A Systematic Mapping on Software Engineering Processes Applied to Digital Game Development

Sanderson P Barbosa,[1] André Luiz Castro Leal[2]

Núcleo de Práticas de Engenharia de Software Aplicadas a Games (NuESGames), Department of Computing, Institute of Exact Sciences, Universidade Federal Rural do Rio de Janeiro, 23897-000, Seropédica, RJ, Brazil

{sandersonbarbosa36, andrecastr } @gmail.com

Abstract

Digital games, if considered software products, can and should be built with technical criteria and supported by Software Engineering (SE) practices to properly achieve desired qualities. However, specificities can be considered when these are compared side to side, such as the traditional game publishing method, the need for audiovisual asset development or even story scripting. This paper reports on a systematic mapping of existing research on the use and development of SE based processes and their application on the game development lifecycle, and investigates which types of games these are being applied to. Three scientific databases were used for the mapping, out of which 287 articles were analyzed. 17 were identified as pertinent, and are reported in the final results. Educational games were the most common, and many used specifically developed processes to stages of game development. The most prominent traditional processes reported were implementation and requirements. Generally, this field of research appears to be in early stages of maturity and further studies, validating and proposing models, should be conducted.

1 Introduction

The process of high quality software development consists of several stages, each with its specificities in complexity and applicable methods, making each scenario unique [1]. Software Engineering (SE) is the knowledge area established to support the development of software products, in all stages of its lifecycle, by the use of methods and tools that help professionals apply the necessary processes to construct high quality software products [2].

Traditionally, a software product will go through many different stages during its entire lifecycle. These include, but are not limited to: requirements elicitation; planning; modeling; implementation; implantation and post-mortem [2]. These processes are well defined, as well as methods to properly achieve them with successful results, by the SE field of knowledge.

Digital games can be understood as software products if considered the intersections between them and traditional software, such as the need to make use of computational resources, scope and deadline definition for deliveries and quality assessment criteria [3]. However, the specificities of digital game development are often not covered by traditional SE processes, given the nature and intention of player interactions, of which quality assessment is often intangible and immeasurable when compared to those of traditional software users. We investigate the research on the use of software engineering processes, traditional or specifically developed to fit the needs of digital game construction, by reviewing the literature in this specific research topic, by means of a systematic mapping study [4].

A systematic mapping is a method aiming at building a classification scheme and structuring a software engineering field of interest. The analysis of results focuses on frequencies of publications for categories within the scheme. Thereby, the coverage of the research field can be determined. Different facets of the scheme can also be combined to answer more specific research questions [4].

The goal of this mapping study is to find and classify scientific work on Digital Game Development Processes directly. Towards this end, it is important to identify the available literature, authors, period, and types of models, domains, engineering process, languages, architecture and applications to better understand this research topic. The conducted process followed the guidelines for Systematic Mapping Study (SMS) proposed by Petersen, Kitchenham, and colleagues [4] [5] [6].

The remainder of this paper is organized as follows: section 2 presents the background; section 3 describes the research method in which this study was performed; section 4 presents and discusses the achieved results; section 5 discusses and summarizes related works; and section 6 concludes the paper.

2 Background

2.1 Digital games and software engineering

SE processes are well defined sets of actions, procedures and tools that, when properly applied to the appropriate development scenario, aid software developers to achieve a high quality software product, which satisfies the idealized necessities for each system [1]. More specifically, the process of understanding and defining such necessities includes both requirements elicitation and system modeling, critical to all posterior stages of software development.

Given the differences between them and traditional software, digital games have specific necessities, often not covered by traditional SE. The lack of one specific customer and the large number of different genres of digital games are examples of such specificities, which lead development teams to often apply 'artistic' (*ad hoc*) methods to construct their products [7]. However, the rise of the digital games market and the many intersections between the two kinds of software imply that specific methods to plan, model, implement and publish digital games can be defined and formalized by academic literature.

In [8], the proposed software development process when applied do digital games exemplifies some specificities of this domain. For instance, developing story and script are two initial steps in the game's lifecycle, considering target audience and age group; defining characters' relations and personalities, as well as conflicts and resolutions between such characters.

Game Design Documents (*GDDs*) are also an alternative to early game development stages. By organizing the game's content in clear and easy to understand documentation, it is possible to describe problems and define schedules to be addressed by the development team. In addition, such documents may also include early sketches of features, a short synopsis of the game's main selling points (pitch), or even small, contained functional prototypes [9]. With such aspects considered, it is possible to see clear parallels between the traditional software lifecycle and the proposed digital game lifecycle models.

