A Systematic Mapping of Hybrid Games in the Academy

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Abstract. *Hybrid games can be defined as games that combine digital and analog elements in their composition. However, hybrid games bring with them challenges from both the digital and analog domains, making their development and evaluation complex. The main objective of this paper is to rise state of the art and the practice of hybrid games in academia. A standard systematic mapping methodology using digital databases for research was applied and 31 works out of a total of 395 were accepted. Through their analysis it was possible to identify the main technologies used, the areas of greatest predominance in the use of hybrid games and the methods of most used assessment.*

Keywords: *Hybrid Games, Systematic Mapping, Game Design*

1. Introduction

Games in their various facets are increasingly part of our daily lives, whether in digital or analogue formats. **Hybrid games** are born from the combination of elements of these two divergent game formats. [Kosa and Spronck 2018] define them as games that use physical and virtual components, such as smartphones or tablets, to enrich the users' gaming experience. Hybrid games presented good acceptance by players, and many authors also have shown their effectiveness as teaching tools, for example, in language and Chemistry learning as in the works of [Berns et al. 2016] and [Wu et al. 2018] respectively.

We carried out a systematic mapping to understand the practical and state-of-the-art of this type of game in the academy. Our goal was to overview the development methods, usage scenarios, evaluation methods, and acceptance levels of the hybrid games. The mapping was divided into four stages, at first a search string was performed in 5 search bases and 395 works were found. From these papers, duplicates and those that did not meet the established time interval (2015 - 2019) were removed. In the third step, false positives were removed based on the inclusion and exclusion criteria. In the last step, a survey was sent to the authors of the 31 selected works to obtain more information in addition to that contained in the papers.

The remainder of this paper is organized as follows: Section 2 presents the theoretical reference. Section 3 contains the methodology used in the systematic mapping and its results are discussed in detail in section 4. Finally, section 6 shows the future work and final considerations of the systematic mapping.

2. Hybrid Games

We adopted an extension of the Kosa and Spronck's definition [Kosa and Spronck 2018], in which hybrid games have many levels of hybridization, ranging from games that are closer to entirely physical (analogue) to fully digital (Figure 1). For example, there are cases like *XCOM: The Board Game*[1] in which the only digital part is a mobile application. The app works as the game master, responsible for delegating the missions, possible actions, and game *timers*. But, players do everything else, like positioning, resource management, drawing cards, etc., in an analogue way. The digital app is also unaware of the overall state of the game. This game is closer to the analogue extreme of Figure 1.

Figure 1. Hybridization Levels

On the other hand, games such as *World of Yo-ho*[2] are closer to the digital extreme of Figure 1. In this game, almost the entire gameplay takes place on the *smartphone* screen, with the player only positioning the device and moving it around on a physical map. All other interactions are done through the game's digital interface on the device.

There are also cases located in the middle of the spectrum, such as *Keep talking, and nobody explodes*[3]. In this game, one of the players needs to defuse a bomb (digital part) and the other has the manual on how to defuse the bomb (analogue part). The two must work together to defuse the bomb within the allotted time.

3. Methodology

According to [Kitchenham et al. 2006], a systematic mapping is a way of identifying, evaluating and interpreting all available research relevant to a particular research question, for the purpose of gathering or gathering evidence to answer this question. This mapping was built using the P.I.C.O. (Population, Intervention, Comparison and Outcome) method as suggested by [Kitchenham et al. 2006]. It followed a similar methodology performed in the work of [de Lima Veras et al. 2019]. We carried out the mapping study in four steps. At **first**, we performed a search on five research bases, using a *query string*, namely: ACM Digital Library (123), IEEE Xplore (47), Scopus (95), Web of Science (60), and Springer Link (70), totalling 395 works found. We chose these databases since their engines facilitate the execution of the search string and optimize the results found. From these articles, we removed duplicates and those that did not meet the established time interval of 5 years (2015 - 2019). At the end of the **second step**, 138 articles remained for reading titles and abstracts. The evaluator used the *Zotero* tool to speed up this step, which is an academic reference management software that facilitates the identification of similar works from different bases.

