SOFTWARE MATURITY LEVEL AND THE TRAINING OF QUALIFIED PERSONNEL IN SOFTWARE TECHNOLOGIES AT IFBA

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ABSTRACT

The Brazilian Digital Games Industry has grown significantly over the past few years, resulting in the approval, by the Federal Senate, of Bill PL 2.796/2021, which creates the legal framework for the electronic games industry. Educational programs aimed at the development of games in Brazil are a necessity for the training of talents and promotion of innovation for this segment. Being a high-risk business, digital game development requires metrics that can assess the development of the technology. In this context, the objective of this work was to present a correlation between the level of readiness of software technology and the process of digital game development, as well as to analyze IFBA courses that increase the supply of qualified personnel in digital game development. For this, bibliographic and documentary research procedures were used. 4 technology readiness level (TRL) scales applied to software developed by American and Brazilian government agencies were identified, all adapted from the TRL scales and requiring adjustments for application in the various software technologies. The DG-STRL scale, by Ferreira and Ribeiro, correlates the stages of digital game development with the TRL for software technology, being an instrument focused on the sector. It was observed that the IFBA offers game development courses at the level of continuing education, undergraduate and specialization, contributing to the training of talented developers, capable of competing on a global scale.

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INTRODUCTION

The use of software technology (ST) currently gives this type of technology a fundamental and ubiquitous role in our society, as it permeates almost every aspect of everyday life. ST is present both in the way individuals communicate and relate, as well as in the way they consume information, work and have fun. It is undeniable that ST has had a profound impact on all sectors and layers of society (VAN DIJCK, 2013).

TS has revolutionized communications, allowing, for example, instant communication on a global scale through the most diverse platforms: email, social networks, instant messaging and videoconferences (VAN DIJCK, 2013). It also brought people from different parts of the world together, shortening geographical distances and expanding the development of social and professional networks. The internet and other ST have democratized access to information, making it possible for practically anyone, anywhere to access a vast and varied amount of knowledge, although there are still places and communities where its use deserves better attention in terms of this access. The democratization of this access has profoundly impacted the way humanity learns, educates itself, and stays informed about global events, social and cultural issues.

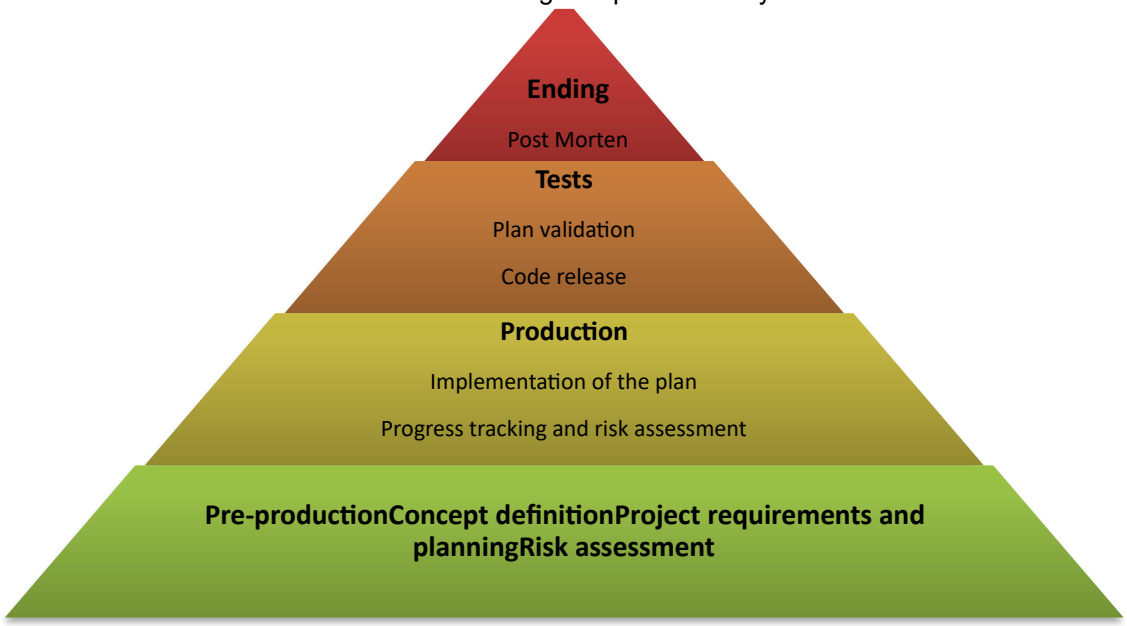
By redefining traditional business models and industries, such as in the automation of industrial processes, it is observed that companies from the most varied sectors are incorporating ST aiming at: a) increasing their efficiency, b) reducing costs, and c) improving the customer and user experience. SWTs have also encouraged innovation and entrepreneurship, as they provide new opportunities for individuals and businesses to create and launch new products and services in the market. In this sense, the growing use of software development tools, access to cloud computing resources, and the emergence of new industries around technologies such as artificial intelligence, blockchain, augmented reality, and digital game development can be highlighted (HARARI, 2020).