In this study we seek to discover if the processes of digital game development have become a body of knowledge of their own, and are addressed in formal literature, taking into consideration the applicability limitations of traditional software engineering processes to this scenario. We also seek to understand which specific project management methodologies have proven most applicable and/or effective to the development of digital games.

2.2 Systematic Mapping

A systematic mapping is a method aiming at building a classification scheme and structuring a software engineering field of interest. The analysis of results focuses on frequencies of publications for categories within the scheme; thereby the coverage of the research field can be determined. Different facets of the scheme can also be combined to answer more specific research questions [4].

The goal of this mapping study is to find and classify scientific work on the usage and development of software engineering processes applied to digital games development. Towards this end, we identify the studies available in the literature, and analyze them focusing on research questions related to: (i) different types of models and processes applied; (ii) different game genres to which such processes and models have been applied to; (iii) the usage of traditional software engineering processes and development of specific processes; and (iv) which project management models work best in such scenarios.

3 Research Method

The research method for the mapping study presented in this paper was based on the guidelines given by Kitchenham & Charters [5], which involves three main phases: (i) Planning: refers to the pre-review activities, and aims at establishing a review protocol defining the research questions, inclusion and exclusion criteria, sources of studies, search string, and mapping procedures; (ii) Conducting: searches and selects the studies, in order to extract and synthesize data from them; (iii) Reporting: final phase that aims at writing up the results and circulating them to potentially interested parties. In this phase the findings of the systematic mapping study are used to answer the research questions. These activities were conducted by the two authors of this paper, and both of them worked in the entire process.

It is worthwhile to point out that we decided not to assess the quality of the selected studies, and thus we do not consider quality assessment criteria for selecting studies. This decision is in line with most mapping studies, as discussed in [6]. It is justified by the fact that the goal of a mapping study is to provide a broad overview of the topic area, and thus it does not need to address the quality of individual studies [10].

3.1 Research Questions

As it was aforementioned, the main goal of this SM is to provide an overview of software engineering processes applied to the development of digital games. The list below with ID (identifier), Research Question and Rationale presents the research questions that this study seeks to answer, as well as the rationales for considering them.

RQ1 - When have the studies been published?
This research question seeks to provide a temporal view of research evolution on Game Development Model (GDM).

RQ2 - Where have the studies been published?
This research questions seeks to identify whether there are specific publication venues for research on GDM.

RQ3 - Which kinds of models are being used in the studies?
This research questions seeks to identify which tools and/or languages have been used to model game development processes.

RQ4 - Which game genres have been modeled?
This research questions seeks to identify which types of digital games have proven, thus far, to be most suitable for modeling.

RQ5 - Which skill domains have been modeled?
This research questions seeks to provide an overview of which types of skills (e.g. storytelling, audiovisual design) have proven suitable for process modeling.

RQ6 - Which Software Engineering processes have been used in the studies?
This research question seeks to discover which traditional software engineering processes (e.g. requirements, planning) are currently applied to game development.

3.2 Study Selection

In order to select the studies to conduct this research, several aspects were taken in consideration, such as (a) definition of search string; (b) selection of sources; (c) selection of the control articles and (d) the inclusion and exclusion criteria. These aspects are discussed as follows:

(a) Search String:
Our search string was defined and redefined multiple times until it would properly yield, when applied to our sources, both the control articles and a relatively small perceived number of unrelated articles.

game AND process AND (model OR language OR architecture)

(b) Sources:

To conduct the study, the following sources were considered: ACM Digital Library (https://dl.acm.org); IEEE Xplore (http://ieeexplore.ieee.org); and Science Direct (http://www.elsevier.com).

Both Scopus (http://www.scopus.com) and Web of Science (http://www.webofknowledge.com) were also considered as possible sources, however, Scopus yielded far too many results even after applying several filters; whereas Web of Science had access restrictions which we were not able to circumvent.

(c) Control Articles:

The control articles (CAs) were selected manually, after conducting a simple search on the platforms not yet considering the aforementioned search string. Such CAs were read and assessed to properly define them as such, considering whether or not their content was in accordance to the theme of Game Development Models/Processes. The CAs used in our study were: CA1 - Embedding DEVS Methodology in CBD Process for Development of War Game Simulators [#2], CA2 - A documental approach to adventure game development [#13], CA3 - A Process Framework for Serious Games Development for Motor Rehabilitation Therapy [#6], CA4 - A serious game development process using competency approach: Case Study: Elementary School Math [#5].

