and analysis of user stories. Here, we propose the SEG BAKERE which assists in learning the theory and application of user stories with a focus on their specification and analysis. BAKERE is a multilevel, single-player puzzle game for mobile phones. The player is challenged to assemble high-quality user stories by combining predefined building blocks [18]. Thematically, the game takes place in a bakery, and the building blocks are parts of a cake: the bottom cake layer, the icing, and the decoration. We have chosen this theme because of the widespread popularity of baking in the media (e.g., TV shows, mobile phone games).

BAKERE has the potential to complement traditional or on-line courses that cover RE topics, either as part of an intro-

ductory software engineering course or a specialized course on RE. We describe our on-going embedding of BAKERE in an RE course, through which we aim to extend the game. The students are required to build expansion packs: collections of user stories that the game can interpret to create new challenges for the players. This activity has educational merits too, as it makes students exercise higher-order thinking skills.

The remainder of this paper is organized as follows. BAKERE is introduced in Section II. The preliminary validation of the game is presented in Section III. The research roadmap and conclusions are presented in Section IV.

II. BAKERE GAME

We describe the general game concept in Section II-A, detail the learning objectives in Section II-B, and outline the game elements and mechanics in Section II-C.

A. Game Concept

BAKERE assists in the learning and practicing of user stories. The game is an association puzzle game, where a player has to ‘build’ a user story by selecting among a set of building blocks. The building blocks realize the three structural components of a user story: role, action, and benefit. Thematically, the game takes place in a bakery, where the building blocks are a cake’s ingredients: the bottom (role), the icing (action), and the decoration (benefit).

The game is structured into multiple levels, each focusing on certain learning objectives. As the player progresses through the game, they learn and apply increasingly advanced concepts concerning user stories and their use in agile RE. BAKERE is mostly intended for people who are learning about user stories, whether as part of a broader software engineering or in a more specialized RE course. While some levels build on the Quality User Story (QUS) framework by Lucassen *et al.* [18], the core game mechanics allow its adoption in a variety of educational environments. A distinguishing trait of BAKERE is its focus on cognitive processes at the levels of *applying* and *analyzing*, as opposed to the lower-order thinking skills that characterize most other games for RE [3].

To engage players, BAKERE relies on multiple game design principles, such as rapid on-boarding, appealing graphics, a reward system, and multiple levels with increasingly difficult challenges. The principal game mechanics are illustrated in Fig. 1, which shows the prototype implementation of BAKERE on an Android phone. On the left side of the figure, the current score, timer, and cake that is being built are shown. On the right, the player picks the ingredients to compose the cake while building a user story (shown at the bottom). In the figure, the player has already selected the first two building blocks for the current cake, realizing the role and action of the user story: “As a Student, I want to get a notification when a lecture is dropped.” At this point, the player is dragging the third part, the benefit, “I know I do not have to attend the lecture” as a decoration to complete the current cake/story.

The same mechanics are also used to educate on acceptance criteria, which are often written on the back of a user story

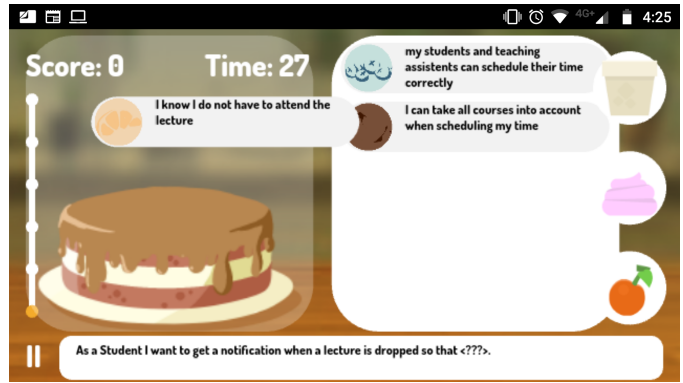


Fig. 1. The player decorates a cake by choosing the *benefit* of a user story

card. To simplify the explanation, except in the level-by-level description of Section II-B, we use the term *user story* in a general sense that also includes *acceptance criteria*.

B. Learning Objectives

The educational foundations of BAKERE originate from the research on user stories in RE [18], [19]. We take inspiration from those materials and adopt those aspects that we see fit for a mapping to a digital game. Specifically, our selection of learning objectives pays attention to preserving the enjoyability of the game. BAKERE is a complementary learning tool, rather than a replacement of traditional lectures or tutorials.

We describe the learning objectives following Bloom’s revised taxonomy [7]. Overall, BAKERE aims to let the player/learner apply their knowledge and use their analytical skills. We present the learning objectives on a level by level basis. There are four levels in the game (i.e., Levels 1,2,3,4).

