


**PROTOTYPE TESTING: MULTICASE STUDY IN A PROFESSIONAL MASTERS DEGREE
IN NORTHERN BRAZIL**

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ARTICLE INFO	ABSTRACT
<p>Article history: Received: January, 02nd 2024 Accepted: February, 26th 2024</p>	<p>Objective: This study describes the significance of prototype tests for quality assurance in the engineering of technological products based on multi-case research on products generated in a professional master's course in the North of Brazil.</p>
<p>Keywords: Test Evaluation; Test Validity; Product Quality; Prototype Tests; Technological Innovation.</p>	<p>Theoretical Framework: The constructed theoretical architecture is based on the technology generation process recommended by the Scientific-Technological Method (MCT). The method is composed of two operational dimensions, one aimed at generating scientific knowledge to be used in the other stage, for technological creation. In this study, only the stages of the scientific dimension were used.</p>
	<p>Methodology: The method used was the conceptual bibliographic one, which consists of a) defining research questions, b) collecting data, c) organizing and analyzing data and d) generating answers to the research questions. Furthermore, the multi-case study technique was used, through the results of three technological products in the area of Education.</p>
	<p>Findings: The results showed that prototype testing represents not only a relevant stage in product development but can also be seen as a management tool so that the generated artifacts stand out for their quality, efficiency and effectiveness.</p>
	<p>Research, Practical and Social Implications: The main practical implication is that carrying out prototype tests generates greater reliability and credibility to the process of generating technologies related to the processes relevant to product engineering.</p>
	<p>Originality/Value: The study demonstrates that an artifact can only be considered a technology if its prototype passes all the tests to which it is subjected.</p>
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TESTES DE PROTÓTIPO: ESTUDO MULTICASOS EM UM MESTRADO PROFISSIONAL DO NORTE DO BRASIL

RESUMO

Objetivo: Este estudo descreve a significância dos testes de protótipo para a garantia da qualidade na engenharia de produtos tecnológicos com base em pesquisa multicase de produtos gerados em um curso de mestrado profissional da região Norte do Brasil.

Referencial Teórico: A arquitetura teórica construída está assentada no processo de geração de tecnologias preconizada pelo Método Científico-Tecnológico (MCT). O método é composto por duas dimensões operacionais, uma voltada para a geração de conhecimentos científicos para serem utilizados na outra etapa, para a criação tecnológica. Neste estudo foi utilizada apenas as etapas da dimensão científica.

Metodologia: O método utilizado foi o bibliográfico conceitual, que consiste em a) definir perguntas de pesquisa, b) coletar dados, c) organizar e analisar dados e d) gerar respostas para as perguntas de pesquisa. Além disso, fez-se uso da técnica de estudo multicase, através dos resultados de três produtos tecnológicos na área de Ensino.

Resultados: Os resultados apontaram que os testes de protótipo representam não apenas uma etapa relevante do desenvolvimento de produtos como também podem ser vistos como uma ferramenta de gestão para que os artefatos gerados se notabilizem pela qualidade, eficiência e eficácia.

Pesquisa, Implicações Práticas e Sociais: A principal implicação prática é que a realização de testes de protótipo gera maior confiabilidade e credibilidade ao processo de geração de tecnologias conexo com os processos pertinentes à engenharia de produto.

Originalidade/Valor: O estudo demonstra que um artefato só pode ser considerado uma tecnologia se seu protótipo for aprovado em todos os testes a que for submetido.

Palavras-chave: Avaliação de Testes, Validade de Testes, Qualidade do Produto, Testes de Protótipo, Inovação Tecnológica.

PRUEBAS DE PROTOTIPO: ESTUDIO DE CASOS MÚLTIPLES EN UNA MAESTRÍA PROFESIONAL EN EL NORTE DE BRASIL

RESUMEN

Objetivo: Este estudio describe la importancia de las pruebas de prototipos para el aseguramiento de la calidad en la ingeniería de productos tecnológicos a partir de una investigación de casos múltiples sobre productos generados en una maestría profesional en el Norte de Brasil.

Marco Teórico: La arquitectura teórica construida se basa en el proceso de generación de tecnología recomendado por el Método Científico-Tecnológico (MCT). El método se compone de dos dimensiones operativas, una orientada a generar conocimiento científico para ser utilizado en la otra etapa, para la creación tecnológica. En este estudio se utilizaron únicamente las etapas de la dimensión científica.