(d) Inclusion and Exclusion Criteria:

The selection criteria are organized in one inclusion criterion (IC) and six exclusion criteria (EC). The inclusion criterion is: (IC1) The publication concerns the subject of Digital Game Process Modeling directly. The exclusion criteria are: (EC1) The study does not provide an abstract; (EC2) The study is just an abstract; (EC3) The study is not written in English#2; (EC4) The study is a copy or an older version of another study already considered; (EC5) The study is not a primary study (e.g. proceedings, editorials, summaries of keynotes, tutorials, etc.); (EC6) It is not possible to have access to a full version of the publication.

For EC3 two exceptions were made as both the title and abstracts of the studies were available in English, although the complete study was only available in Portuguese. These articles were [#3] and [#10].

4 Results

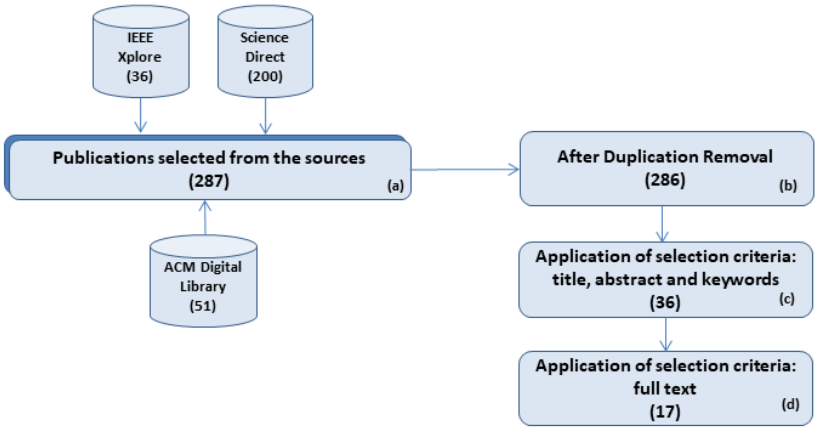
In this section are presented the results for each of the defined research questions (RQ), considering the set of studies selected at the end of the mapping process.

Our search string was used to query the aforementioned sources, generating raw results. At the end of all three queries, 287 studies were returned in total, being 36 from IEEE Xplore, 200 from Science Direct and 51 from the ACM Digital Library. These results were then scrutinized for any duplicates, i.e., the same publication returned by different sources, which were then removed. However, only one duplicate was found, leaving 286 studies to be analyzed according to the selection criteria (inclusion and exclusion criteria – IC and ECs).

These criteria were first applied to the articles' title, abstract and keywords (1st filter). If the analysis indicated that the publication satisfied the IC, it was marked as selected; otherwise it should be marked as non-compliant with the IC (~IC). If one of the exclusion criteria was met, the publication was also marked accordingly (e.g., EC5), indicating that it should be removed from the list. This left us with a total of 36 articles, to which the same process was executed once again, considering now the full text of the publication (2nd filter) instead of its superficial contents. From this second analysis, 20 articles were considered valid, and an ID was assigned to identify these studies throughout the rest of the mapping. The complete list of the selected studies is presented in Appendix A.

Figure 1 summarizes the evolution of the result set during the different stages of the systematic mapping process.

Figure 1: Article count throughout the selection process.



A deep analysis of the remaining 17 articles led to identifying answers to the research questions proposed for this study. The following subsections detail the results obtained for each research question. The studies are referenced by their IDs, as assigned in Appendix A.

4.1 When have the studies been published? (RQ1)

The intention of RQ1 is to show when the effort of research is concentrated. To answer the question, Figure 2 shows the total number of publications over the years. We highlight the concentration of publications in the last decade, but also draw attention to the fact that research in game process and methodologies date back to the year of 2007. Additionally, Table 1 presents the list of articles by year.

Figure 2: Number of published articles per year.

