Designing a Mobile Game for Introducing Learners to a Soap Making process

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Abstract*:* Bunno's Fabulous Soap-Making Challenge is intended to be both, a game that is played for fun and a game from which subject content can be learned. The game is modelled on and represents authentic, real-world chemical processes. Specifically, it promotes the learning of aspects central to the soap-making process. The game is a resource-managing game in which players plan, organize, and execute the production of soap. Players source the raw materials, acquire the technical equipment, create an efficient lab setup and produce and sell soap in an economically sustainable way. The game is centrally based on the idea of constructivist learning. Players encounter an inspiring and challenging situation and are active, in control, and make their own decisions and experiences. Their actions trigger immediate responses and are consequential. The main contribution of this article is a detailed description, a conceptual explanation, and a critical discussion of the game design. In addition, this article briefly describes the educational theory which informs the project, how the game design is actually realized in the implemented game and how it can be played, and the game's educational content and the projected learning outcomes.

Keywords: chemical engineering, education, game design, learning

1. Introduction

Digital games have proven to be considerably relevant for educational and training purposes (Gordillo et al., 2022; Suzuki et al., 2021). The innate ability of games to provide active, engaging, and experiential learning environments supports their growing adoption in educational settings. Furthermore, game-based learning – the integration of learning contents into games for educational purposes, fosters the constructivist learning approach promoting personalised learning and new knowledge construction (Nino & Evans, 2015). Science, Technology, Engineering, and Mathematics (STEM) subjects have been found to benefit from games as a pedagogical tool (Hu et al., 2022; Suzuki et al., 2021). Games can potentially make the learning and retention of knowledge in these subjects more effective while improving learners' experience. This could, in turn, increase interest in STEM education.

There are, however, limitations to the number of relevant available games that enhance learning while entertaining players. Although there are many educational games available to players, there are fewer games that are relevant to STEM education. In order to take advantage of the affordances of games, particularly in STEM education, it is necessary that relevant games on different topics are readily available. An understanding of how to design games that are both fun and educating could as well increase the number of STEM games available to learners and educators.

The use of games in (formal) education has been proposed and also implemented many times (McGonigal, 2011; Gee, 2007), before and after the 'digitalisation of society or the massive economic success of computer games' (Fuchs, 2014, p.136). Various notions are associated with the idea of purposeful play. In education, Majuri et al. list "serious games, edugames or games for education, game-based learning, and lately, gamification" (2018, p.12). Many contexts and various learning practices, and different educational content have been targeted (Atmaja et al., 2020; Evangelopoulou & Xinogalos, 2018; Squire, 2006; Vargianniti & Karpouzis, 2020). Games (specifically digital games) are incredibly popular with players, and players spend much time playing them and improving their performance. The idea of educational games is here taken to be to channel some of the energy players lavishly spend on games with no or very little educationally relevant content towards games from which players can learn useful knowledge and skills. While a lot of enthusiasm appears to exist for the endeavour, and great expectations are regularly formulated (Xi & Hamari, 2019), the purposeful exploitation of play for learning has yet met with often mixed results (Cermak-Sassenrath, 2022; Dichev & Dicheva, 2017; Koivisto & Hamari, 2019), and has also drawn a fair amount of criticism (Fizek, 2014; Raczkowski, 2014; Dichev & Dicheva, 2017; Tulloch & Randell-Moon, 2018). Many hard questions about the intricate connections between play, learning theories, and practical implementations continue to exist (Rodrigues da Silva et al., 2019). This paper describes the design of a digital game that teaches the principles of soap making to learners. It is not only a fun game but one that mimics the actual scientific process of soap making while incorporating other activities in the supply chain.

Bunno's Fabulous Soap-Making Challenge (Figure 1) is a mobile game designed to teach soap-making to players. It is intended to be a game that is played for fun and a game from which subject content can be learned (Cobb, 2007). The game facilitates an engaging and challenging activity that is modeled on and represents authentic and accurate real-world chemical processes. Specifically, the game promotes learning about the soap-making process.