Battaiola (2000) considers that the digital game is composed of three parts: a) plot, which defines, in addition to the theme, the sequence of events, the objectives of the game, in short, the plot; b) motor, it is the mechanism that controls the actions (player) and reactions (environment) of the game, as well as their consequences; c) interactive interface, with the function of communicating between the player and the game engine, enabling the entry of the player's actions and the audiovisual responses to changes in the environment.

For Chandler (2012, p. 3), "the production process begins with the definition of the initial concept of the game and ends with the creation of a gold master version of the final code, with the rest happening between these two points". Also according to the author, there is a basic structure to support the production process of a game, which must be

considered, regardless of the budget available, the size of the team involved or the scope of the game, and this process is divided into four main stages: a) pre-production, b) production, c) testing, and d) finalization, as shown in Figure 1.

FIGURE 1 - Basic game production cycle



Source: adapted from Chandler, 2012, p. 4.

The computer industry, and most notably the Brazilian Digital Games Industry (IBJD), has grown significantly over the past few years, becoming a dynamic and influential sector in both the country's economy and culture, with ramifications in the most diverse areas of knowledge. According to Fleury, Nakano and Sakuda (2014), the economic activity related to the IBJD presented, in the early 2010s, the possibility of higher growth rates when compared to the average of the economy in general. For the aforementioned authors, the IBJD has a strong relationship with the knowledge economy due to its characteristics: a) low-cost reproduction, b) productive flexibility, c) base on intangible assets, d) great modularity, e) economies of scale of demand and scope of supply (FLEURY; NAKANO; SAKUDA, 2014).

Another very important point for the development of the IBJD is the support given to the sector by the Brazilian government, through initiatives such as tax incentives, subsidies and financing programs aimed at promoting innovation and growth in the sector. One of the most assertive actions was the approval by the Federal Senate, on March 13, 2024, of Bill (PL) 2.796/2021, which creates the legal framework for the electronic games industry (BRASIL, platform Gov.br, 2024). The Executive Secretary of the Ministry of Culture, Márcio Tavares, stated that "Games now have a legal instrument that will strengthen the

production chain, the development of this very important industry. 75% of Brazilians play games" (BRASIL, plataforma Gov.br, 2024, p.1).

The development of digital games stands out as a sector of the economy with great potential for growth and high-level job creation. This sector appears in the current economic scenario as a dynamic industry, with constantly redefined standards of competition and competitiveness, greatly globalized and focused on well-structured market systems. Estimates for the year 2023 pointed to a world market that would move around US$ 184 billion, consisting of around 3.31 billion players (NEWZOO, 2024). Newzoo is a game market analysis and intelligence company, and according to a survey produced by it, "the global gaming market will generate annual revenues of US$ 205.4 billion in 2026" (NEWZOO, 2024, p. 17).

Brazil has followed this global potential of the digital games segment. Also according to data released by Newzoo (2024), in 2023, Brazil has more than 100 million players, representing 3% of the world's users, placing Brazil among the 10 largest consumers on the planet. These data point to a significant contribution of the IBJD to the Brazilian economy, generating revenue through game sales, in-game purchases, as well as advertising and exports. As the digital games sector advances, it creates job opportunities in the most varied fields, such as programming, art, design, marketing, and management (PESQUISA GAME BRASIL, 2024, p. 32-37).

The 2024 Game Brasil Survey[5], celebrating its 11th edition, points out that 73.9% of Brazilians usually play video games on the most diverse platforms (PESQUISA GAME BRASIL, 2024), constituting a very rich market for the development and supply of games. The Brazilian gaming market continues to expand, driven by factors such as: a) "an increase in the base of new couples who live with children or are fathers and mothers" (PESQUISA GAME BRASIL, 2024, p. 20), representing 69.5% of the Brazilian gamer consumer, b) the adoption of smartphones, the preferred platform for 61% of women (PESQUISA GAME BRASIL, 2024), c) the growth of the middle class with disposable income for entertainment purposes, representing 64.8% of gamers (PESQUISA GAME BRASIL, 2024).

Also according to data from the 11th Edition of the Game Brasil Survey, a large number of individuals, 85.4% of those who responded to the survey, assume that

[5] The Game Brasil Survey is developed and produced by a partnership between Blend New Research, ESPM, Go Gamers and Sioux Group. The entire survey is developed with proprietary questionnaires with topics that involve the gamer audience and its entire ecosystem, in Brazil and Latin America in key countries such as Argentina, Chile, Colombia and Mexico. The consulting company Go Gamers is the business unit responsible for the development, production and publication of the survey annually within the official channels pesquisagamebrasil.com.br and gogamers.gg.