Metodología: El método utilizado fue el bibliográfico conceptual, el cual consiste en a) definir preguntas de investigación, b) recolectar datos, c) organizar y analizar datos y d) generar respuestas a las preguntas de investigación. Además, se utilizó la técnica del estudio de casos múltiples, a través de los resultados de tres productos tecnológicos del área de Educación.

Resultados: Los resultados mostraron que las pruebas de prototipos representan no sólo una etapa relevante en el desarrollo de productos sino que también pueden verse como una herramienta de gestión para que los artefactos generados se destaquen por su calidad, eficiencia y eficacia.

Investigación, Implicaciones Prácticas y Sociales: La principal implicación práctica es que la realización de pruebas de prototipos genera mayor confiabilidad y credibilidad al proceso de generación de tecnologías relacionadas con los procesos relevantes para la ingeniería de productos.

Originalidad/Valor: El estudio demuestra que un artefacto sólo puede ser considerado una tecnología si su prototipo supera todas las pruebas a las que es sometido.

Palabras clave: Evaluación de Pruebas, Validez de Pruebas, Calidad del Producto, Pruebas de Prototipos, Innovación Tecnológica.

1 INTRODUCTION

Today's world is characterized by being technological (Nascimento-e-Silva, 2020). This state of affairs is called a knowledge society, characterized by the predominant influence of the internet and other technologies, which are increasingly added to the daily tasks of humanity (Kriezyu, 2019). It is considered that the technological artifacts that are used on a large scale today (smartphones, laptops, smart televisions, among others) were once prototypes that had to undergo successive tests to be made available to their respective public of interest.

This study aims to highlight the significance of product tests through a multicase study covering three technological products in Education. The core of the study is to highlight that one cannot idealize technical products without adequately devising the tests that will be used with a view to their validation. To this end, both the test concept and the prototype definition will be demonstrated, and, finally, the significance of these tests to ensure the credibility and quality relevant to the generation of technologies (Ketokivi & Choi, 2014; Slack et al., 2009).

Two reasons, one theoretical and the other practical, motivated this study. The theoretical factor is associated with the perceived scarcity regarding the theme of prototype tests. Not only in the field of Engineering but in other areas of knowledge, one can see the incipient state of theoretical-empirical publications on this topic. The second item that encouraged the realization of this textual construction is of a practical nature and aims to demonstrate a possible method to be practiced due to its main characteristic: being procedural.

The scientific-technological method developed by Nascimento-e-Silva (2020) only works if all the steps that integrate it are performed correctly. This is the preponderant factor for technological products to be generated and generates benefits not only for their respective areas of application but also for society as a whole since every technology must bring with it advantages and differentials that justify its implementation (Nascimento-e-Silva, 2017; Silva & Nascimento-e-Silva, 2020a).

2 PROTOTYPES: LITERATURE REVIEW

It can be considered that prototypes are unfinished versions whose configuration is as close as possible to a product in its final version (Rogers et al., 2013; Silva, 2019; Nascimento-e-Silva, 2020). For example, when a new car model is launched, before its launch on the market, several tests are carried out to check if the controls on the control panel work as they should, if

the steering is lighter, if the innovations inserted in this new model have a quick response when activated, etc. It is necessary to ensure that the cars catch customers' attention and prevent recalls from occurring.

The reason for being prototypes is linked to their magnitude in the product development process. It means more is needed to define aspects related to design, quality, and the total number of functionalities that characterize a product. It is necessary to test the points of the deficient prototype, which leads to corrections and improvements (Nascimento-e-Silva et al., 2013; Paraschivescu & Cotîrlet, 2015; Salunke & Hebbar, 2015). The importance of this procedure resides in the failure to conduct the prototypes can cause a defect not yet detected to be evidenced with the product already in the customers' possession. Therefore, it is recommended to carry out tests on prototypes before manufacturing the product in its final version (Avis et al., 2012).

With the correct use of prototypes, it is possible to analyze with a high degree of assertiveness all aspects and attributes of a product still in its development phase. It is emphasized that the results obtained during the creation and testing phase of prototypes represent a crucial factor in determining the success or failure of projects concerning product engineering (Jensen et al., 2016).

