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The road towards friendly, classroom-centered interactive digital contents authoring

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Abstract: In this paper, we argue for the need of new kinds of visual, digital game authoring tools. The main goal for this project is to reconceptualization the programming of interactive digital contents, to minimize the coding aspects, and focus instead on the creative and design-like parts, leveraging on a tangible metaphor, so to empower teachers and pupils to create digital interactive content, expanding the creative affordances offered by digital games. The resulting tool is called Stick&Click, it is based on findings from our past research, and it targets the pedagogical practice of editing games that is currently common in Danish primary schools. The study is organized according to the research through design approach, and centers around user needs and experience. We discuss our explorations of the computational model behind Stick&Click, requirements and design principles, and alternative ways to visualize its user interface.

Keywords: game design, game programming, primary school, learning, tangible metaphors.

1. Introduction

In the past 10 years we have been working on recontextualization and reconceptualization of interactive digital contents, to make them more accessible to teachers, pupils and young students, in and outside the classroom. Our goal has been to empower digital creativity and close the gap between tinkering in the physical world and authoring of game-like digital materials, which require a certain degree of programming skills. Our approach centers around user needs (Preece, Rogers & Sharp, 2019), from the perspective of teachers and pupils, which we investigate typically using ethnographic qualitative methods. In this way, we aim at collecting not only changes in performances or self-reported data, which are related to the conscious level of human experience (Löwgren & Stolterman, 2007), but also unarticulated needs, actual practices and concrete adaptations of methods (Dunne, 2018), and reactions derived from personal values, which are related to the unconscious level of human experience and cannot be captured through surveys (Preece, Rogers & Sharp, 2019). This qualitative approach is usually adopted in research through design (Zimmerman & Forlizzi, 2014) where new knowledge is gathered through the creation of prototypes, to explore the design of new technologies as well the nature of human experience.

In this paper, we leverage data from previous user centered design projects, from which we found that Danish primary schools often employ games and design of games as learning resources for their pupils. Games, digital as well as role-play and paper-based games (e.g. card games and board games), are seen as more creative and playful alternatives to traditional written assignments, enabling pupils to engage with the learning content in new ways, hence eliciting new understandings. It emerged through our previous studies that teachers exploit the popularity of digital games as a motivational resource for supporting learning, however, we found that digital games can be experienced as less creative than paper-based games, as these can be redefined based on social agreement among teachers and pupils. Digital games come as a black box, which can be played only in a particular way and cannot be changed nor created from scratch without advanced programming skills (Marchetti, 2016), hence digital games cannot be easily customized according to pedagogical needs. Interestingly, during our studies (Valente

& Marchetti, 2012, Valente & Marchetti, 2015, Valente & Marchetti, 2019) we found that teachers have systematically expressed interest in being able to edit or at least customize existing digital games and also to enable their pupils to customize or design digital games, to better meet their pedagogical needs. Moreover, Danish schools have engaged in different initiatives to enable their pupils to learn how to program, using systems like Scratch, Minecraft or Blockly, and are currently in the process of formalizing Computational Thinking (CT for short) as a subject. Therefore, Danish schools are open in exploring different digital tools that could enable a richer engagement with digital technologies, than what is typically afforded by available digital games or editors.

Starting from these premises, we present in this paper our investigation around a possible system to support creative authoring of digital games, targeting the pedagogical practice of editing games that is currently taking place in the classrooms of Danish schools. Our goal with this project is to empower teachers and pupils, to expand the creative affordances offered by digital games and learning platforms, enabling them to create interactive content.

Section 2 presents related work and our previous studies that provide the basis for the design and implementation of our new web-based prototype tool; the incremental development of tool itself is discussed in section 3. Section 4 concludes the paper, presenting ongoing and future work.