"electronic games are among their main forms of entertainment" (GAME BRASIL SURVEY, 2024, p.23). There are several factors that interfere in consumption behaviors and in the choice of use of multiple platforms for games: Computer, Console and Smartphone. The data in this edition of the PGB also indicate that practically 3 out of 4 Brazilians (73.9%) usually use digital games, and, of these, 50.9% represent the female audience, data influenced "mainly by smartphones, which historically is a platform with a greater presence of the female audience" (PESQUISA GAME BRASIL, 2024, p. 17).

Another interesting data, presented by Pesquisa Game Brasil in 2024, highlights that approximately 52.4% of the individuals interviewed, when asked about professions in the Brazilian games market, believe that this sector "offers good opportunities for work and career" (PESQUISA GAME BRASIL, 2024, p. 31). Considering these data, as well as the five public policy objectives to foster the Brazilian Digital Games Industry (IBJD), members of the Report "Proposition of Public Policies Directed to the Brazilian Digital Games Industry" (FLEURY; NAKANO; SAKUDA, 2014), notably Goal 2: Empower Human Resources to create, manage, and operate world-class companies (SAKUDA; FORTIM, 2018), the importance of investing in training courses aimed at the development of the IBJD is verified.

Educational programs aimed at the development of games in Brazil are a necessity for the training of talents and, consequently, the promotion of innovation for IBJD. Firstly, the promotion of these programs meets a growing demand for skilled professionals in the gaming industry. With its expansion, there is an increasing need for game developers, with the skills and knowledge necessary for the overall growth and maturation of the Brazilian digital games sector, including the adoption of criteria for evaluating the level of readiness of software technology.

The Federal Institute of Education, Science and Technology of Bahia (IFBA), fulfilling its role as an Institution of Science and Technology (ICT), identifying this gap in professional training, in the context of the IBJD, began to invest in Course Implementation Projects focused on the theme of digital games, notably after 2018 (IFBA, 2018a, 2018b, 2019a, 2021). This action is essentially linked to the fulfillment of a specific objective: "Increase the supply of qualified human resources in line with the needs of the sector" (SAKUDA; FORTIM, 2018, p. 221).

By investing in the education and training of future game developers, the IFBA works by laying the local foundation for continued growth, innovation, and competitiveness in the global digital gaming market. By providing students with hands-on training, access to industry-standard tools and technologies, and opportunities for networking and

collaboration, IFBA has created an environment conducive to the development of creativity and innovation. This, in turn, leads to the development of high-quality games and the emergence of talented game developers who can compete on a global scale.

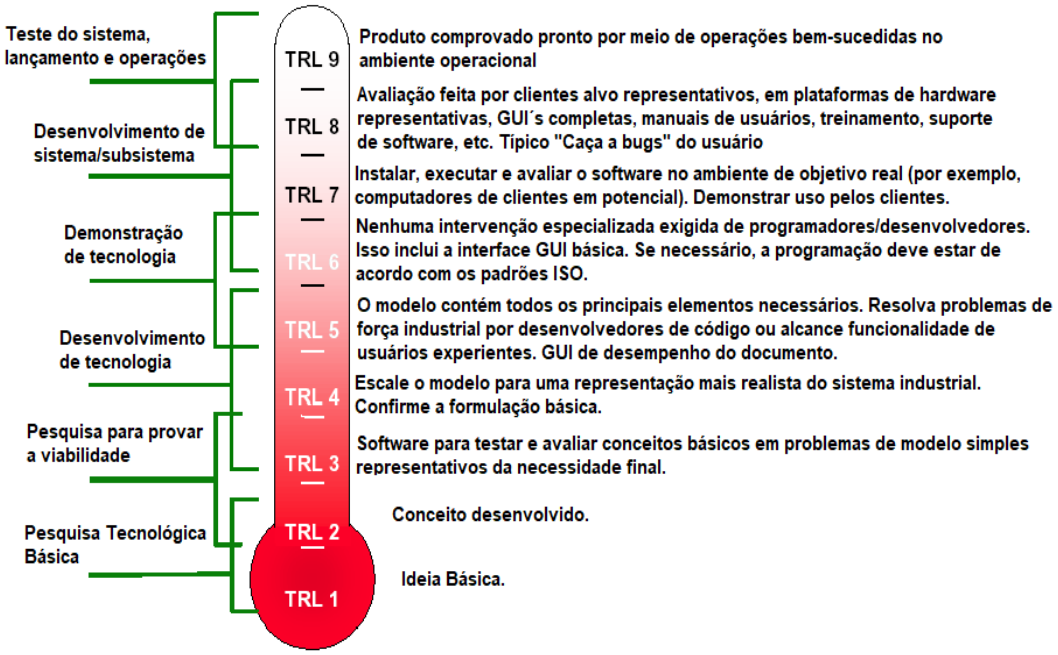
In the professional training and digital game production environments, project management techniques are used to monitor the development of this technology, its launch deadlines and available budget. However, no tools were found that associate the analysis of the level of technological readiness with this development process, which could favor the completion of the product until its commercialization. Considering that, normally, the volume and diversity of resources involved in these development processes require well-defined points of adjustment and controls, in addition to a constant risk analysis, it became necessary to find a solution to this demand.