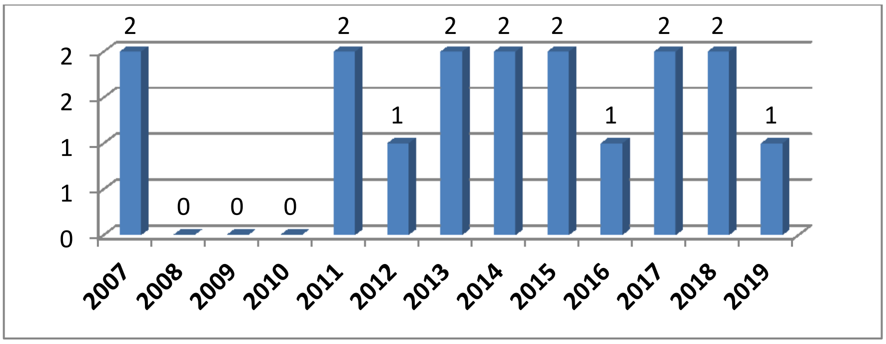


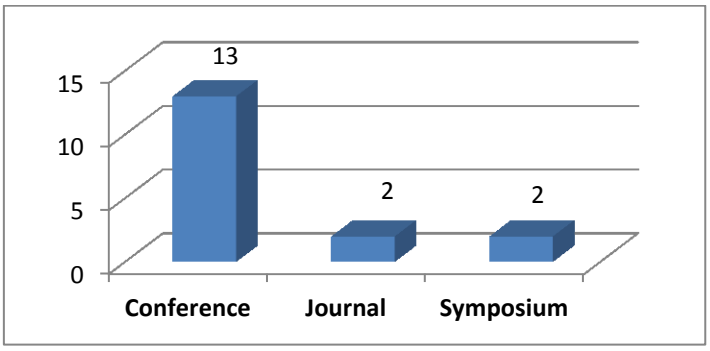
Table 1: Articles per publication year

Year	Article IDs
2007	#2, #13
2008	None
2009	None
2010	None
2011	#1, #9
2012	#15
2013	#8, #11
2014	#5, #7
2015	#16, #17
2016	#6
2017	#10, #12
2018	#3, #4
2019	#14

4.2 Where have the studies been published? (RQ2)

RQ2 concentrated on where the results of scientific research with software game process and methodologies are published. Figure 3 shows the total number of articles grouped by venue type (conference, journal and symposium).

Figure 3: Number of published articles per venue type



Most articles (76%) were published in conferences. Table 2 presents the list of articles by venue type, detailing conference, symposium, and journal.

Table 2: Published articles per venue type

Venue Type	**Article IDs**	**%**
Conference	#1, #2, #5, #6, #7, #8, #10, #11, #12, #14, #15, #16, #17	78
Journal	#9, #13	11
Symposium	#3, #4	11

Figure 4 identifies the different conferences on which the articles were published and the number of articles published on each one. Table 3 details which articles were published on said conferences.

Figure 4: Publication number per conference

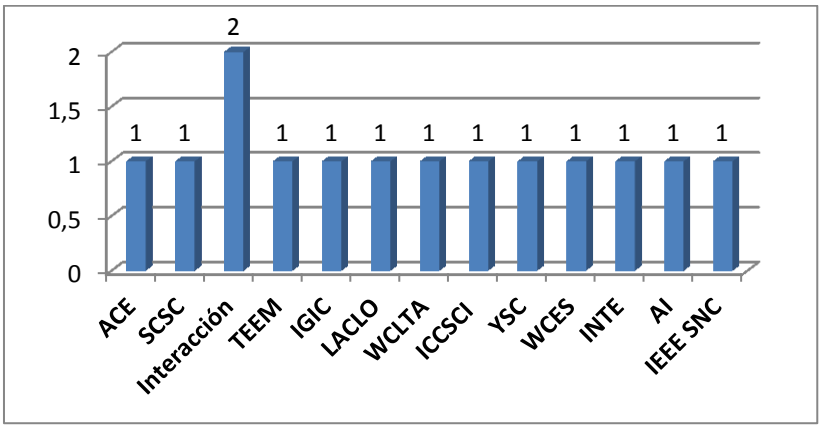


Table 3: Published articles per conference

Conference	Article IDs
ACE	#1
SCSC	#2
Interacción	#5, #6
TEEM	#7
IGIC	#8
LACLO	#10
WCLTA	#11
ICCSCI	#12
YSC	#14
WCES	#15
INTE	#16
AI	#17

Given the low number of publications on journals and symposiums, figures are not necessary to showcase them. Tables 4 and 5, respectively, show which journals and symposiums published which articles.