2. Related work – Game design in the classroom

Recently the Danish school systems have been experiencing a digitization process, which is causing a generalized integration of digital technologies inside the school, consequently, teachers are exploring new approaches to motivate their pupils in engaging with their learning content and to foster them new, deeper understandings (Marchetti & Valente, 2016). In our study, we approach primary schools as complex information ecologies (Nardi & O'Day, 1999), in which technological changes take place as an organic transformation, causing a deep reconceptualization of existing practices affecting how teachers and pupils engage in learning processes inside the classroom. During our previous studies, we found that use of games, in digital or analogue form, is a spread practice in Danish schools, aiming at fostering deeper understandings of the subjects at hands and at motivating their pupils at engaging with their learning material on an independent basis (Møller, 2016, Hoffmeyer et al, 2017). A typical workflow that we observed would start with teachers introducing a topic in a lecture; pupils would then be invited to engage with books and other available digital resources that the teachers have gathered for them, such as: articles or videos available on-line, or games. In the end, the children would be invited to play the given games and/or to produce creative artefacts that could exemplify their understanding of the subject, in the form of board or card games, videos, or digital slide presentations.

Several studies have been conducted in Denmark and internationally regarding the use of games in literacy and language (Fenyveri, 2018, Cadierno & Eskildsen, 2018) and also in mathematics (Misfeldt & Zacho, 2016). Commercial digital games were found to contribute to motivation and rich interaction in the class. Moreover, Cadierno and Eskildsen (2018) investigated the use of games in English classes with oral and written English, in comparison to games with only oral or written English input. Results from their study shows that use of games with both oral and written English contributed significantly to children's high scores in vocabulary tests (Cadierno & Eskildsen, 2018). Similarly, Fenyveri (2018) found that engagement in games and videos found on YouTube, worked as motivational resources for primary school pupils to engage in learning of English. However, games and videos, do not only work for motivation, but as a familiar territory for applying knowledge. As a consequence, the pupils are able to better memorize words and use them correctly, as through the game they have reflected on the contextual use of the terms that they have learned.

Despite all of these studies and evidence for the usefulness of existing digital contents and self-created analogue games, we repeatedly observed a lack of tools for authoring digital games (and interactive digital contents more in general), specifically targeted at teachers and pupils. This difficulty in creating games for learning is seen in Danish schools for instance in the explorations conducted with the authoring of different media productions, such as interactive scenarios (Misfeldt & Zacho, 2016) and movies editing with iPad (Møller, 2016), which were found beneficial in terms of fostering creativity, collaboration, and forms of peer learning. In Misfeldt and Zacho (2016) observations in the mathematics classes revealed how teachers and pupils relate to games as something to "design", in order to exploratory engage with the subject and prepare for open-ended projects. Editing short movies on an iPad has the advantage of supporting touch-based forms of multimodal interactions, which would

not be in focus with other media. In this way the children engage in a multimodal form of negotiation, communicating with each other through haptics, visually and verbally to negotiate on the outcome to be created and solve potential conflicts (Møller, 2016).

Moreover, these productions can be used as forms of informal assessment, as the pupils have to engage in depth with the learning content to reelaborate it in the form of movies or games. In this way, the artefacts created by the pupils carry the knowledge that they have acquired, hence these can be used as triggers for assessment, as *boundary objects* (Star & Griesemer, 1989) of conversation between teachers and pupils on the subject at hand. However, it was found that criteria for assessment based on multimedia productions are vague and lack clarity. According to Hoffmeyer et al (2017), students respond better to assessment if supported by feedback based on explicit criteria, which can not only highlight what is wrong, but also where there can be improvement and how. Hence these practices are challenging traditional assessment approaches, demanding for the establishment of new criteria regarding "form, content and typology" (Hoffmeyer et al, 2017, p.27) to become an acknowledged form of assessment.

Issues emerged also when both teachers and pupils have to adapt to using new tools, which require a learning process on their own right. In this respect we found that teachers were adapting in different ways to the integration of digital technologies in the classroom (Marchetti & Valente, 2016), and we identified three main attitudes towards technologies:

1. IT Concerned – teachers who are relying preferably on low-tech solutions, often paper-based such as written scores for role-play and board games,
2. IT Mediators – teachers who are integrating in their teaching different available media which were not specifically designed for learning,
3. IT Designers – teachers who would like to involve technologies in a more creative way, creating their own media content.