A widely used method to assess the level of readiness of a given technology, the *Technology Readiness Level* (TRL), has become an important metric for decision makers. Ferreira and Ribeiro (2024) point out that the concept of measuring technological maturity levels was proposed in a 1969 report by the *National Aeronautics and Space Administration* (NASA). This original concept of TRL was formulated mostly in terms of hardware, and this creates some difficulty for the analysis of software technology maturity.

Marson (2018), exemplifying the use of TRL applied to the development of a product, presents the following description of the 9 TRL levels: 1) Research of basic principles; 2) Formulation of the concept of the technology or possible application; 3) Development of experimental or theoretical proof of concept; 4) Validation in a laboratory environment; 5) Validation in an environment close to reality; 6) Demonstration of prototype in an environment close to the real one; 7) Demonstration of prototype in operational environment; 8) Product qualification through testing and demonstration and, 9) Product operation in an operational environment (MARSON, 2018, p. 1).

Armstrong (2010) stated that, mainly due to the critical performance functionalities, large and complex systems began to have their development processes gradually more dependent on software, which increased the importance of the application of TRL for software development (ARMSTRONG, 2010). This fact motivated the performance of interpretative studies of the methodology in order to meet the peculiarities of technologies in specific sectors, such as software development, creating TRL equivalences, for example, such as the Software Technology Readiness Level (STRL) (EMBRAPII, 2020). Figure 2 shows a version adapted to TRL for software development.

FIGURE 2 - Software-adapted TRL scale



Source: Adapted based on NASA (2017, p. 265) and Veras (2018, p.7).

Considering the context of the IBJD, this research aims to present a correlation between the level of readiness of software technology and the process of digital game development, as well as to analyze IFBA courses that increase the supply of qualified personnel in digital game development.

This work is justified by contributing to the discussion on the training of qualified professionals by an ICT, professionals destined to a sector in full expansion, that of the IBJD. In addition, it contextualizes this training with the software technology readiness level (STRL), one of the most used metrics for evaluating technologies in this sector, which, as highlighted by Ferreira and Ribeiro (2024), has a high economic return and great growth potential for Brazil (FERREIRA, RIBEIRO, 2024). It is believed that this reflection will contribute both to the professional training of developers for the IBJD, and to the evaluation of the level of readiness of software technology, more specifically when the software is a digital game.

METHODOLOGY

This is an exploratory research with descriptive aspects, aiming to identify the STRL scales used as a reference in software technology readiness assessments in the Brazilian context, to present the professional training proposals for the IBJD of the IFBA, and to correlate the process of development of digital games and the STRL. As highlighted by Gil (2002), when used together, exploratory and descriptive research bring with them the development of perceptions or an improvement of concepts (exploratory), in addition to

establishing connections or presenting particularities (descriptive) existing in a given object of study.

The research also presents a qualitative approach, based on bibliographic and documentary research, based on inferences of the authors based on the literature and institutional documents, presenting: the STRL scales; the stages of the digital game development process, and the professional training proposals implemented by the IFBA.

To build the theoretical framework about STRL, the databases available on the CAPES Journal Portal (CAPES, 2024), and on the Brazilian Digital Library of Theses and Dissertations (IBICT, 2024) were consulted, using descriptors such as: Software *Technological Readiness Level*), without temporal or territorial delimitation. Regarding professional training, a documentary research was carried out, with a search and selection of documents related to national public policies aimed at the IBJD, as well as the IFBA Course Pedagogical Projects (PPC) related to the IBJD.

The research focused on the PPC selected for the composition of the research corpus, namely: a) Higher Education Course in Technology in Digital Games (STJD) (IFBA, 2018a); b) Higher Education Course in Technology in Digital Games Distance Modality (STJD-EAD) (IFBA, 2018b); c) Specialization Course in Development of Applications and Games for Mobile Devices (EDAGDM) (IFBA, 2019); d) Initial and Continuing Training (FIC) of Digital Game Programmer for Mobile Devices (PJDDM) (IFBA, 2021). How the II IBJD Census systematizes data on the objectives aimed at the sector in Brazil (SAKUDA; FORTIM, 2018), these PPC were analyzed in the light of these objectives.

Regarding the organization and treatment of the data, it was decided to adopt the guidelines of the content analysis proposed by Bardin (2016), aiming to interpret the qualitative material objectively and systematically.

RESULTS AND DISCUSSION

This section is divided into four subsections. In the first, the courses offered by IFBA focused on the Development of Digital Games (DJD) are presented. The characterization of the basic cycle of production of digital games, without intending to exhaust the theme, makes up the second subsection. The concept of Software Technology Readiness Level (STRL), with the identification of the main scales used, is addressed in the third subsection. Finally, in the last subsection, we have the presentation of the DG – STRL, a proposition based on the correlation between the STRL scale and the stages of development of a digital game.