Table 4: Published articles per journal

Journal	Article IDs
IEEE SNC	#9
SCP	#13

Table 5: Published articles per symposium

Symposium	Article IDs
SBSI	#9
CHI PLAY	#13

4.3 Which kinds of models are being used in the studies? (RQ3)

Figure 5 shows the different types of models, newly proposed or otherwise pre-existing, used in the development process reported in the papers. Some of these used very specific approaches, such as the ARCS (Attention, Relevance, Confidence, Satisfaction) Model seen in [#16] or the Six-Facet Model in [#11]. Some papers demonstrated the usage of more than one modeling method and thus were accounted more than once. Table 6 specifies them.

In order to improve visibility, some model names seen in Figure 6 were shortened. DSL, seen in [#1], stands for Domain-Specific Language. BPMN is Business Process Modeling Notation; IPO [#15] is Input-Process-Outcome; SGDP [#5, #6] is Serious Game Development Process Model and EGM [#10] is Educational Game Metamodel.

Figure 5: Distribution of modeling methods used in the studies

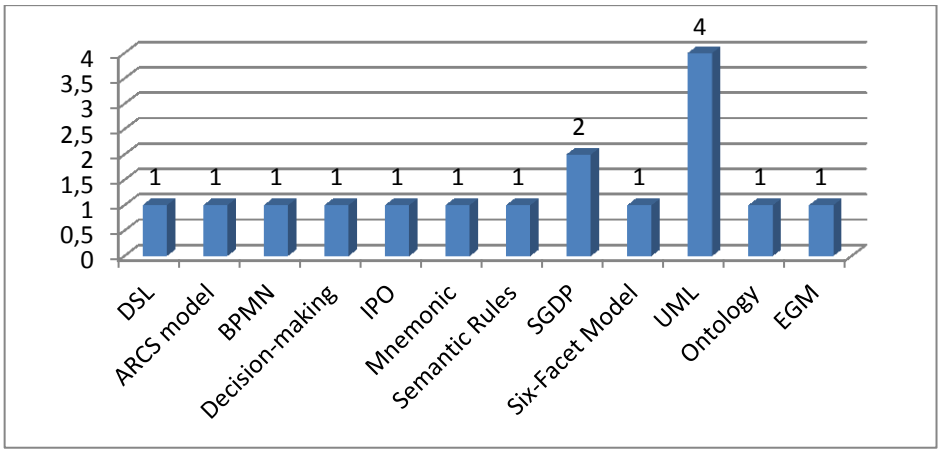


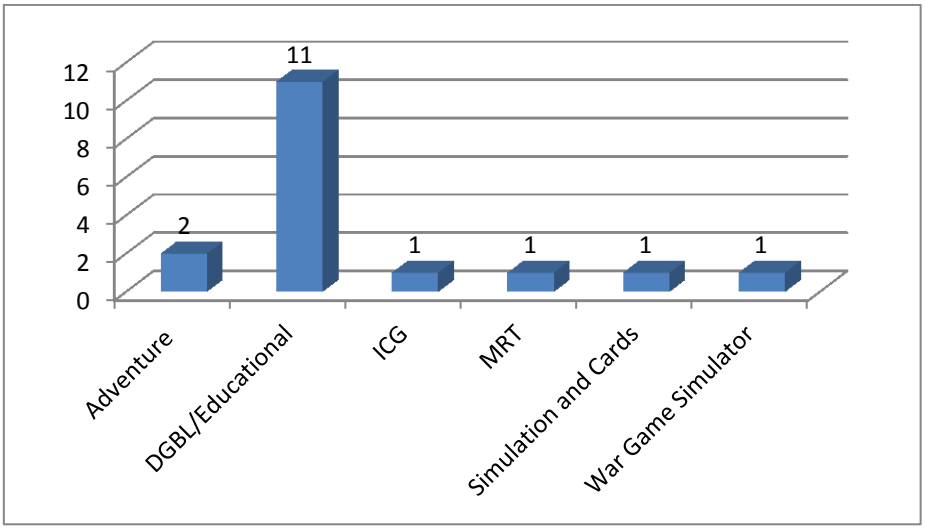
Table 6: Articles separated by modeling method

Model	Article IDs
DSL	#1
ARCS Model	#11
BPMN	#3
Decision-Making	#17
IPO	#15
Mnemonic	#12
SGDP	#5, #6
Six-Facet Model	#11
UML	#2, #7, #8, #10
Ontology	#7
EGM	#9

4.4 Which game genres have been modeled? (RQ4)

Figure 6 shows which different types of games, known as genres, have been modeled in the studies. Here, DGBL refers to Digital Game Based Learning, and is the most prominent type of game explored in these papers. ICG stands for Integrated Co-located Games, which is specifically found in [#4]. MRT is the case of [#6], or Serious Game for Motor Rehabilitation Therapy.