1) *Building a User Story*: in Level 1, which is introduced by a short tutorial, the player is educated on the basic structure and usage of a user story. To score points, the player has to create suitable user stories for a given epic (see Fig. 2). The learning objectives are the following:

- O_{1.1} *Remember* the structural make-up of a user story: role, action, and benefit;
- O_{1.2} *Understand* the connection between an epic (context) and a user story;
- O_{1.3} *Apply* the knowledge from O_{1.1} and O_{1.2} by combining building blocks into correct user stories given a context.

Objective O_{1.3} is shared with Levels 2 and 3, which also adopt the game mechanics of associating the building blocks of a user story.

2) *Quality User Story Framework, basics*: Level 2 focuses on letting the player gain experience with the QUS framework; in particular, three simple quality criteria that concern the writing of an individual user story are considered:

- *Atomic*: does a user story tackle one problem at a time?
- *Minimal*: does a story contain nothing more than a role, action, and benefit?
- *Full sentence*: is a user story formulated as a well-formed sentence (in English)?

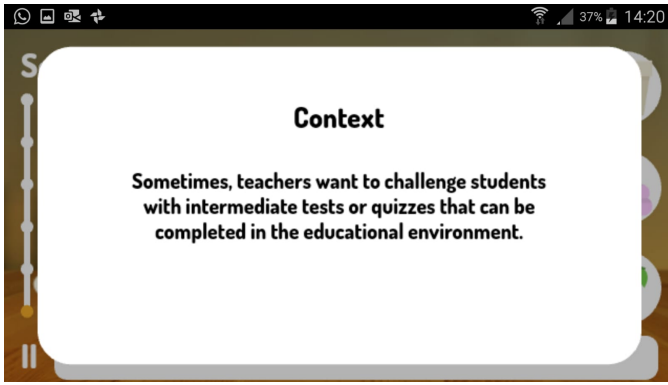


Fig. 2. Epics are shown to introduce an association batch; this transition helps in the learning objective $O_{1.2}$

Unlike Level 1, in which all building blocks shall be associated, in this level the challenge for the player is to not associate those building blocks that suffer from one or more quality defects. The number of criteria to simultaneously keep track of increases as the level progresses. The learning objectives for this level are as follows:

- $O_{2.1}$ *Remember* that different quality criteria exist for user stories, specifically the QUS framework [18] and the criteria it entails;
- $O_{2.2}$ *Understand* that high-quality user stories fulfill all of these criteria and how they are met;
- $O_{2.3}$ *Evaluate* which user stories in a set are correct and which ones contain defects.

3) *QUS Framework, advanced*: Level 3 shares the same learning objectives as Level 2 ($O_{2.1} - O_{2.3}$) and applies them to three additional quality criteria:

- *Problem oriented*: does a story only specify the problem, not the solution to it?
- *Unambiguous*: does a user story possess a single meaning, or is the wording ambiguous so that multiple meanings can be entailed?
- *Independent*: is a user story work specified on its own without referring to other user stories in the set?

4) *Acceptance criteria*: In Level 4, the player is educated on acceptance criteria, their purpose, and their structure. We take Dan North's notation [20] for expressing acceptance criteria: "Given some context, When some action is carried out, Then a set of observable consequences occur."

In this level, the context for the association challenge is specified as a user story (instead of an epic), while the player has to associate the building blocks of an acceptance criterion (instead of a user story).

The learning objectives are as follows:

- $O_{4.1}$ *Remember* what acceptance criteria are and why they are used;
- $O_{4.2}$ *Understand* the relationship between acceptance criteria and user stories;
- $O_{4.3}$ *Apply* the knowledge from $O_{4.1}$ and $O_{4.2}$ to build acceptance criteria by combining existing blocks.

C. Game Elements

BAKERE is currently a single-player game, where the player engages in the challenges presented by the game. The main objectives are to score points and to reach the end of the game. To do so, the player has to correctly combine the building blocks of user stories (in Level 4, acceptance criteria).

Each of the four levels includes some challenges, or batches, of user stories. Each of these batches requires the association of three to five user stories. The number of user stories per batch increases as the player progresses through the game.

Points are scored as defined in Fig. 3. The scoring of each user story depends on the time it takes for the player to associate its elements (in seconds) and whether or not it is correct. The faster a user story is completed correctly, the more points are assigned. A nearly instantaneous correct answer is awarded 200 points; a correct answer using more than 45 seconds is awarded 0 points. For incorrect answers, the scoring system is inverted: many negative points for a quick incorrect answer (to avoid guessing), and smaller penalties for incorrect answers that take longer. The scoring scheme employs an exponential function where the number of points scored decreases only slightly in the first few seconds, but the reward becomes much smaller as we approach the 45 seconds. A converse scheme is used for wrong answers. Note that we do not intend to link the points with a grade for the learner.