It is opportune to point out transparency regarding the results obtained in the prototyping phase of technological products. These results must faithfully portray the users' accurate perception of the prototype's performance. Nascimento-e-Silva (2020) clarifies that one of the characteristics that should be affected by prototypes is reliability. In other words, the customer must unquestionably realize that that prototype has attributes related to efficiency, effectiveness, and quality (Slack et al., 2009).

In addition to being necessary materials for product validation, prototypes also represent relevant learning tools. The use of the term learning is not for nothing since the product development process encompasses a series of procedures necessary to deliver a specific technological artifact. In addition, the prototyping of technological products causes information to be generated through the performance of the tests, which, therefore, will subsidize the decision-making process of the product engineering design team (Ege, 2020; Ulrich & Eppinger, 2012; Jensen et al., 2016).

It is considered that the significance of prototypes is not limited to the context of testing and validating technological products. It can be inferred that prototypes also represent a management tool in product engineering. This is because the results from the prototyping phase

can stimulate dialogue between the parties interested in the construction of the product to make the decision-making process more assertive about the actions that must be taken until the prototype is considered capable of being made available to its respective consumer market (Rhinow et al., 2012).

From this perspective, it is considered that prototypes have a dual function in the making of product engineering projects. The first is related to the certification of the pertinence of each functionality that integrates the structure of the prototypes. With these results in hand, the prototypes' second function is to meet the expectations of the various stakeholders participating in product engineering projects (Isa et al., 2015). It is emphasized that the fulfillment of both functions described is necessary for technological products to be recognized for meeting human needs (Arizen & Suhartini, 2020).

The creation of prototypes is characterized by the anticipation of problems that may compromise the performance of technological artifacts. This is because when creating a product, there is an unknown about its effectiveness, which needs to be tested to prove its effectiveness, efficiency, and reliability, among other aspects highlighted by Nascimento-e-Silva (2020). When dealing with the initial uncertainty that affects product development, it is considered that prototypes help reduce the degree of this unknown since carrying out tests anticipates problems that may occur in actual contexts of use of the artifact (Peukert & Vilsmaier, 2021).

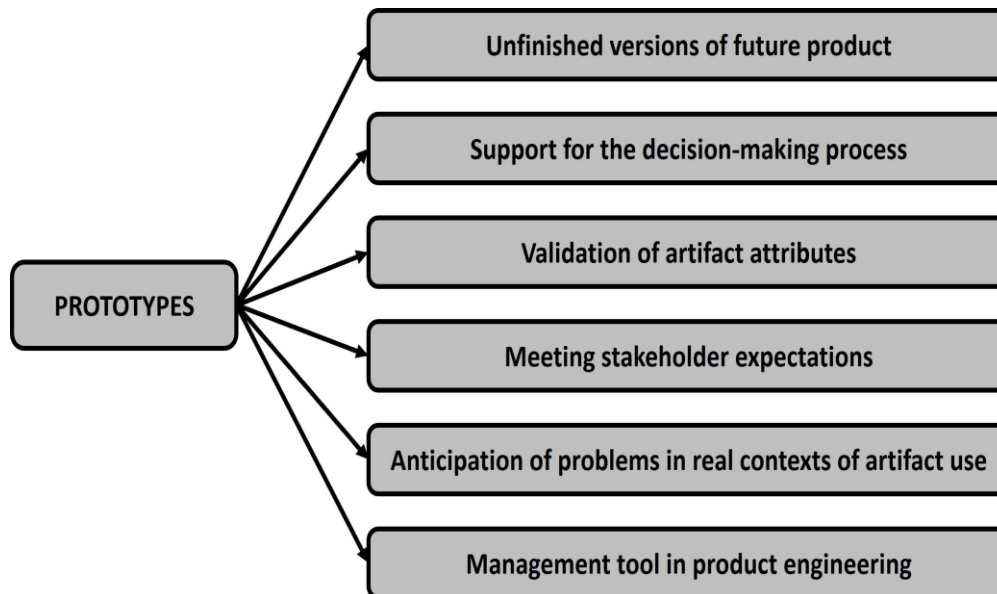
For this study, prototypes can be considered unfinished versions of technological artifacts whose creation is a fundamental part of the success of product engineering projects. Prototypes are deemed to have a dual function, which confirms their significance in the context of technology generation. The first one is validating all the components that are part of the structure of the technological artifacts. The second is meeting the expectations of engineering project participants, who can use the results of the prototyping phase to decide what actions to take for the product engineering process to be successful. These functions are guaranteed through the tests to which they are necessarily submitted.