[1] https://bigbossbattle.com/xcom-the-board-game-xenopoly/
[2] https://www.kickstarter.com/projects/iello/world-of-yo-ho
[3] https://bit.ly/3eiGNEa

In the **third** step, one of the authors read the titles and abstracts of all articles to remove false positives, papers that fit the search string but do not meet the inclusion and exclusion criteria listed in the section 3.1 - reducing the number of works to 61. In the third step, the evaluator completed the articles' complete reading and selected those that fit the established criteria. At the end of this stage, we removed 32 documents, and 29 works were accepted in the systematic mapping. In the **fourth** step, we sent a form to the authors of the selected articles. Our goal was to find more information beyond that contained in their works. We asked them about their game development experience and their difficulties throughout their research with hybrid games. After this step, based on the authors' suggestions, two new works were added that had not been found through the search string, totalling 31 accepted works that are analyzed in this systematic mapping.

3.1. Search String and Inclusion and Exclusion Criteria

We built the search string to survey the research works on hybrid games, which were in line with the inclusion and exclusion criteria listed below.

Table 1. Mapping delimitation following P.I.C.O.

Population	Full articles and expanded abstracts involving games.
Intervention (independent variables - controlled)	Primary studies that produced hybrid games or tools for them.
Comparison	Not applicable in this case.
Outcomes (dependent variables - treatment results)	Evidences that point to the positive use of technologies such as NFC or RFID, in expanding the user experience.

Search string adopted: (GAME) AND (NFC OR RFID OR QR CODE OR BEACONS OR OBJECT RECOGNITION) AND (CARD OR TABLETOP OR HYBRID).

As mentioned before, although all papers found matched the search string and contained all the keywords, we expected that many of them did not directly address issues related to hybrid games. To filter these works, we the used following **Exclusion criteria**:

- We excluded works that are not published in academic or peer-reviewed.
- We excluded works that are not in publication format or do not have enough data.
- We exclude papers that are not in English or Portuguese.
- Exclusion of works not published in the last five years (2015 - 2019), the period in which we carried out the mapping study.
- We removed papers with secondary studies or that only mention hybrid games but do not have tools, methods or games in the scope of work.

Some **Inclusion criteria** were used to accept works quickly. They were:

- Include papers having a hybrid game in their scope, whether or not it is the focus of the research.
- Inclusion of papers with tools that help create or evaluate a hybrid game.
- Works that use or address evaluation methods used to evaluate a hybrid game.
- Papers depicting an acceptance assessment of a hybrid game.

We postulated eight research questions to survey the practical and state of the art of hybrid games. Table 2 lists them with their respective purposes.

Table 2. List of systematic mapping research questions.

RQ1	How were the hybrid games developed during 2015-2019?	Identify the main characteristics of a hybrid game and the main games of this type.
RQ2	What are the digital technologies used?	Identify key technologies used in hybrid game development and how they are being used.
RQ3	What were the development challenges reported?	Identify the main challenges in the development of hybrid games. As well as possible solutions.
RQ4	Are there tools that help the development of this type of game (e.g., framework, middleware)?	Identify the existence of tools to help the development of hybrid table games. As well as the most used tools.
RQ5	Which game genres have already been explored in the academy?	Identify which game genres have already been explored by hybrid table games.
RQ6	What was the target audience?	Identify target and real audiences for hybrid games.
RQ7	How were they evaluated (e.g., experience, playtest)?	Identify which evaluation methods are most frequently used in hybrid table games.
RQ8	What was the acceptance of these games?	Identify the acceptance and target audience opinion about hybrid table games.

4. Results

As mentioned in 3, in total, 31 articles were found. Readers can find the complete list of them on the footnote link [4]. Figure 2 shows the survey's distribution by country of origin. Sixteen countries appear on the map, highlighting Taiwan with four articles found. There was no repetition of authors among the 31 articles in the mapping.

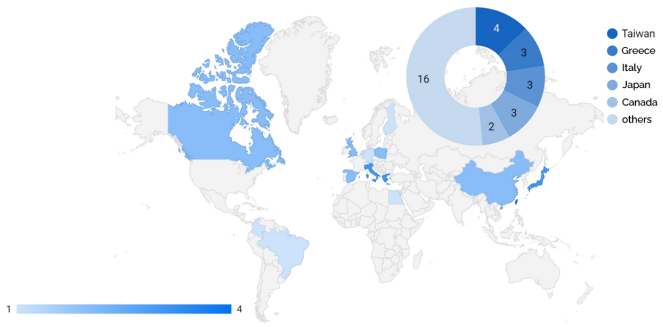

Figure 2. Distribution of works by country of origin of the research.