Figure 6: Distribution of game genres studies in the papers



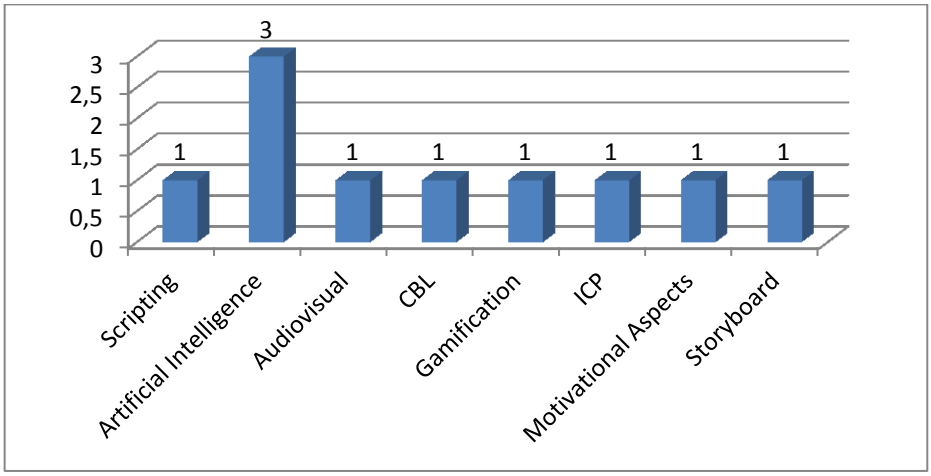
335 Table 7: Article IDs by genre type

Game Genre	Article IDs
Adventure	#1, #13
DGBL/Educational	#3, #5, #7, #8, #9, #10, #11, #12, #15, #16, #17
ICG	#4
MRT	#6
Simulation and Cards	#14
War Game Simulator	#2

336 ## 4.5 Which skill domains have been modeled? (RQ5)

337 Figure 7 shows which skill domains have been modeled in the studies.
338 By this we propose to understand what parts of the game development
339 process have been well defined and have methods to support them. In
340 this Figure, CBL [#10] stands for Challenge Based Learning, ICP [#4]
341 is Iterative Creation Process and Motivational Aspects [#16] is short for
342 Motivational Aspects of Learning Environments.

343 Figure 7: Skill domains modeled in the studies



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347 Table 8: Articles separated by skill domains modeled

Domain	Article IDs
Scripting	#1
Artificial Intelligence	#14, #15, #17
Audiovisual	#9
CBL	#10
Gamification	#12
ICP	#4
Motivational Aspects	#16
Storyboard	#13

348 **4.6 Which traditional Software Engineering processes have**
349 **been used in the studies? (RQ5)**

350 Figure 8 shows traditional software engineering processes used and
351 expressed by the studies. Considering the differences between tradi-
352 tional software development and digital game development, some of
353 these processes have been applied only partially or have been some-
354 how adapted to fit the needs of the product.

355 Figure 8: Traditional SE processes used in the studies

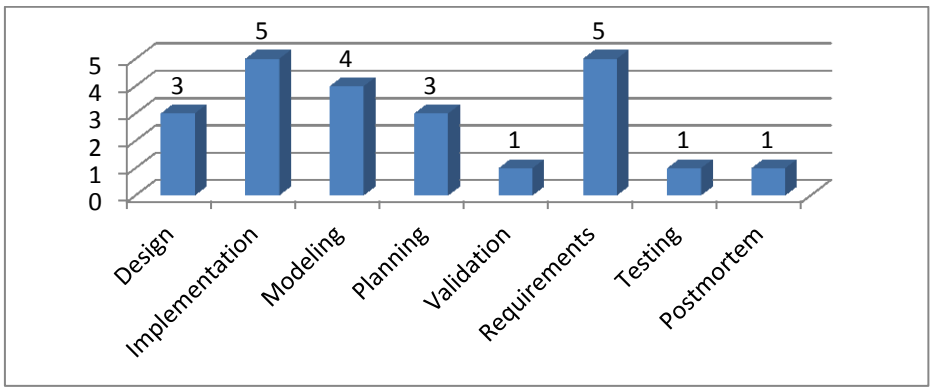

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Table 9: Articles separated by SE processes used