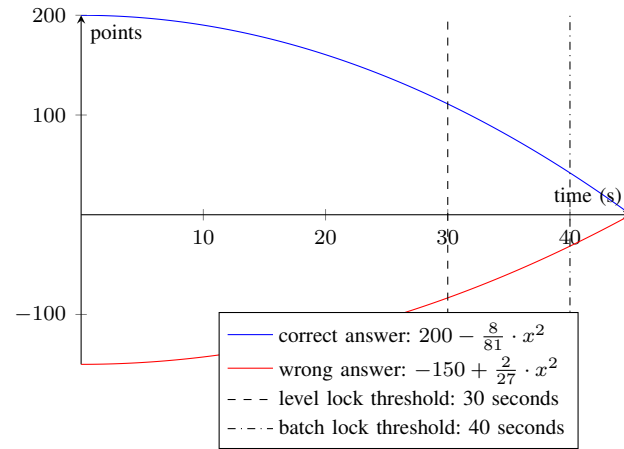


Fig. 3. Plot illustrating the point scoring scheme; completion time is shown on the x-axis, while the number of points awarded is on the y-axis

Additional point-based obstacles are set to make it harder for the player to advance in the game:

- *Batch lock*: to complete a batch, a certain number of points must be scored. The game requires a player to take less than 40 seconds per story on average. If an insufficient number of points is scored, an additional batch of user stories is given to the learner, who has to associate one of those user stories correctly.
- *Level lock*: to unlock a level, the player needs to accumulate a certain number of points. If that is not the case, the player needs to re-play a previous level to gain more points; the points that have already been earned in that

level before retrying are deducted to deter players from repeating the levels in which they have high scores. The level lock score is based on 30 seconds per user story.

The cake bakery metaphor is the basis of the game play. Just like you assemble a cake by combining its ingredients, you author a user story by putting together its role, action, and benefit. Both audio and visual elements are aligned with the theme: the colours are based on publicly available bakery and pastry theme palettes (see Section III-A for details). Animations are played to give feedback and create a feeling of satisfaction when dropping an item; these are augmented with an audio cue to improve the game feel and to generate feedback. A celebratory audio cue is played and a colourful particle explosion (see Fig. 4) is shown for correctly associated user stories. When finishing a batch or a level, fireworks are shown accompanied by another, longer celebratory sound. When an error is made, a buzzing sound is played.

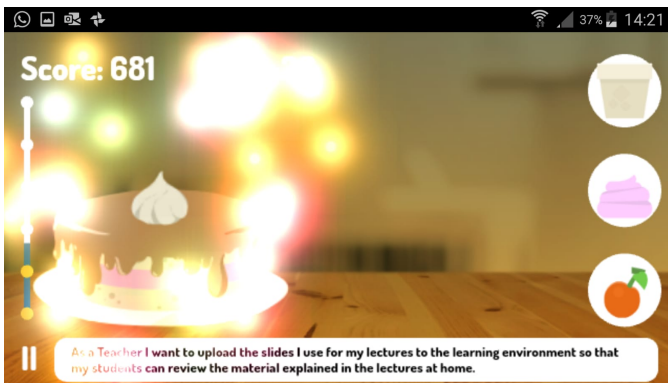


Fig. 4. The player is rewarded via graphical and auditory cues when a correct association is made

We employ the time for play, time for thought serious game design pattern [21], which alternates phases in which the game play is central and phases where reflection is necessary. Every level is introduced by a description of the level's learning objectives, and by examples of correct associations and errors (time-for-thought). The learner plays the level by associating the user stories in the batches (time-for-play). When a level completes, a short debriefing is performed (Fig. 5), in which players are shown their level performance, indicating their main mistakes as well as the tasks in which the player performed the best (time-for-thought).

Finally, to make the game usable in a classroom setting, BAKERE can optionally activate an online leaderboard that keeps track of high scores. When the students in a class play the game simultaneously, their single play mode becomes a multilateral competition among all students, and an additional objective is introduced: outscoring the other students.

III. PRELIMINARY VALIDATION

While a thorough evaluation of BAKERE has not been performed yet, preliminary results have been obtained through the creation of a prototype and the execution of playtesting sessions to improve the game.