We did not identify a clear predominance of vehicles and conferences. However, we found three articles from the ACM CHI Play conference [5]. This conference focuses on promoting the meeting of researchers and professionals in games and human-computer interaction (HCI). We also found two papers from the GALA (Games and Learning Alliance Conference) [6], a conference on Serious Games research.

[4] encurtador.com.br/evCKO
[5] https://chiplay.acm.org/
[6] https://conf.seriousgamessociety.org/

Reading the accepted works, we extracted hybrid games, tools and methods used in development to deal with diverse game-type challenges. With these results, we answer the research questions in the following subsections.

4.1. RQ1: How were the hybrid games developed during 2015-2019 ?

In general, the hybrid games found have an educational or technological nature. Of the 31 works accepted, 13 are educational, and ten are technical demonstrations. The rest of the works are distributed among the other areas as in the graphic of Figure 3. For instance, they were used as tools on a hybrid table to demonstrate a multi-touch technology and to assist teaching in the works of [Berns et al. 2016], [Chang et al. 2017] and [Wu et al. 2018]. In the health domain, we find the work [Kang et al. 2016], which uses hybrid games to prevent dementia in the elderly.

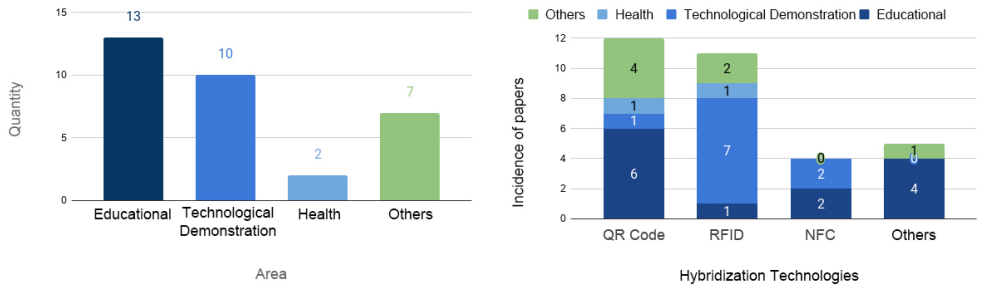

Figure 3. Left: Works by domain. Right: Most used technologies in each area.

4.2. RQ2: What are the digital technologies used?

All works use technologies for reading *tags* or patterns to establish the relationship between the digital and analogue worlds of the game. Figure 3 shows the incidence of technologies, with the QR Code (12 articles), NFC - Near Field Communication (4), and RFID - Radio-Frequency IDentification (11) being the most used.

In the cases of [Berns et al. 2016], [Chang et al. 2017] and [Wu et al. 2018], for example, QR Codes were used in maps. Geo-located information promoted a bridge between the games' physical and digital world of the games (Figure [Berns et al. 2016]). In [Elmiligi et al. 2016] and [Thar et al. 2018], researchers chose to use *NFC*. In [Bassuony et al. 2016] and [Hsieh et al. 2018], the technology chosen was RFID. There are also cases, such as [Andrea et al. 2018], in which players used a bar code to communicate with the physical pieces of the game. Few works like the one by [Ponticorvo et al. 2017] did not use reading technologies but flasks with essences to train children's sense of smell. From the crossing between the data collected for questions RQ1 and RQ2, it is possible to identify a predominance within the areas to use specific technologies. For example, 6 of the 13 accepted works use QR Codes in the educational space in their games. In contrast, the games in the technology demonstration area used RFID much more, as shown in Figure 3.

4.3. RQ3 - What were the development challenges reported?

In the 31 documents, we did not find any reported challenges while developing their hybrid games. In most cases, hybrid games are used as research tools. Therefore they

play a secondary role in research, and sometimes their development is little reported. but through the survey sent to the authors, it was possible to identify difficulties such as heterogeneity of devices and absence of proper assessment tools.