The first category is represented by a few individuals, often dealing with classes of pupils with special needs. The second category is the most represented and includes teachers, who are expressing an open and opportunistic attitude towards technology, so that they are ready to embrace and recontextualize for their teaching activities whatever technology is available. These are often open also to input from their pupils to find suitable technologies. The third category includes teachers, who are also open to experiment with technologies, but would like to reedit or even create their own interactive content. Interestingly, we noticed that teachers in this third category end up choosing paper-based solutions when they want to design their own games, similarly to the teachers who are IT concerned, as the level of programming skills required for such a task is too high.

On the other hand, during one of our studies aimed at designing a table top game on the Viking Age (Marchetti, 2016), we observed groups of 10 years old children expressing themselves creating their own game pieces. Moreover, we observed a few of the kids spontaneously engaging in forms of playful play (Sutton-Smith, 1997). These kids spent all their time creating game pieces and rules of play for their mates, who in turn were happy to include the newly created pieces with the ones they made for themselves.

As digital technologies have become increasingly present in the classroom, the teachers have gone through a learning process on their own, to familiarize with the new available resources and with how these were affecting their teaching practice. At the same time, as the teachers have become more competent, they also became more aware of their needs, setting new demands for self-expression, for themselves and their students; our explicitly attempts to address such needs.

3. Stick&Click

The initial idea came from the results of the tests conducted with paper materials and digital games, as in Marchetti and Valente (2017) and Fables (Valente & Marchetti, 2019). In both cases simple rules allowed the pupils to author their own materials into digital, non-linear, and visual novels; hence we wanted to identify a single mechanism, as simple as possible, that we could use as a formal model for such digital, interactive artefacts.

In both studies we used web-based prototype tools to let the pupils enact our scenarios, so it was natural to look at central ideas in web programming; moreover, in previous work one of us used a set of static HTML pages with hyperlinks and images to reason about non-linear narrative in designerly ways, as one of us attempted with a class of young adults, in Marchetti & Valente (2016).

From the point of view of game design, planning a visual non-linear story is often done via *sticky notes* and tangible materials, a set of activities that is very close to the typical tinkering we observed many times in Danish primary schools. However, the final goal of digital game designers is of course to create a digital game, while pupils and teachers usually would stop at table-top or pen-and-paper games. Finally, in our attempts to find a metaphor that could help us explain our experiments to primary school practitioners and their pupils, we looked at *action transfers* and *sticker albums*, which albeit being toys, can be easily associated and reappropriated as props and materials to be used in game design.

Our first experiment was then to define a simple JavaScript library, to make it very easy (for us at that time) to create non-linear visual novels with static HTML. The main interaction mechanism was images with HMLT anchors; we used some simple CSS ricks so that all the pages were fullscreen and responsive, allowing us to deploy on mobile devices from the start. Minimal persistence-like support was added, so that the state of every image in the page could be stored and retrieved from *LocalStorage*, effectively allowing a player stop to and resume playing. Since we were targeting mobile devices, such as tablets which are commonly used in Danish primary schools, we realized that our idea could easily express non-linear digital games in the style of point-and-click games.