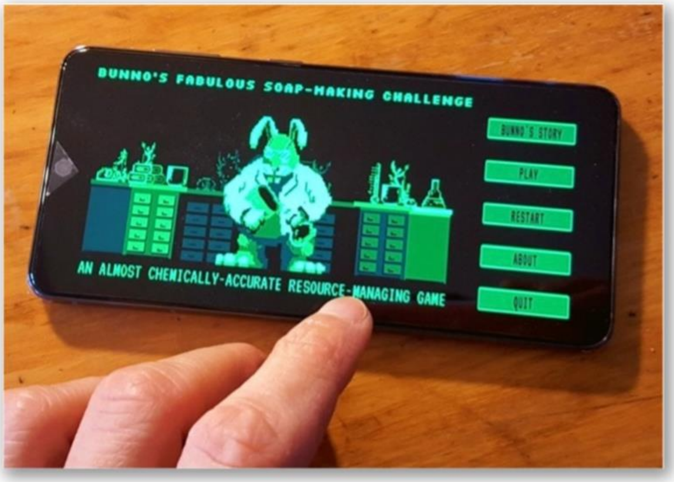


Figure 1: The game's menu screen

The main contribution of this article is a detailed description, a conceptual explanation, and a critical discussion of the game design. In addition, this article briefly describes the educational theory which informs the project, how the game design is actually realized in the game prototype, and how it can be played. Finally, the game's educational content and the projected learning outcomes are summarized.

2. Educational theory

A constructivist educational perspective informs the design of the game. Constructivist learning theory considers learners to be knowledge creators; learners actively construct their own subjective mental representation of reality by linking new information to prior knowledge (Wu et al., 2012). Games provide active learning environments that promote experimentation while enhancing higher-level knowledge construction. This game empowers learners to learn by doing, creating new experiences, and applying previous knowledge. The situation requires the skillful intervention of the players and incentivizes participation and explorative processes of investigation. The subject content becomes meaningful because it is needed and used in context, with observable and relevant in-game consequences. This is taken to be an effective and engaging way to learn that also promotes the practical application of the learned content.

3. Game design

The game design is based on the idea of facilitating, for the players, a hands-on and highly interactive experience of the chemical process and of several of its essential properties. For instance, the players acquire materials, operate equipment, and move substances from one step to another. The players' actions trigger appropriate, dynamic responses, for instance, when heating substances. All actions of the player and responses from the game are supported by rich, multi-sensory feedback in the form of graphics, animations, and sounds. The interaction with the items and mechanics of the game provides direct and immediate feedback, naturally and tightly integrated with the process at hand. For instance, useful actions such as filling water or lye into a pot (by dragging and dropping on-screen items) are intuitively supported by graphical highlighting and audio feedback; other actions have feedback that signals that they are not useful, e.g., the dragged item is being moved back, and an audio sound signals error (very brief, textual hints are also given in a few in-game situations, such as when starting the game for the first time). The way players learn about the in-game activities is similar to how players learn to play entertainment game titles; in an exploratory, emerging, and spontaneous process, not by following orders or a plan made ahead of the interaction (Charsky & Ressler, 2011). The resulting experience should support an intuitive understanding of the processes based on players' own observations and immediate experiences.

Decisions have been made with regard to scoping the game content and the level of detail. The game is clearly selective in its representation of actual chemical processes. The content is simplified in at least three dimensions: First, a decision for one specific chemical process to create soap has been made. Secondly, the range of available equipment and raw materials in the game has been limited. Thirdly, the properties of the items in the game have been simplified and abstracted (for instance, heaters do not use any fuel that would need to be supplied, materials do not need to be transported, vessels do not fall over, and chemical reactions are sped up). The world surrounding the game is outlined only; delivery times, e.g., of materials, taxes, hiring of workers and variable prices, and many other aspects are omitted.

There is a tradeoff between accuracy and playability; the focus of the game is on playability, and this produces some inconsistencies. For instance, the intermediate product (trace) that is created during the soap-making process is not buyable in the shop. It can be argued both ways: it should be buyable because it is a shop, and all other in-game items can be bought and sold there; on the other hand, the point of the game is to make soap, and not only to trade items. Having trace not offered in the shop sends a clear message to players that the way to produce soap is by initiating the chemical process with all intermediate products. Usually, such inconsistencies are tacitly tolerated by players.