4.4. RQ4: Are there tools that help the development of this type of game (e.g., framework, middleware) ?

We did not find specific tools for hybrid games among the 31 articles. Only the work of [Valdivieso et al. 2018] reported having created a platform called *CREANDO*. It assists in the development of pervasive games. Game developers could use its functionalities for hybrid game creation. For instance, the tool offers communication with indoor wireless technologies (e.g., Beacons) and pattern recognition technologies (e.g., QR Codes).

4.5. RQ5: Which game genres have already been explored in the academy?

We found educational and strategy games in the mapping. A particular case is the work of [Nojima et al. 2018], in which authors proposed a *hybrid sport*, i.e., a new version of the classic burn game using equipment that allows adding digital elements such as strengths and life to the participants. Thus, they adapted their natural physical abilities to the game.

4.6. RQ6: What was the target audience?

There was no clear predominance of the target audience. In the case of educational games, the audience ranged from elementary school students, in [Ponticorvo et al. 2017], to higher education students as in [Berns et al. 2016]. In the case of health games, such as the work of [Chao et al. 2017], the audience was older people who have some degree of dementia. In [Tondello et al. 2015], the target audience was the participants of a research event. The game goal was to promote interaction between the conference participants.

4.7. RQ7: How were they evaluated (e.g., experience evaluation, playtest, use of instruments)?

Generally, we found two types of evaluations in works involving hybrid games: pre- and post-test interviews and questionnaires. The questionnaires include authors' instruments and well-known questionnaires such as *SUXES* used in [Vuorio et al. 2019] and the *Emoti-SAM*, which was adopted in the work of [Carbajal and Baranauskas 2019]. These two instruments are used to evaluate the user experience. In the case of their questionnaires, the authors applied most of them in educational contexts. One goal was to measure students' knowledge before and after the "treatment" with the hybrid game. An example is the work of [Chang et al. 2017]. Some authors mentioned using interviews, but the articles do not detail their construction and application. We found both the use of semi-structured interviews as in [Kasapakis et al. 2015], as well as fully structured, for example, in [Chang et al. 2017] in which authors asked the participating students about the learning method adopted.

4.8. RQ8: What was the acceptance of these games?

Only 13 of the 31 works carried out this type of evaluation, and generally, the acceptance was positive. In the cases of [Berns et al. 2016] (12 participants), [Carbajal and Baranauskas 2019] (19 participants), [Kasapakis et al. 2015] (30 participants) and [Kopeć et al. 2017] (30 participants) the approval was 100%. The work

with the most participants was that of [Vuorio et al. 2019] with 328 respondents and acceptance of 79%. There was also work that chose to make their acceptance assessment through questionnaires on a *Likert* scale, as in [Wu et al. 2018] (151 participants), [Covaci et al. 2018] (117 participants) and [Shih et al. 2017](20 participants) who had their approval with an average of 3.25, 3.89 and 3.93 respectively.

In educational contexts such as [Chang et al. 2017], students reported feeling more motivated and engaged to learn content through hybrid games and to participate more actively in technological contexts such as in [Nojima et al. 2018] in which when asked if they would play again, 97% of the 16 participants answered yes.

5. Survey

The survey consisted of 13 questions, of which eight were objective and five were subjective. The table with all questions and their purposes is available at the link in the footnote[7]. We sent the survey to the authors of the 29 articles via e-mail. For authors who did not have valid e-mails or did not put their contact details in the documents, we contacted them through the Research Gate platform. Of 116 submissions, 13 authors responded to the form. It's a low rate but close to 45% of the number of papers we found.

For question Q01, 69.2% of the authors stated that they had more than three years of experience with game development. In Q02, 69.3% answered that they had developed three or more hybrid games, demonstrating the presence of researchers who are also experienced in our mapping theme. As for Q03, 69.2% of the authors answered that they did not use any game design methodology in developing their hybrid games. Instead, three authors responded that they used SCRUM, and one author answered that they used GNS, a theory developed by Ron Edwards and published on the blog The Forge[8]. Continuing with the Game Design topic, in Q04, only two authors stated that they had using Game Design methodologies. One of the authors wrote: "I have used many game design methodologies but mostly focused on general game design concepts (e.g., Story, Narrative, Mechanics)" and another author replied, "We the games in collaboration with an experienced game design company [...] Then we adapt the development process to their timelines and methodologies". None of the authors claimed to have used or knew any specific methodology for hybrid games. This result provides evidence for a gap in hybrid game research. No proper game methodologies are used to develop them.