It is assumed that a test is a process composed of steps, and it is necessary to detail each step. Thus, the first step concerns defining what will be tested and whether the material will be physical or virtual (Racat & Capelli, 2020). From the definition of what will be tested, it is necessary to define the components to be tested since the functioning of each part that makes up the product must be evaluated. For example, the tests of an e-book are directly related to assessing the cover, the size of the paragraphs, the quality of the figures, and the

clarity of the text, among others. Figure 1 summarizes the main points highlighted in this first part of the study on prototypes.

Figure 1

Ain characteristics of the prototypes



Source: Prepared by authors.

It is noteworthy, as presented by Nascimento-e-Silva (2020, p. 69), that “[...] only the attributes strictly necessary for its operation safely and in compliance with what is expected by the test should be part of the test. your target audience”. Having defined the components to be tested, it is necessary to apply the tests. To use the tests, the target audience and the sample of subjects who will handle the technology produced must be defined.

Finally, there is the analysis of the test results. Through the respondents' feedback, it will be possible to identify which aspects of the product were positive and which parts need to be fixed and improved (Graban, 2013; Neves, 2014; Paraschivescu & Cotîrlet, 2015; Salunke & Hebbar, 2015). Thus, the aspects must be adjusted as necessary and undergo new tests until the possibilities of failures are exhausted. “What is expected with the frequency of tests-adjustments-retests-adjustments is the gradual reduction of flaws and non-conformities in the prototype” (Nascimento-e-Silva, 2020, p. 71).

When considering the test as an evaluation to guarantee the efficiency and effectiveness of a product, it is necessary to verify the form of evaluation of this product. In this regard, there are three possibilities to be considered: a) qualitative: in which the users' opinions will indicate how powerful the technological artifact is; b) quantitative: a form of evaluation that will be

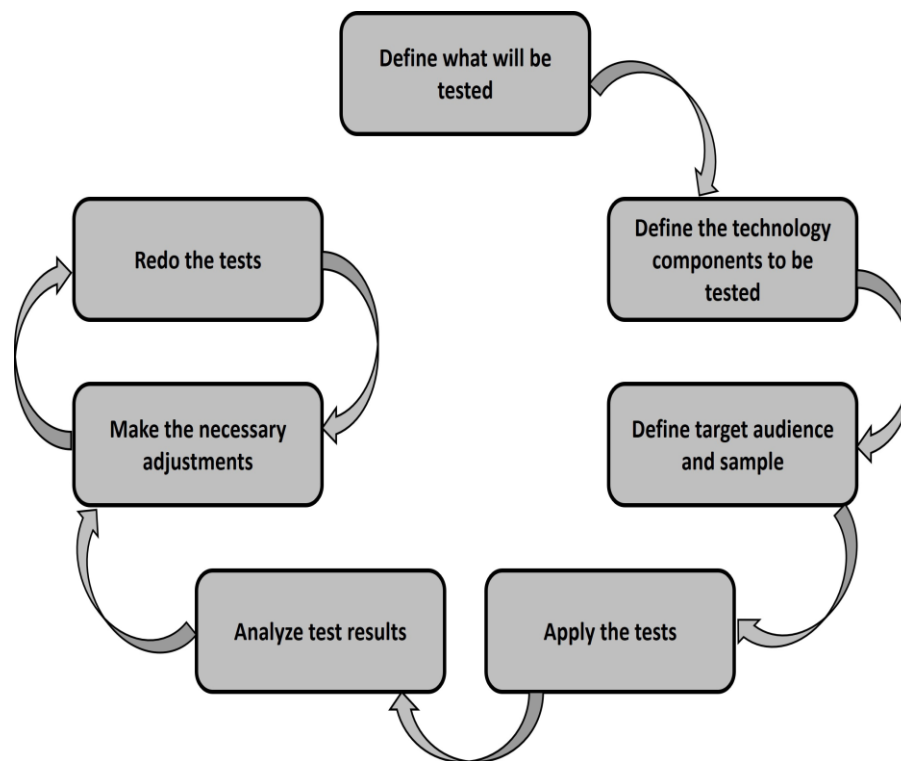
based on mathematical or statistical data to substantiate the degree of satisfaction of people with the prototype, and; c) mixed: which is the combination of the two methodologies previously described (Herling et al., 2013; Oliveira, 2019).