THE IFBA: COURSES FOCUSED ON THE DEVELOPMENT OF DIGITAL GAMES

The following courses offered by the IFBA were identified with the theme of digital game development and aimed at the professional training of developers of these games: 1) Specialization in Development of Applications and Games for Mobile Devices (EDAGDM), a lato sensu postgraduate course approved in 2019; 2) Superior Technology in Digital Games (STJD), undergraduate course approved in 2018 in the face-to-face and distance modalities; 3) Initial and Continuing Training (FIC) course for Digital Game Programmers for Mobile Devices, approved in 2021.

A common feature of all these courses offered by IFBA is the emphasis given to the development of digital games for the platform made up of Mobile Devices, that is, portable devices such as: smartphone, notebook, tablet, etc. This decision is appropriate, since these devices make up the preferred platform for 62.7% of Brazilian players (PESQUISA GAME BRASIL, 2024).

The lato sensu EDAGDM graduate course is presented as an "innovative course that integrates the various areas of knowledge, through an interdisciplinary and contextualized methodology" (IFBA, 2019a, p. 16), which is aimed at the production of "applications and digital games for mobile devices, meeting various demands, such as entertainment, education, people training, marketing, simulation and rehabilitation" (idem, p. 18). The graduate of this course works "from the analysis of the customer's needs, planning of the application's resources, development, implementation of architecture, tools and resources, to the realization and configuration of tests" (idem, p. 34).

In the Pedagogical Course Project (PPC) of the STJD course (in the face-to-face and distance modalities), the commitment to the training of professionals (technologists and entrepreneurs) in the area of DJD is affirmed, enabling them in the development of games, systems, animations directed to various areas of knowledge always "in an integrated way, following the standards of quality and productivity learned during their training" (IFBA, 2018b, p. 60). Also according to the PPC, the proposed professional training, in addition to being innovative, unprecedented in the region and state of Bahia, and being offered by a federal institution of education, "is in line with the definition of the National Catalog of Higher Technology Courses recommended by the Ministry of Education" (idem, p. 61). Such training guarantees the graduate the performance in the segment of digital entertainment, computer graphics, allowing him, among other things, the DJD in the areas of "entertainment, adventure, simulation, animations for campaigns, soundtracks and short films" (idem, p. 62). The multiplicity of performance profiles in the DJD, explored and proposed by the STJD course, directs professional training, such as: 1) Game design:

where the developer will act in the conception of the game, from its elaboration to the detailed description of each aspect present in the game, such as: "objectives, plot, characters, scenario and all the mechanics of the game" (idem, p. 62); 2) Digital Game Programmer: the professional responsible for programming and coding the game, integrating the stages of the game, giving rise to the prototypes and the final product.

The FIC course in Digital Game Programmer emphasizes the performance of developers "in the processes of development/maintenance of digital games, meeting norms and standards of quality, usability, interactivity, integrity and information security" (IFBA, 2021, p. 9). It is a short course (220 hours), very focused on practice, and which is intended "for students and/or workers with High School Attending or Complete, interested in the area of Digital Games or professionals who work in the area and seek improvement" (idem, p. 9). Its Curricular Matrix was organized into two modules: I-Basic Module, with the aim of dealing with contents considered fundamental to the student's follow-up of the course, and II-Specific Module, aimed at the qualification itself.

It is observed that the courses aimed at the DJD of the IFBA are presented, to a greater or lesser extent, in line with several of the goals pointed out in the IBJD censuses. Several correlations between the goals pointed out in the public policies for the development of the IBJD and the characteristics found in the PPCs of the IFBA courses were identified and presented in Ferreira et al. (2023).

THE BASIC CYCLE OF DIGITAL GAME PRODUCTION

The first stage of this cycle, known as pre-production, is critical due to the responsibility of defining what the game will be like, how much time will be needed for its creation process, in addition to the sizing of human and financial resources. It is also at this stage of a game's production cycle that two technical documents that are very relevant to the success of the digital game come into play: the High Concept Document (HCD) and the Game Design Document (GDD). They record the following information about the game: a) concept, b) planning, c) characteristics, d) requirements and, e) limitations. It is in the first of them, the HCD, that the general concept of the game is briefly described, presenting only its main characteristics, as well as the initial idea of its design.

Some questions need to be answered in this cycle, such as: 1) Has the initial concept of the game been defined? 2) Have the platform and gender been specified? 3) Has the technology been evaluated against the desired feature set? 4) Has the basic design documentation been completed? 5) Has the basic technical documentation been

completed? 6) Has the budget been completed? and, 7) Has the initial schedule been completed?