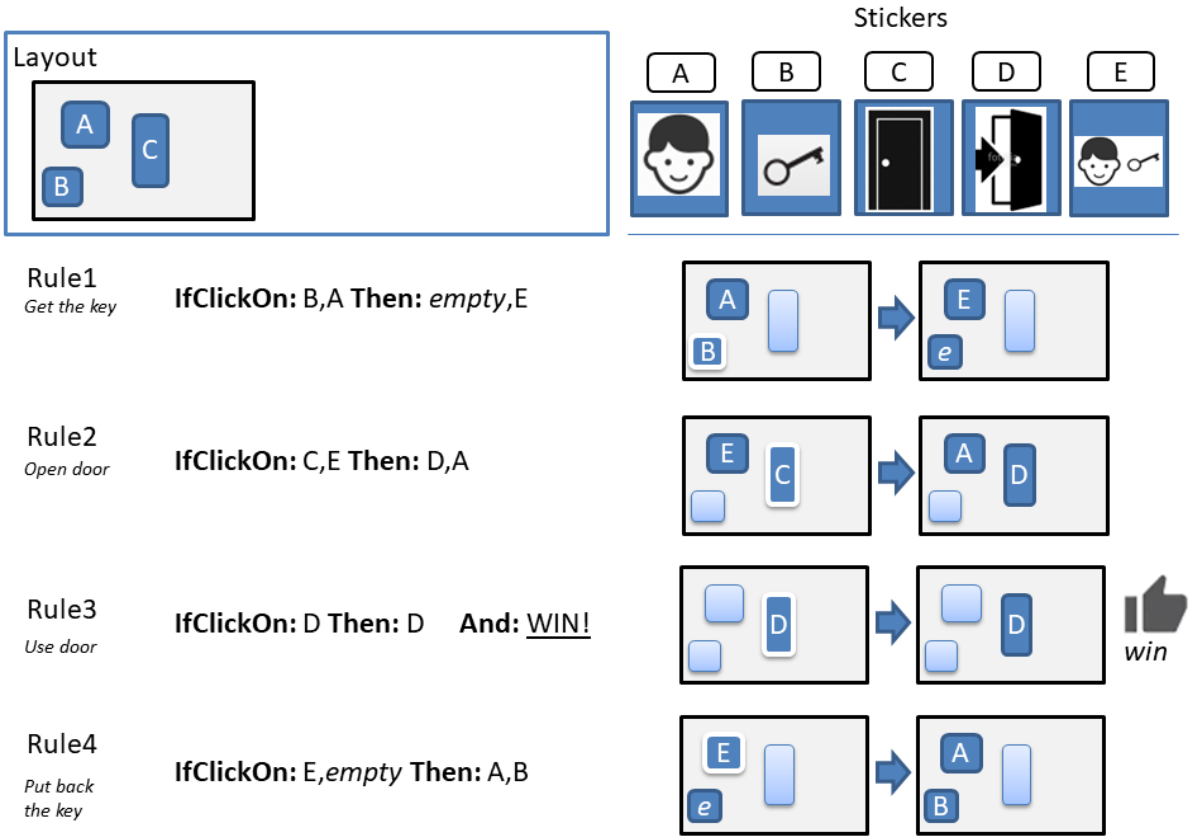

Figure 1. A simple example of a game definition.

In our scenario, the author of the game would define one of such games by doing the following:

- Define a layout for each page, i.e. rectangular regions that we call *markers*,
- Decide which images, from a palette of self-created ones, will initially occupy which markers,
- Then define rules for the game, so that when the player clicks on an image (with its associated hyperlinks) two things could happen:
    - the game could change page,
    - or the image might change to another.

Since this scenario could be summarized as "the game designer places stickers on pages and then the player would click on them", we gave this system the name **Stick&Click**. The most difficult part of the design of Stick&Click was to find a good way to express the rules avoiding the typical difficulties of coding.

We looked at rewriting systems and simple IF-THEN statements, and we decided that visual rules with a match-rewrite structure should work well here, in particularly taking in consideration what we know about the pupils' visual and reasoning skills from Marchetti and Valente (2017).

As visible in Figure 1, the rules have the following structure: if the player clicks on a certain image, then the image rewrites to another image, and perhaps the game ends because the player has won. In general, however, we wanted to have more *contextually aware* rules, so for example rule 1 in Figure 1 states that if the player clicks on image B, which is the key (wherever that might be in the page), **and** somewhere else in the page there is an instance of image A, the face of the boy, then image B is replaced by the label *empty* and A changes to E, the boy holding the key. The label *empty* is interesting, since it does not represent an image in the palette (i.e. one of the "stickers" used in this game), but instead it is an invisible special symbol.