Indeed, how the test is evaluated will depend on the type of product used. For example, when conducting an interview, it is interesting to carry out a test with a particular sample population so that the questions used help the researcher reach his objective. However, this will only be possible if the interview questions are well formulated. Thus, the more adjusted the questions in an interview or the questions in a questionnaire are, the better the result of the research will be (Silva et al. 2019b).

The first step in testing is knowing what to test. Imagine creating an extension course. There are numerous products linked to this technology. So, it is necessary to identify what should be tested; that is should you try the software, the written texts, the recorded videos, and the acceptance by the target audience? Finally, the ideal is to have a well-defined what will be tested and then apply the conformity, usability, and reliability tests described by Nascimento-e-Silva (2020).

In the second stage, as shown in the previous figure, the product components that will be tested are defined. At this point, it should be considered whether the input components, that is, those that will be used to compose the structural phase of the test, are adequate so that the output components, that is, the results, can be achieved. Furthermore, the output components must completely agree with the expected objective and with what was defined in the previous phase, where it was determined what would be tested.

In the third stage, it is suggested that the target audience and sample be defined, in which the tests will be applied. It is observed that the target audience will depend on the product and technology to be tested. For example, if the product to be tested is sheet music software, there is no point in applying the tests to a population that needs help understanding music; if that happens, the test will become unfeasible. The sample size to be tested will depend on the product created. This implies that the sample used is the one with the number of people necessary for the flaws to be corrected. It should be noted that “many final products are not free of defects, but their weaknesses do not compromise their functionality nor their adoption by the target audience (Nascimento-e-Silva, 2020). Figure 2 shows the stages of the prototyping process.

Figure 2*Stages of the prototyping process*

Source: Prepared by authors.

For example, in creating software that will measure the high school dropout level, it is understood that the software is the main item to measure its performance. Regarding the creation of extension courses, the study by Souza (2020) demonstrated that there must be congruence between what is to be evaluated and the population of respondents to be reached. In the specific case of Souza (2020), who created an extension course on Industry 4.0, the group of participants was formed by 20 workers from factories in the Industrial District of Manaus (Igrejas, 2017). As this public is directly interested in the effects of the Fourth Industrial Revolution, the respondents' perception was relevant to ascertain whether or not the created product was easy to assimilate.

For the fourth step, defined as the application step, it is necessary to put the test into practice. In this stage, in addition to collecting and cataloging the expected data, it is possible to verify the missing components for developing this execution. It is understood that in these aspects, this step also demonstrates that it is necessary to have reasonable control and management of the collected information, as these will substantially interfere with the final result. Santana (2009) explains that the definition of evaluation parameters of a prototype's

functionality is directly related to the degree of knowledge of users or potential consumers of the generated technology.

The analysis of the results constitutes the fifth step. All data collected and cataloged will be thoroughly verified and transformed into results. In this phase, it is possible to understand the meaning of the collected data and synthesize them, thus confirming which components are not by the test objective and complementing or modifying existing members according to the results obtained. In summary, these collected data can point to only two possible outcomes: a) the technology works and can be disclosed to its target audience, or; b) the technology presents points that need rectification (Lubwama, 2020).

After analyzing the feedback received by the test participants, it is necessary to make adjustments to the failures identified in the previous step. These adjustments must be carried out entirely; that is, all the required tests are carried out so that the changes also occur together since there will be failures related to others (Nascimento-e-Silva, 2020). Thus, adjustments must be made by the undesired results detected in the tests and performance failures or risks to the integrity of the product, its customers, users, or consumers.

The last step, defined by retesting, will only sometimes be mandatory, as it will depend on the result obtained in the previous step, where the data already collected were readjusted. In this regard, it is worth mentioning that in an analysis where a test has perfect data as a final result, the adjustments phase is automatically excluded, and it is not necessary to carry out a new trial (Nascimento-e-Silva, 2020).