The game design strives to use only a few parts but to facilitate a high level of integration of these parts with each other. The game is easy to start and has only a few objects and activities, but the behavior and interaction between the parts are complex and emergent. For instance, players need to decide when to switch from a small-scale production process to larger batch sizes with more advanced (and expensive) equipment.

Although typically, casual games avoid text and use mainly graphics, this game does use text labels for all items in the game combined with iconographic imagery (e.g., for the materials). This makes the game accessible and easy to play and, at the same time, communicates correct designations to players. All feedback is given directly and naturally through game play, not, for instance, through text in pop-up dialog boxes.

The game should not only incentivize players to learn about the soap-making process but also enable them to learn about it by trying out *how to make soap*. The game is suggestive of many of the activities that lead to the successful production of soap and of the needed materials and equipment. For instance, by providing the player with an in-game currency and a shop with items, it should be rather clear to players that buying items is part of the game.

Equipment such as heaters and pots have obvious functions that align with everyday experiences players have. The different categories of items available give hints, as well: For instance, equipment is provided in various sizes or qualities; in-line with experiences from other games, it might make sense to start with the smallest and cheapest option. All raw materials included in the game are probably needed to make soap; they are packaged in the correct package sizes for one batch of soap. The heaters and pots show small icons of the needed materials that need to be added for the process to start (Figure 2).

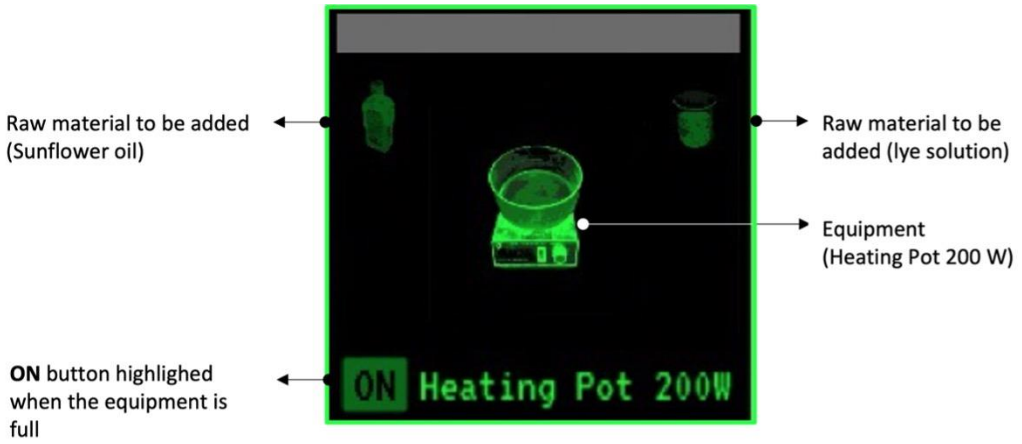


Figure 2. The user needs one unit of sunflower oil and one unit of lye solution to fill the heating pot of 200W

There are several items in the shop that are obviously unrelated to the soap-making process and are rather expensive, such as bubble bottles, ponds, matches, crayons, etc. (Figure 3). There is no information provided, and it is unclear to players what in-game effects they have (if any). These items are included in the game for two reasons: (1) To give players something to strive for. The items are not needed to play or win the game, so they constitute luxury goods. The items stand for achievements, and by acquiring them, players can reward themselves for succeeding in the game. Having acquired a particularly hard to get item might also serve as basis for bragging about it, for instance, towards friends also playing the game[1]. (2) The items may have hidden or unknown in-game effects. There are no explanations what these items do in the game, or what they can be used for, so players may be curious (or surprised) to find out. We are also not disclosing the effects here, so the only way to find out if the items do anything, or what they do, is to play the game, and to play it well.

[1] Note that this is a different approach than trophies or rewards such as medals which as handed out to players in gamification initiatives.