The author of Stick&Click games can freely define new labels, to help her mark interesting locations in the page. The use of special symbols is common in theoretical Computer Science, and we made use of these marker-like symbols in our Paper Turing Machine (Valente & Marchetti, 2011), when complex computations needed to be performed; leaving a special symbol on the tape of the Paper Turing Machine made the rules simpler to express, as we wanted the same for Stick&Click's rewriting rules.

In Figure 2 it is shown the state diagram representing all possible navigations throughout the page. More complex games can be defined by having multiple pages, which in turn means that the rules can also have a JUMP clause, similar to the target URL of an HTML anchor.

The important feature for us is that both the graphics and the logic (i.e. the rules) of the point-and-click game in the making are defined by the user, without explicitly coding. The rules themselves can be expressed more visually, as shown in the right part of Figure 1, and work on a match-rewrite principle. The only interactivity available to the player is to trigger one of the rules, the first declared that matches the current state of the images on the screen, by clicking on one of the "stickers".

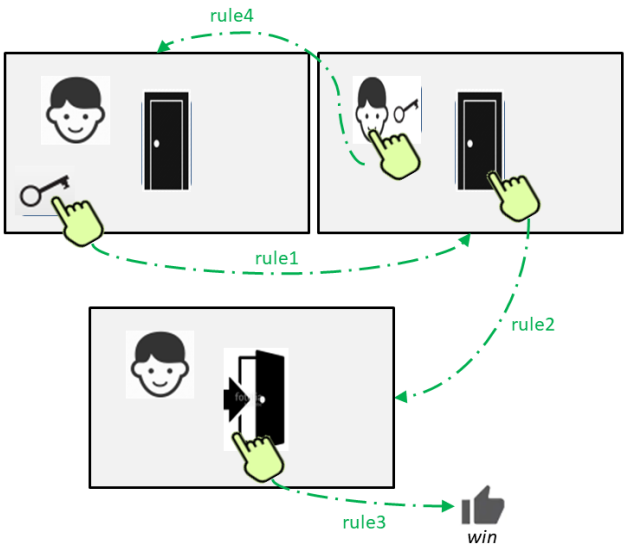

Figure 2. Navigation diagram for the game.

3.1 More experiments

The first set of experiments we performed with Stick&Click consisted in the creation of very short non-linear, interactive visual novels, using HTML and the JavaScript library described above. We mainly performed functional tests and explored expressiveness and scenarios of use. After having worked for a few months with this first implementation, we wrote a transpiler in Node.js, capable to

take a JSON specification file and a folder of images, and create an entire website of static webpages, implementing the game described in the JSON file. We explored the expressiveness of Stick&Click by creating parts of a few point-and-click games, mockups for user interfaces with navigation, and a minimalistic adventure game with gameplay similar to LCD games (see https://archive.org/details/handheldhistory). A later version of the transpiler was able to create a single-page application (i.e. a SPA) starting from a JSON specification file and the images for the stickers. For us the advantage of a SPA as that the player would always resume from the correct place in the visual novel, and the LocalStorage-based persistence would still suffice to be able to stop and resume playing.

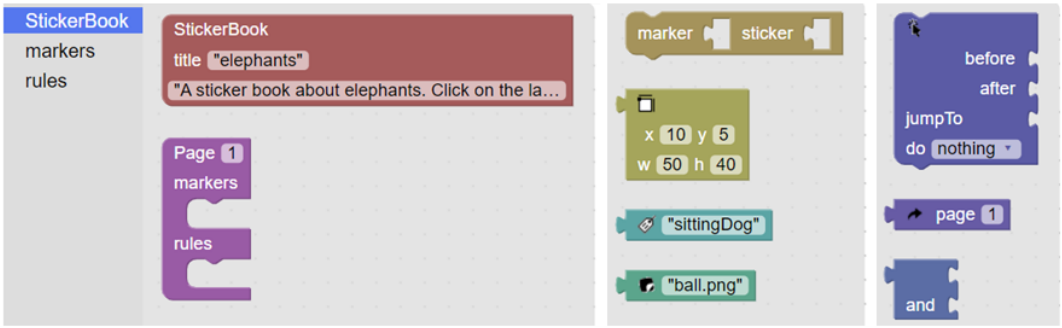

Figure 3. Instructions of the Stick&Click Blockly language.