In production, the second stage of this cycle, those involved in the development of the game start the production of *assets* (constituent elements of a game) and its code. The boundary between this stage and its predecessor is usually very tenuous, for this reason some of the items related to the game in development may still be in the pre-production stage. Even if the process is all planned in the previous step, "surprises" should be expected, such as the addition, change, or even removal of some feature or *asset*.

To evaluate the evolution of ST development, in this case, the game, also in this phase several questions are asked, such as: 1) Is there a defined process for the control of unbridled growth? 2) Is the risk assessment taking place regularly throughout production? 3) Is there a game plan that progress tracking can be based on? 4) Is there a set process for the producer to track the progress of all tasks? 5) Does each task have clearly defined exit criteria? and, 6) Are all stakeholders in agreement on what the exit criteria will be?

Another critical phase of this process is known as the testing stage. In it, the game undergoes a full functioning check, until it does not present any fatal bugs, or fatal errors. It is worth mentioning that the tests take place from the production stage, verifying the new features and new features added to the game. After full implementation of the game's assets and features, the development team's focus will be directed to fixing bugs and creating new builds (compiled and executable versions of the game). This step can be subdivided into two parts: the validation of the plan and the release of the code.

Several questions are asked to direct and monitor the development process at this stage: 1) Has the test plan been updated for the quality department? 2) Were the testing stages considered in the schedule? 3) Has the bug tracking software been made available to the testers and development team? 4) Have all areas of the game been tested? 5) Did the development team submit a final candidate for the code release? and, 6) Is there enough time in the schedule for the quality department to complete the test plan on the code release candidate?

In the post-production phase (completion), after the code is released and its manufacture is approved, the game's production process needs to be closed. This phase is composed of two elements: the archiving plan and learning from experience. The first of these involves creating strategies and implementing a system to store, organize, and manage all assets, code, and documentation created during the game's development lifecycle. In the second, the *post-mortem* is made, a retrospective analysis carried out by the development team after the completion of the digital game project. Then the process is

considered finished, presenting some deliverables, including: 1) Game Files: all the files necessary to run the game (graphics, audio, videos, scripts) and any other essential content; 2) Installation Instructions: A guide with clear instructions on how to install and launch the game on different platforms (personal computer, console, mobile devices); 3) System Requirements: Minimum and recommended system requirements to run the game, including hardware and software specifications, and, 4) Contact Information: Contact details of the game's support team or developers so that players can contact in case of any issues or questions.

In the basic development cycle of a digital game, especially those whose risks are high, there is usually an iterative, repetitive production process, with the execution of several production cycles. Therefore, iteratively assessing the level of readiness of this type of technology requires the adoption of reliable metrics, such as the STRL scale.

AS ESCALAS DE *SOFTWARE TECHNOLOGY READINESS LEVELS (STRL)*

Through the bibliographic survey, it was found that Mankins (2009) classified the sequence of stages or stages of development of a technology, using the TRL scale as a metric, described in nine levels of technological readiness. It is found that, generally:

- The procedures related to TRL levels 1 to 3 are carried out in research institutions, notably higher education institutions (Academia);
- TRL levels 4 to 6 include the so-called "Valley of the Death of Innovation", as most projects are unable to advance from these stages, which require greater volumes of financing, infrastructure to *scaleup* and several other inputs, towards the higher TRLs;
- The space occupied by the productive sector figures mainly in the TRL levels from 7 to 9, since the actors in this sector make use of the technology created, transforming it into finished products, for launch on the market.

The levels indicated above are the basis for the TRL scales, including software technology. An STRL scale is an extension of the TRL concept specifically applied to the development of software technology. While TRL focuses on assessing the readiness stage of a technology in general, STRL focuses on the specific assessment of the readiness of software technologies. Like the TRL, the STRL is a numbered scale ranging from 1 to 9, where each of the levels represents a different stage in the software development life cycle, as shown in Exhibit 1.

TABLE 1 - Levels of readiness of software technology.

STRL	Characteristics
1	Emphasizes the concept of TS: The idea for the software is conceived, but has not yet been formally analyzed or documented.
2	Focus on TS analysis: At this level, the TS concept is analyzed, initial requirements are identified, and a high-level architecture can already be outlined.
3	Emphasis on design: At this stage, the TS requirements are detailed and specified, and the software design is elaborated, and may even include low-fidelity prototyping.
4	TS implementation starts: The software is implemented according to the specified design.
5	Testing of TS components begins: Each individual component of the software is tested to ensure that it functions correctly.
6	The components tested in the previous phase begin to be integrated: The different components of the software are integrated and tested together.
7	After integration, system testing begins: The complete software is tested as an integrated system in a representative environment.
8	After validation in a representative environment, the operation and maintenance phase begins: The software is operational and maintained, and can be adjusted as needed.
9	The last step addresses TS's reliability and maturity: The software is fully developed, tested and in regular operation, demonstrating stability and reliability under real operating conditions

Source: Adapted from Persons and Mackin (2020, p. 115-118).