The game does not include an end condition, such as number of coins earned or kilogramme of soap produced. As a resource-managing game, there are constantly opportunities for the optimization of the in-game processes. The players decide when to stop playing. We expect three scenarios for situations when players stop playing the game: (1) They fail to set up an economically sustainable production and run out of money; effectively, the game does end in such a situation, because players cannot act anymore. (2) They have acquired most or all of the bonus items and feel they have succeeded in beating the game. (3) They have mastered the game, and were successful in establishing a well-working system of soap production. Of course, players may continue to play the game after they have beaten it and enjoy their mastery of it. Also, it is a rather common practice that players chose to play a game they have already won multiple times in different ways. For instance, they might try to play the game while using only a subset of the available equipment; or they might speedrun the game, and see how fast they can make 1000 coins or similar.

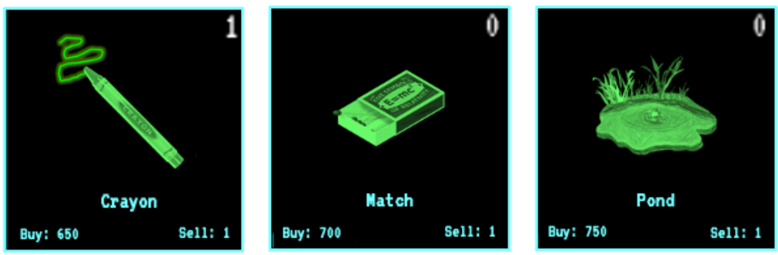


Figure 3. Examples of items unrelated to the soap-making process[2].

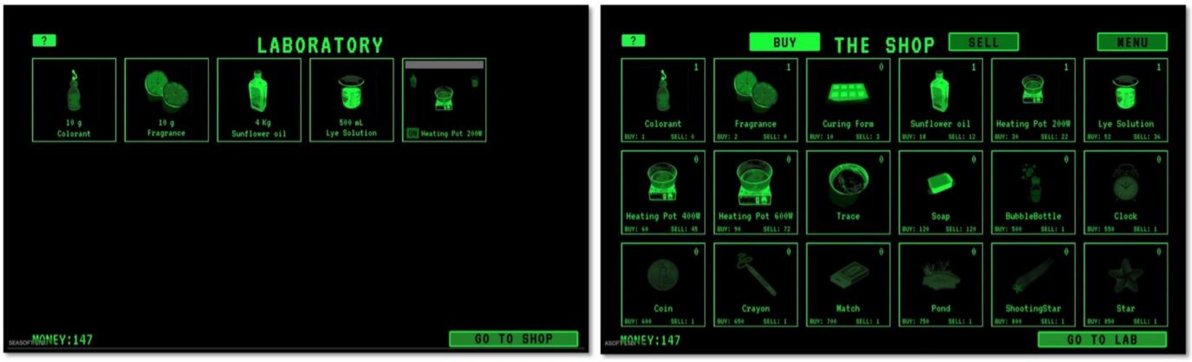
4. The game

The game is a digital, single player, resource-managing game. During game play, players plan, organize and initiate the soap-making process and control and manage it over time. Players also need to be aware of economic aspects of the endeavor, such as questions of efficiency and capacity utilization, and to keep the equipment upgraded in-sync with the (increasing) scale of the manufacturing process.

Structurally, the game consists of two complementary parts; one part in which infrastructure is built up (bought, arranged, sold), and one part where this infrastructure is used (to manufacture soap). Both parts enable and rely on each other; the infrastructure enables the manufacture of soap, and through the manufacture of soap, money is earned to sustain the infrastructure. In the lab, players arrange equipment, store raw materials, and start and

[2] The items' images were modified and obtained from freepng.fr, maxpixel.net, toppng.com, and pngfind.com.

manage the chemical process (Figure 4a); in the shop, players acquire the needed items and also sell the product (Figure 4b).



a) b)

Figure 4. Game screens: a) The lab with materials and equipment; b) The in-game shop

The game should be popular with players and compete with similar games. It thus runs on multiple gaming platforms and is released as a free game through established online channels for the distribution of commercial or indie casual games, such as the Google *Play Store*.