Certainly we did not expect teachers and pupils to be able or interested in writing a JSON file to define a game, hence we manually designed a Blockly language based on our Stick&Click JavaScript library. Google's Blockly offers a visual GUI to create custom Blockly languages (see https://opensource.google.com/projects/blockly). We spent a couple of months learning Blockly and we decided to take advantage of the evaluation mechanism to export JSON files: for each Stick&Click game visually defined using our blocks, the Blockly language was able to export the JSON file needed to create the actual webpages for the game (with the Node.js transpiler described above). The instructions of the Blockly language are shown in Figure 3.

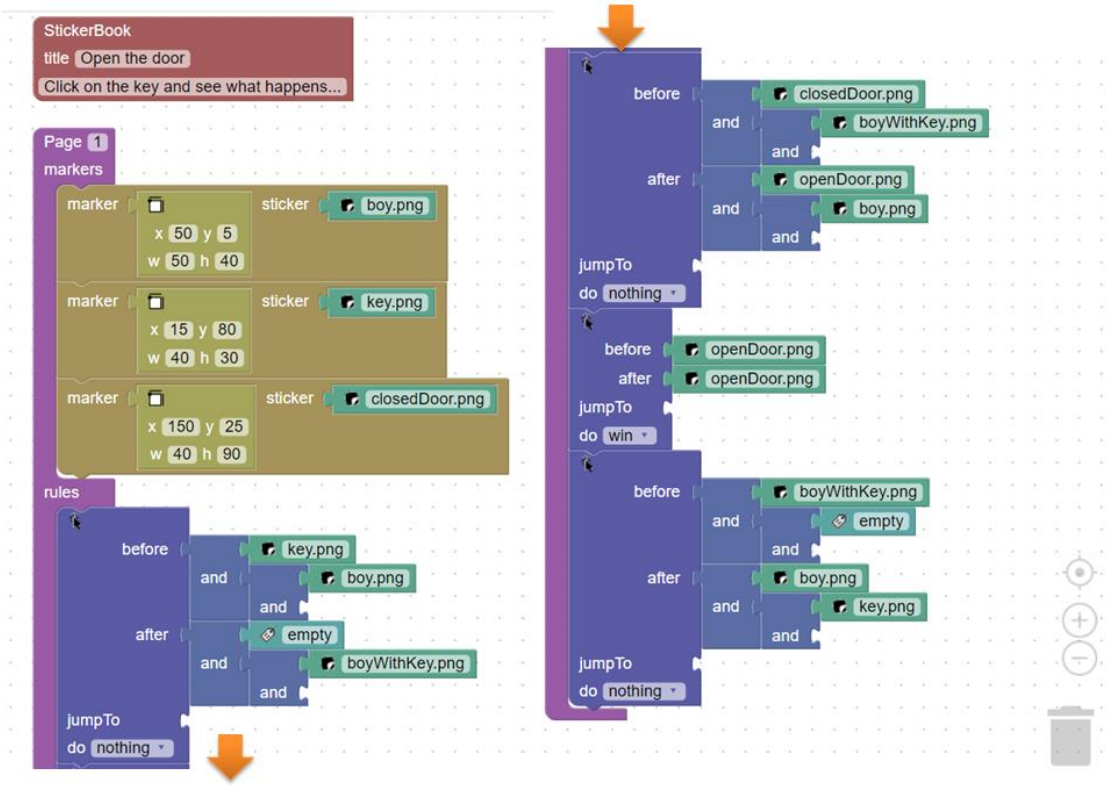

Figure 4. The game from Figure 1, redefined with the Stick&Click Blockly language.