Regarding development difficulties, in Q05, 66.7% of the authors stated that developing a hybrid game is more complex than developing a digital game. The same happens in Q06, in which 72.7% of the authors report that creating a hybrid game is more challenging than an analog game. This indicates increased difficulty when developing a game that integrates elements from both domains.

When asked in Q07 and Q08 about using assessment instruments, 53.8% of the authors responded that they had not used instruments. Three authors used their instruments, and only two claimed to use questionnaires already known in the literature, respectively, the GEQ and SUXES forms. The latter was adapted by the authors. A result corroborates the information found in the mapping and previously commented on in the discussion of

[7] encurtador.com.br/bfhoF

[8] http://www.indie-rpgs.com/articles/1/

RQ7. In P09, 83.3% of respondents stated that having a specific assessment instrument for hybrid games would be interesting. One of the authors replied, "It will be great if I can assess the effect of hybridising". Other characteristics pointed out as desirable by the authors were the possibility of evaluating the players' level of engagement and the elements that make up the game separately.

One author highlighted "[...] confining a Hybrid Game evaluation is not easy to do as they differ so much and will continue to have differences as technology evolves.". However, how Usability and Learning can remain among all hybrid games and can be a basis for starting to develop assessment instruments for them." His report points to the difficulty in evaluating a hybrid game, highlighted in questions Q10 and Q11, which respectively questioned the problem of assessing a hybrid game to a fully digital and analog-only game. In Q10, 66.7% of respondents stated that it is more challenging to evaluate a hybrid game. In Q11, 72.7% answered that it is more challenging to evaluate a hybrid game compared to an analog-only game.

In Q12, the authors answered that the main advantages of using hybrid games lie in the possibility of different and innovative experiences. In addition, the authors also put the benefit of greater involvement between players. One author highlights: "The context is more natural. It encourages non-players to participate". As a disadvantage of using hybrid games, the authors mentioned the difficulty of dealing with heterogeneous devices and the increase in the game's complexity. One of the authors pointed out that the problems can vary from game to game, in some cases needing a master or support for different devices. In Q13, the authors cited the complexity of dealing with heterogeneous devices mentioned three times by them as the main difficulty in developing a hybrid game. In addition, other problems were noted, such as the need for specific software in some cases (2 mentions) and the amount of programming without an appropriate framework (2 mentions).

6. Final considerations and Future Work

From the analysis of the systematic mapping, we identified some trends in the research of and with hybrid games. The predominance of works in education and technology demonstration is one example. Also, QR Codes and RFID appeared as the leading technologies to bridge the digital and physical worlds of the games. In addition, the preference for pre-and post-test interviews and questionnaires as research evaluation methods is notable. Only 13 games underwent acceptance tests, and in all of them, the participants reported that the experience was mostly positive.

In the works mapped, we find a predominance in the education domain, followed by technological demonstrations. QR Codes and RFID are the most used communication technologies in their respective areas. Also, we did not identify specific evaluation instruments for hybrid games. Most authors adopted questionnaires and interviews as evaluation methods. In all works listing acceptance assessments, the evaluation results were positive. We identified from the survey analysis with the authors that they do not use and are unaware of Game Design methodologies targeting hybrid games. Only 2 of the 13 authors used general Game Design methodologies in their games, which shows a gap in the hybrid games domain since those games are created without the proper methods. We also noted a consensus among them regarding the difficulty in developing and evaluating a hybrid game compared to fully digital or analogue-only games. Also, the au-

thors stated that it would be interesting to have a specific instrument for evaluating hybrid games due to their mixed characteristics of the digital and physical domains.

This systematic mapping is part of a master's research that aims to understand the impacts of technological insertion in hybrid card games. For this, a hybrid game called Elementals is being developed in 3 versions with different levels of hybridization based on the mapping results. The following steps will be testing the versions, and we hope to find evidence of the impacts caused by the technological insertion.

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