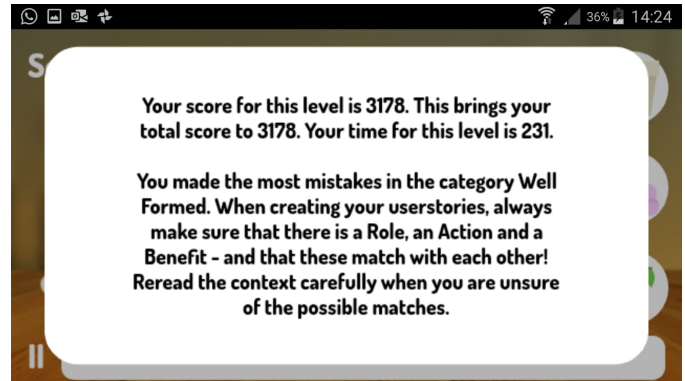


Fig. 5. A debriefing screen is shown at the end of each level

A. BAKERE Prototype

The BAKERE prototype is an application created using HTML5 and Javascript in combination with the Phaser 3 Game Framework [22], which is specifically designed for creating 2D web-based games (mobile or PC). This framework offers many features such as simplified asset handling and easily accessible input elements; furthermore, extensive documentation exists.

To turn the web application into native mobile applications for Android, iOS, or Windows Phone, the Apache Cordova toolset has been used [23]. This toolset adopts a shared Javascript API to generate hybrid web applications that have a similar look-and-feel as native mobile applications, while behaving like web applications under the hood.

The game assets are a mix of new components specifically created for BAKERE and existing components from open source databases. These assets include: (i) a freely available Google web font called Dosis [24]; (ii) the menu buttons, which are taken from a Creative Commons 0 (CC0) sprite sheet hosted at Kenney [25]; (iii) the audio assets, which are obtained from Freesound [26] under the CC0 licence; and (iv) the particle effects and sprites, freely available on Phaser [22].

B. BAKERE Playtesting

Two playtesting sessions were held during the development of BAKERE to ensure its quality; the game was assessed at different stages of completeness. The first session involved three participants in March 2019, when the prototype's initial game mechanics had been implemented. The second session involved nine participants in April 2019 as a final test with a feature-complete game before the adoption of the game in an RE course.

During the first playtest session, the participants were tasked with playing through all four levels of the game using a subset of the database as input. Each participant was asked to use the think-aloud protocol while playing through the game and their progress was observed by first author, who developed the game. Additionally, their time performance was logged with respect to different achievements: completion of the first user story, completion of the first batch of user stories, and completion of each level. Finally, when bugs or usability issues were found, these too were noted for further development.

Our findings in this playtesting session led to a general shortening of the game. We found that the levels in this version of the game were too long, and we therefore removed some batches: two batches in Levels 1 and 4, and one batch in Levels 2 and 3. Also, we observed how the first user story and batch took much longer than the following ones, and therefore removed one user story to simplify the first batch. Finally, the participants indicated that Levels 2 and 3 had too few defective user stories; thus, we increased the number of defective user stories for the player to avoid associating.

The purpose of the second test session was to make final adjustments to the difficulty of the game, scoring system, and time limits imposed upon the players. It also functioned as a stress test, to see if a larger group of players using the game at the same time would not overload the online leaderboard functionality. The participants were asked to speak aloud as they play the game, and to answer short questions about usability and enjoyment upon finishing the game.

The main findings concerned the usability and the difficulty of the game. The participants reported the level introductions were too long, which led to a significant shortening of those texts. One major change was the removal of the QUS criteria description before a level; instead, details could be retrieved on demand while the learner is playing. Concerning difficulty, we found that several players were unable to reach the level lock threshold because association errors subtracted points. Thus, we reduced the difficulty by requiring a maximum of 30 seconds per user story instead of 25 seconds. Also, the players reported that Level 3 was easier than Level 2. To address this, we swapped the *full sentence* and *problem oriented* criteria from their original placements in Levels 3 and 2, respectively. Level 4 was also reported as being easier than the first three levels; however, this aligned well with the dramatic arc principle in which a drama intensity is expected to decrease between the climax and the end. Finally, small improvements were identified, such as showing the points achieved after each batch and level. A general appreciation for the leaderboard was expressed, but its effectiveness was not extensively evaluated. Due to the excessive game difficulty, the scored points were manually adjusted during the playtesting.

IV. ROADMAP AND CONCLUSION

We present how we are using BAKERE in an educational setting in Section IV-A, future game enhancements in Section IV-B, and implications of the research in Section IV-C.