To declare a new game with the Blockly-based visual GUI for Stick&Click, the author creates a "StickerBook" (see block on the top-left of Figure 4), and she provides a title and a description for the game. The sticker book also contains pages, each numbered, and each page has a list of markers (which define the initial layout as in Figure 1) and a list of rules. A marker is defined by a rectangle and a sticker, which in turn can be an actual image or a label. Rules are defined by specifying the list of images and labels that should match (i.e the *before* clause) and how they should be changed (in the *after* part of the rule); by default, the first sticker of the *before* clause is the one clicked by the player. Each rule can also force the game to change page, via its jumpTo clause, or even stop the game and display a Win or Lose message to the player.

As an example, Figure 4 shows the same simple game in Figure 1, defined using the Blockly language. Using this new toolchain, the Blockly language and the Node.js transpiler, it was very simple for us to reimplement all our previous test games, hence gain better understanding of the expressive power and versatility of Stick&Click. However, these rapidly developed spikes were never meant to become complete authoring tools, instead we surveyed various languages and platforms that we could use to create an actual, testable prototype, to show to our contacts in local primary and early secondary Danish schools.

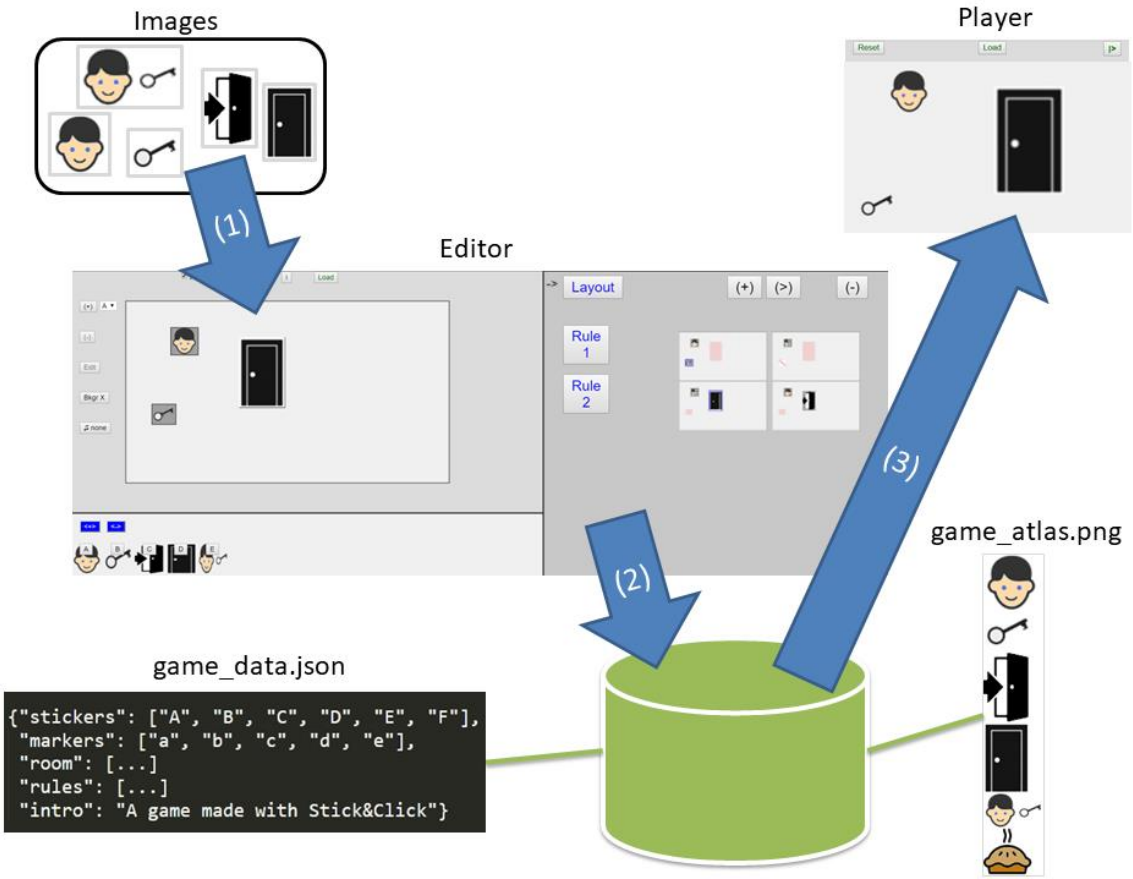

Figure 5. The game with the boy, defined inside the latest P5 prototype.

From our previous work in Valente & Marchetti (2019) we know that block-code can be intimidating for non-programmers, and in our experience it can make teachers feel tense, as they feel it shifts focus from their subjects and contents to programming; and that is another reason why we wanted a visual GUI but without hinting at code, as far as possible. Moreover, the part of Stick&Click that would benefit mostly from block-code is the definition of rules; but even for those we believe we can find less algorithmic and more directly visual ways to express them.

We considered implementing Stick&Click in various platforms; we made spikes in Processing, Java (using Android Studio), Python 3 (leveraging on the Pygame Zero library). Important features of our new tool should be the ability to run online and on mobile devices, so finally we opted for P5 (as documented in https://p5js.org/), a JavaScript implementation of Processing.

The current prototype in P5 has web-based editor and a player; its features are:

- Game author can upload her stickers images,
- Only a single page can be defined for now,
- Rules are fully implemented, in a visual before/after fashion, without block code,
- The prototype exports each project as 2 files: a JSON specification of the game a large image containing all stickers (i.e. an atlas),