SE Process	Article IDs
Design	#5, #16, #17
Implementation	#2, #5, #6, #13, #15
Modeling	#6, #9, #10, #11
Planning	#4, #6, #10
Validation	#6
Requirements	#1, #3, #5, #12, #13
Testing	#5
Postmortem	#5

4.7 Discussion

We believe that the data presented as response to our research questions (RQs) and the hypotheses that can be derived from certain analyses of such data can provide us with an overview of the general landscape of this area and foster a debate that contributes to the scientific community interested in this field of research.

The yearly distribution of articles yielded by RQ1 does not show a relative increase or decrease of interest in the field by scholars. By discovering which types of venues most of these studies are published (RQ2), we can create an overview of the maturity on which this sort of study has acquired over said years. Most of the articles have been published in conferences, by which we can assess the field is still immature. This assumption is further strengthened by the low quantity of published articles seen in RQ1.

By discovering which models are being used (RQ3), we see that there is a good amount of adaptation required and used in these processes, further indicating that digital game development has considerably different needs from traditional software development. Interestingly, the most common modeling method was UML, largely due to its generalist nature and open-ended structure. As for game genres (RQ4), we can see that the most prolific are educational games, or Digital Game Based Learning (DGBL) systems. By uncovering which different types of games have been modeled, we seek to not only gain insight as to which types of games are studied in formal publications but also which have proven most suitable to modeling. Despite these results, we have no reason to believe these are the most common types of games produced and sold by the video game industry, or that

other in-house methods have been developed by companies and not published as formal studies.

By uncovering which skill domains have been studied and modeled (RQ5), we can see a predominance of models seeking to improve the development of artificial intelligence agent in game environments. Considering non-playable characters, either enemies, interactive non-hostile characters or anything in between, are common to many different games; it makes sense that they would be a topic of interest. We believe, however, that methods to improve the process of developing other specificities to game development such as audiovisual art, sound effects, or story structures, can and should be studied and formalized into software engineering processes.

Finally, by uncovering which SE processes are already being used in the studies (RQ6), we can see that despite having its own specific needs, the process of game development does indeed have many parallels with traditional software development, enough that many unchanged or only slightly adapted processes have been applied. The processes of implementation and requirements were the most commonly expressed. Although most of these games were implemented in one way or another, only articles which deliberately expressed some sort of formality in that process were considered in the counting.

With all RQs considered, it is safe to consider that field of study concerning software engineering processes in game development is still in its infancy, and as such is a field to be explored.

5 Related Work

Several other works have discussed game development models before. We highlight two results yielded in our research, excluded by EC5, as significant studies focused on the theme of GDM. These are [11] and [12]. On [11], the survey analyses over twenty different digital game development postmortem documents and defines, for each document, a process model, modeling activities or process details utilizing Business Process Modeling Notation (BPMN).

On [12], a survey conducted in 2015 is reported, assessing development processes and business aspects of the digital games industry. This survey included additional themes, however, such as sustainability, business and marketing. On the subject of development models, this survey reports that the majority of 61% of companies do not follow any systematic development process, with the remaining 39% report applying either ‘Scrum’, ‘Partial Scrum’, ‘Prototyping’ or other agile method. [12]

6 Conclusions

This systematic mapping study was conceived to acquire knowledge on the state-of-the-art in the use of software engineering processes applied to digital game development. Our intention was to find answers for research questions that could provide us with a panorama of this area, involving: a) types of games modeled; b) kinds of models used; c) specific model development or application of existing techniques; and d) distribution over years and venue types. In this context, we identified 17 relevant studies from 3 different sources for academic publications in Computer Science. As the systematic mapping was concluded during 2019, we understand that some articles of this year are not considered in this study.

Answers to research questions proposed initially provide us with an overview of this research field. When combined, these answers provide us with possible trends in the field, as discussed in Section 5. In particular, the mapping alerted us to the lack of expressive research on the formalisms applied to game development, and of models proposed to support this activity. Future work in this direction includes the validation of proposed models by means of case studies and proposal of new development models based of SE formalisms.

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Appendix A – Systematic Mapping Articles

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