A. Embedding in an RE course

We are currently using BAKERE in the context of an MSC course in RE with approximately 60 enrolled students. Our utilization of the game in the course intertwines distinct goals: providing an engaging construct that embodies the pedagogical objectives the students should achieve as part of the course assessments (workshop exercise, group assignment); and the extension and experimental validation of BAKERE from a research perspective.

Formative assessment (workshop exercise). First, the game is going to enrich the learner experience on the basics of user stories. Through an analysis of a collection of educational materials [19], we have observed the use of exercises to apply the knowledge that has been transmitted through lectures. In our setting, we adapt these materials and fit them into a shorter version that conveys the basic knowledge via theory and examples. After ten days, the students are going to be exposed to a workshop in which they play BAKERE as an exercise. The intent is to heighten their learning experience by applying their knowledge of user stories. While doing so, we aim to stimulate engagement through the embedded game elements and by projecting a real-time leaderboard to foster competition among the students toward obtaining the highest score. This exercise is not going to be graded to mitigate evaluation apprehension threats.

Formative assessment (group assignment). Second, the course includes one assignment in which self-formed groups of two students are asked to create a set of levels for a software system of their choice. We call this collection an *expansion pack*. Our aim is to reach an additional learning objective: “the student is able to create both correct and defective user stories.” Note how this learning objective reaches the highest level in the cognitive dimension [7]: *create*. This cognitive level would be difficult to reach through BAKERE’s game mechanics. The addition of more complex mechanics to achieve this level has not been pursued as it may make the game less enjoyable. The student groups have two weeks to create an expansion pack that is defined as per Table I. The groups are provided a template in an Excel file format for the assignment. This task is part of a graded assignment that counts 10% of the final course grade. This assignment aims to help the students master the user story notation.

TABLE I
THE CONTENTS OF AN EXPANSION PACK, WHICH ARE GOING TO BE DELIVERED BY GROUPS OF STUDENTS DURING THE RE COURSE

Item	Quantity
Epics for a software system	8
Correct user stories	40: 5 per epic
Defective user stories	24: 4 per criterion
Correct acceptance criteria	15, in batches of 3

Game extension. After checking the correctness of the expansion packs submitted by the groups, we plan to select some of the most innovative levels and make them part of BAKERE. The import functionality is already implemented in the prototype, thereby allowing the player to select which expansion pack to play when starting the game. Besides our use in the RE course, we are going to employ BAKERE to train professionals in the software companies in our network.

Game validation. While conducting our experiment within the context of the RE course, we are going to measure learning gain and retention. This evaluation includes a pre-test that is administered before the game, a post-test right after the game is played, and an additional test one month after the play session. Exercises are going to be created for these tests

that assess the same knowledge but through slightly different quizzes, to avoid resemblance with the game mechanics.

B. Game Enhancements

An important design decision, after evaluating multiple game concepts, is the selection of a drag-and-drop association game that is set in a cake bakery. Nevertheless, the same puzzle game mechanics can be adapted to different themes. Besides simple variations, such as composing pizzas, burgers, or ice creams, we can explore radically different themes, including customizing a car or a motorbike.

Also, we have opted for user story learning based on their popularity and our educational needs. It is possible to reuse the same game concept for other contexts, such as the many facets of ambiguity in RE [27]: vague terms; attachment, elliptical, and anaphoric ambiguity; language errors, and so on.

Finally, just like any other game, we plan to tune the scoring system and the level of difficulty to deliver a consistently engaging game experience. This tuning is going to rely on the analysis of the outcomes of BAKERE's use in the RE course.

C. Implications

We have presented BAKERE: the first example of a full-fledged educational game for the specification and analysis of user story requirements. In comparison with other existing games for RE, BAKERE supports higher levels in the cognitive knowledge dimension of Bloom's taxonomy of learning.

The main game mechanics are borrowed from a notoriously engaging game series: cooking and baking games. We have made this choice to avoid a common pitfall in serious games: creating a game that focuses on the educational aspects but falls short in engaging the players [28].

Furthermore, we have presented our ongoing work on embedding BAKERE in an RE course at the MSc level. While doing so, we strive to ensure a high-quality learning experience for the students, while obtaining feedback about the game. A unique expected output is that the students' learning process is going to result in expansion packs for BAKERE.

Our research goal toward the next edition of the IEEE RE conference is to present a revised version of BAKERE that includes the expansion packs and has been tested empirically both in a higher education setting as well as through professional training sessions within our network of collaborating software companies.

Future work includes experimenting with different game mechanics (e.g., fixing defects), using different themes, or making a multi-player version. We facilitate this by offering the code as an open source artifact¹, so that other researchers or RE educators/trainers may adapt it for their needs.

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¹<https://github.com/RELabUU/BakeRE>