- The playback webpage works by loading the 2 files representing a game, and it is fully functional, including animations for victory and playback of background audio files,
- The author can also select a background image and/or sound in the editor.

Figure 5 shows the proposed workflow of a pupil creating a game: first the pupil uploads her custom images to the web editor, then layout and rules are defined and the game description can be saved. Saving a game generates 2 files: a JSON file with the description of the game, and an image file containing a vertical list of all stickers used in the game (the atlas file). A second web-application, the player, can then be used to open the game files and play. This allows pupils to exchange their games or play games generated by their teachers.

4. Ongoing work and conclusions

Stick-n-click is still at a very early stage of design and prototyping, but it represents the latest in a number of explorations we conducted over the past decade. Through our previous studies, we found that games and design of simple paper-based games have become a spread practice in Danish primary schools, where games are seen as a resource for learning and assessment. The process of playing and creating games leads to the creation of boundary objects for reflections and reelaboration of the learning content, enabling for tinkering and shared in depth discussions with teachers and other pupils.

Within this context, digital games appear as black boxes in comparison to paper-based games, limiting the creativity of both teachers and pupils, as in order to edit them or create new ones, advanced programming skills are required. Therefore, our goal with Stick-n-click was to empower teachers and pupils, expanding their opportunity to express themselves creatively in the making of interactive digital games. This project centers on the classroom and its information ecology (Nardi & O'Day, 1999).

A main challenge in our studies was to simplify the practice and logic behind programming simple point and click games, to be accessible to teachers and pupils, without previous programming knowledge.

We are currently looking into open questions such as how to deal with global values in Stick&Click (e.g. the score of the game, which should exist and be the same in all pages of a game), or how to practically orchestrate a primary school class based on game development with our tool. Although we have performed small-scale functional testing during these early phases of development, we are planning a set of tests with teachers of a local school in Denmark, to be run in autumn 2019 and spring 2020. We intend to deploy Stick&Click and observe it within the classroom ecology, with the main goal to make the P5 protoype user-friendly and capable of covering authoring of digital game in the context of CT.

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