To identify STRL scales, the following reports were considered: a) *Software Technology Readiness Assessments Managing Technology Risks in Space System Acquisitions* (The Aerospace Corporation) (NASA, 2013); b) *Beyond Technology Readiness Levels for Software: U.S. Army Workshop Report* (*Software Engineering Institute*) (DoD, 2009); c) *Technology Readiness Assessments Guide* (*U.S. Government Accountability Office*) (GAO, 2020); d) EMBRAPII Operations Manual (2020). With the analysis of these documents, four STRL scales were identified.

One fact that stood out during the process of identifying STRL scales was the relevance given to the topic by the American government. The diversity of ST, implemented in hardware, software, or both, has given ST significant relevance, to the point that it has become the subject of publications by the *Department of Defense* (DoD, 2009), the *National Aeronautics and Space Administration* (NASA, 2013), and the *Government Accountability Office* (GAO, 2020). In Brazil, the Brazilian Company for Industrial Research and Innovation (EMBRAPII, 2020), which adopts the TRL scale to monitor the development of its projects, presented some equivalences to the TRL standard, including software development (*Software Technology Readiness Level*, STRL). Using the ABNT NBR ISO 16290 standard as a basic reference for TRL definitions (ABNT, 2015), EMBRAPII established relationships and characterized the technological maturity of software, STRL.

For the DoD (2009), the TRL scale should have comprehensive definitions for any technology, while interpretations or extensions for specific technologies, such as ST, should be the subject of experts in this field of technology (GRAETTINGER et al., 2002). Also according to the DoD, the maturity of the technology is a useful metric in the decision-

making process of selecting new technologies for development and maturation in an environment of demonstration of advanced technology, technologies that will eventually be transferred to the tactical programs of the DoD (2009). Similarly, NASA (2013) also developed its STRL scale in nine levels of readiness, considering: Level definition; Hardware Description; Description and Software, and, Exit Criteria of each level.

Also noteworthy is the prominent role given to the GAO (2020) when it states that it is "establishing a methodology to assess technological maturity based on best practices that can be used throughout the federal government" (PERSONS, MACKIN, 2020, p. 2). However, according to Persons and Mackin, (2020, p. 66), the GAO also recognizes that "organizations can adapt them to accommodate their own application", since the characterization and conceptualization of SW are not all inclusive, they vary according to technology and application.

Considering the frequent technological development and criticality involved in the construction process of these new technologies, the GAO proposed Three Steps to Evaluate Critical Technologies: Step 1 – Confirm the TRL definitions and discuss the necessary evidence; Step 2 – Evaluate the information; Step 3 – Prepare a classification or opinion (PERSONS, MACKIN, 2020). This denotes an attempt to seek a generalization to a technology area with very specific requirements, as the U.S. government continues to pursue consistent and iterative methods to assess the readiness of technology as part of its investment decision-making process, aiming to self-assess its own technology and help filter out the most promising technologies.

As in the other scales, EMBRAPII's proposal for the evaluation of the readiness of software technology seeks to characterize each of the nine levels by adopting the following criteria: a) the scale of the object; b) the fidelity of the object; c) the environment in which the technology is under development, and d) a description for software (EMBRAPII, 2020). Ferreira and Ribeiro (2024) briefly presented the definitions and descriptions of the STRL levels of these four scales.

DG–STRL: CORRELATION BETWEEN THE STRL SCALE AND THE STAGES OF DEVELOPMENT OF A DIGITAL GAME

A variant of the STRL scale, called DG-STRL (Digital Game – STRL), was proposed by Ferreira and Ribeiro (2023). Aimed specifically at assessing the level of readiness of the TS of digital games, this proposal was inspired by the scale proposed by EMBRAPII, correlating the levels with the steps that make up a basic structure to support the production process of a digital game.

The starting point of the proposal is the pre-production stage, a stage in which the initial concept of the game is defined, as well as its objective, its mission and its final appearance. Ferreira and Ribeiro (2023) propose the correlation of this stage with STRL 1, the level responsible for the basic idea of the technology. Still in this stage of the DJD, the genre and platform of the hardware are defined, the evolution of the game concept (materialization of the digital game world) occurs. The beginning of the character design and gameplay process fits into STRL 2, when the concept of JD was defined, as well as the determination of the platform, genre and its mechanics.

In STRL 3, a preliminary version of the software is expected, materialized in a proof of concept (a simple model, representative of the ultimate need) to test and evaluate the original idea of the game. It is also at this stage of pre-production that the developer (or the development team) begins the validation of new gameplay features, culminating in the initial prototype. In this sequence, prototyping scales, and it is common to use several prototypes at the same time, each of them working from different perspectives of the same JD. As STRL 4 highlights the scalability of a TS model, seeking a more realistic representation of it, the completion of the pre-production stage confirmed the basic formulation of the technology.