A typical playthrough of the game could be similar to this: The player starts with an empty lab and 250~~ Duck money.~~coins. The player clicks on the shop button and enters the shop. In the shop, the player~~she~~ clicks on the buy button and selects (left-click) the small heating pot (200W), 500 ml of lye solution, and 4 kg of sunflower oil. The player goes back to the lab. In the lab, all the bought items have been placed in the available grid position. The player~~She~~ then drops all the ingredients into the pot, one by one. The player checks that all the required ingredients are present and also in the needed quantities. The player~~She~~ then switches the heater on and waits for the pot to reach the required temperature (the player~~she~~ checks the temperature progress bar on top of the heating pot). Flames rise from the pot to signal that the trace is ready, and the heater is switched off automatically. After the process is completed, the trace appears in the first empty space on the grid. The player realises that ~~she needs~~ more tools are needed to finish the process, goes to the shop~~,~~ and buys a curing form. The player~~She~~ returns to the lab and drops the trace into it. But then, the player realizes that fragrance and colorant are also missing, so ~~she~~ returns to the shop. The player ~~She~~ returns to the lab and drops the rest of the raw materials into the curing form~~. But then, the player realizes that fragrance and colorant are also missing, so she returns to the shop. She returns to the lab and drops the rest of the raw materials into the curing form~~. After several minutes, a batch of 6 kg of solid soap appears in the grid, and the curing form is again available for more traces to be created. The player goes to the shop; in the shop, there is now a batch of soap ~~she~~ that can ~~sell.~~be sold. The player~~She~~ makes the sale and is delighted by a rewarding sound. The player invests the money earned in new raw materials and later, after a few days of playing, into upgraded equipment. The player~~She~~ also optimizes the flow of the operations, so there are fewer waiting times, and there is always cash available (e.g., by having more than one batch of soap in (overlapping) production).

5. Projected learning outcomes

The game's educational content is the chemical process of making soap, specifically the *kettle process* (Preston, 1940). Learning in this game happens on multiple levels: On a basic level, players learn about the various materials and equipment used in the process (such as visual appearances, names, and functions). At the same time, the order of operations in several steps for the soap-making process emerges (e.g., heating the materials, then curing, and finally producing soap, Figure 5). At last, complex patterns of dynamic interactions appear, for instance, when aligning the upgrading of the needed equipment over time with the increase in soap batch sizes.

Figure 5: The process as represented in the game: Saponification of the raw materials in a heater, curing, mixing, and cooling of the trace; the finished product (soap)

Educational content is the process of soap making which involves a chemical process and reaction. The game aims to emphasize the usefulness and essential role of chemistry in everyday life by using a common product and process.

The game simplifies the *chemical process* into two main steps: creating a trace and curing the trace to produce soap. The process is inspired by the *kettle process* typically used by small soap producers (Preston, 1940). Additionally, there are different elements related to the process which can be learned from the game. For instance, ingredients, amounts of substances, the time needed for reactions, steps involved in the chemical reaction, effects of, e.g., heating on substances, equipment, and machines involved, issues of scaling of chemical production from individual batches to mass production.

The game simplifies the *chemical transformation* (saponification reaction) in the first step. The player learns that when sunflower oil and lye solutions are mixed at high temperatures, the trace (soap) is formed. To finalize the product, the players realize that the trace needs to be *cured* for a specific time and mixed with certain ingredients to make the final product (colored, scented soap).

6. Conclusion

The main contribution of the article was a detailed description, a conceptual explanation, and a critical discussion of the design of a mobile game that contains educational content. In addition, the article briefly described the educational theory which informs the project, how the game design is actually realized in the implemented game and how it can be played, and the game's educational content and the projected learning outcomes.

Bunno's Fabulous Soap-Making Challenge is intended to be a game that players play for fun and a game from which they can learn subject content. Informed by constructivist learning theory, the game promotes knowledge construction through active experimentation in the game: Players encounter an inspiring and challenging situation and are active, in control, and make their own decisions and experiences. Their actions trigger immediate responses and are consequential.

The game is modeled on and represents authentic, real-world chemical processes. Specifically, it promotes the learning of aspects central to the soap-making process. Moreover, the learning content emphasizes chemistry's usefulness and essential role in everyday life, which can serve as a basis for interest development in STEM subjects. The game is a resource-managing game in which players plan, organize, and execute the production of soap. Players source the raw materials, acquire the technical equipment, create an efficient lab setup and produce and sell soap in an economically sustainable way.

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