The next step of DJD is called production. It deals with the implementation of everything that was planned during the pre-production stage, aiming at the game until it is ready for its commercialization. Although there is no precise point between the end of pre-production and the start of production, at this point in the DJD process they should already be well defined, among other things: a) the idea of the JD, b) the way the JD will be developed, c) who will do each task, d) how long it will take to carry it out. Thus, the correlation of STRL 5 for games with what was exposed in STRL 5 for TS in general is observed, since for this level a model already defined and approved with the main aspects of the game is expected, thus having a prototype more faithful to the digital game project.

Another characteristic of the production stage is that the previously created prototype must be incremented, adding gameplay features, such as: a) how the controller should work; b) how the score will be; c) how the dialogues occurred, d) adjust any other attribute until the next playable version. Similarly, a TS at STRL level 6 is expected to achieve fidelity in the TS demo as it tests a representative prototype of the game.

A preponderant condition to reach the STRL 7 level is to have, at this point, a prototype capable of effectively demonstrating the proposal of the digital game, presenting it close to its final version. Once the testing stage begins, builds are created (compiled version of a program, in this case it is a playable version), versions of the game that provide

its developer with a demonstration and tests of the functionalities, features and assets of JD in production. Usually, the testing stage begins when the release of the alpha version of the digital game approaches. Defects and *crash bugs*, in the various elements of the game are sought and mitigated to ensure that they are fixed before the final delivery of the game. The STRL 8 level is notable for representing the end of the TS production process, which correlates it to the end of this stage of the development of the digital game.

Once the testing stage is over, the release of the game code continues, signaling to everyone that this content is definitive, that the *bugs* have been fixed and the final version can be replicated. Finally, the product can be packaged and sold, indicating that the digital game has already been verified, that everything that had been planned and produced was completed correctly, starting the post-production stage.

In post-production, some important measures are implemented: all the game's codes and assets are organized in a product closure kit and this kit is archived for future reference. As expected for TS STRL 9 level, at this stage of readiness, the technology is ready for the market.

Thus, considering the current scenario of digital game development and the context of the IBJD, it is believed that the adoption of DG - STRL will contribute to the process of evaluating the level of readiness of software technology, more specifically, digital games.

CONCLUSION

The educational programs aimed at the development of digital games are a positive point for the IBJD. By investing in the education and qualified training of future developers of these games, Brazil lays the foundation for continued growth, innovation, and competitiveness in the global gaming market. The expansion of IBJD creates a growing demand for qualified professionals, that is, professionals with a background in design, programming and digital game art.

By offering specialized courses in digital game development, institutions such as IFBA meet this demand, helping to fill this skills gap in the national labor market, in addition to contributing to the overall growth and maturity of IBJD, favoring the diversification of the Brazilian economy, and reducing dependence on traditional sectors, promoting economic resilience and sustainability.

The courses offered by the IFBA offer students: a) practical training; b) access to industry-standard tools and technologies; c) networking and collaboration opportunities, and, d) an environment conducive to the development of creativity and innovation. This

context fosters the development of high-quality digital games, as well as training talented developers capable of competing on a global scale.

The process of developing a software technology is a set of organized and structured activities that aim to create, improve or meet a specific demand from the development of software. There are several methodologies and approaches used in the process of developing a ST. Considering that this process can vary according to a specific context and project requirements, DJD intrinsically becomes a risky business, with unique characteristics that make it quite challenging to assess the level of readiness of the technology.

Both GAO (2020) and EMBRAPII (2020) highlight that the TRL scale is a primary reference for the other technological maturity scales. Considering the characteristics of ST, these institutions advise that for specific cases of technology readiness assessment, such as ST, the descriptions of scales made available by these bodies require interpretation and eventual adaptations, and may even culminate in customized supplements. In this way, it is believed that the proposed correlation between STRL levels and digital game development stages contributes to the analysis of TS readiness (in this case, a digital game), providing a method to assess the TS readiness level in the context of digital game development.

The DG-STRL scale allows for a more comprehensive understanding of how TS readiness, specifically in the case of digital gambling, progresses throughout the different stages of the game development process, ultimately assisting in the assessment and enhancement of TS readiness culminating in the successful commercialization of digital gambling.

FUTURE PERSPECTIVES

As future perspectives, the students intend to conduct a survey of articles that discuss the application of STRL in different areas of ST, such as software development, software technological innovation, software project management and evaluation of emerging software technologies. Another important point for future studies is the evaluation of the impact of the use of STRL on decision-making, seeking to identify how STRL can influence decision-making in organizations, governments, and industries, helping to prioritize investments, resource allocation, and software technology development strategies.

Specifically, considering the digital game development process, a viable proposal is to identify which specific milestones and activities should be considered to measure the level of TS readiness during the definition phase of the initial concept of a digital game. Also another planned study aims to identify which indicators can be used to measure the level of

technological readiness of the software during the code implementation and initial testing phase of a digital game.

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