It is up to the scientist responsible for conducting the work related to the generation of technologies whether or not to carry out the retests. However, as Hammad et al. (2020) pointed out, the risk of not submitting products to performance tests can jeopardize the reputation of the generated technology since errors that are not correctly detected can occur with the product already in the field in possession of users.

When we take into account that after analyzing the data, the result obtained has flaws, needs adjustments, or even did not result in the expected objective; the initial test is automatically invalidated, and it is then necessary to carry out a new trial with all the previous components already analyzed and modified. However, according to Nascimento-e-Silva (2020, p. 71), it is worth noting that whenever there is “[...] rectified failure or non-compliance, a new test is necessary to make sure that they have been resolved”.

Carrying out tests is a mandatory requirement to ensure the credibility of the scientific process, but also the responsibility of the product (Capocasa & Volpi, 2019; Ketokovi & Choi,

2014; Neitzer & Petras, 2019). Thus, the importance of tests in scientific studies involving the production of an artifact/product is noted since tests can help scientists to build a product efficiently and effectively, regardless of the fields in which they are applied. Thus, the level of uncertainty regarding the effectiveness of the tested products decreases considerably, which helps to strengthen the relationship between the product and its potential consumers, especially about aspects of trust and quality (D'Ávila, 2016; Slack et al., 2009).

3 RESEARCH METHODOLOGY

This textual construction was carried out using the conceptual bibliographic method sent by Nascimento-e-Silva (2012; 2020; 2021a; 2021a). It consists of a set of writing techniques formed by four stages: a) definition of research questions; b) data collection; c) data organization and analysis and; d) generation of answers. The first stage of the process consisted of establishing the guiding questions, which can also be called research problems (Brei et al., 2014; Lukosevicius, 2018; Nascimento-e-Silva, 2021b). To carry out this study, the selected research questions were: a) What is a prototype?; b) What is a test?; and c) What steps must be taken for the assertive execution of the tests?

The second step involved searching for each answer that guides the present study. Nascimento-e-Silva (2020) explains that databases are the places recommended by science to search for consistent studies whose content brings the solution to research questions (Nascimento-e-Silva, 2023). Two databases were used: a) Google Scholar and b) Science Direct. To obtain the intended responses, phrases such as “Prototypes are...” and “Tests consist of...” were suggested in the search engine for these databases. National and international studies were used to supply the guiding research questions.

The third phase of the method consisted of organizing and analyzing the previously collected concepts. The answers obtained brought phrases such as “Prototypes can be considered as...” or “Test is...”. These responses were cataloged through an instrument called data mass. Nascimento-e-Silva (2012; 2020; 2023) and Silva and Nascimento-e-Silva (2020) say that this procedure consists of a table formed by two columns, which can be done through an electronic spreadsheet. The references corresponding to each response collected are inserted in the first column, and the reactions in quotation marks with their respective page numbers are transcribed in the second column. The analysis detects the so-called equivalence terms in the conceptualizations raised (Nascimento-e-Silva, 2012; 2020). These terms show the

convergences and differences between one definition and another so that the most repeated aspects will help fulfill the fourth stage of the method: the generation of answers.

With these equivalence terms in hand, the responses were written for each research question previously defined. Carrying out the previous steps is necessary so that the writing of the response reliably reflects the aspects that are most frequent in the responses collected (Nascimento-e-Silva, 2012; 2020; 2023). Regarding the stages of the tests described in this study, each step was explained in a logical sequence, which refers to the idea of a process. It is considered that processes are composed of logically ordered parts that, in the end, will generate a result (Silva et al., 2019a)

In addition to the procedures already mentioned, we chose to use the methodological method known as a multicase study. Triviños (2010) states that this approach represents an expansion of case studies (Yin, 2015). The investigation characterizes it carried out with more than one source of evidence to obtain more knowledge about a given topic. The test results of three technological products were verified, which were fundamental for the final version of these artifacts to be made available to their stakeholders.

4 RESULTS

The three products analyzed here are of the educational type. It is considered that this type of product should have as its main characteristic proposing a solution to a specific problem in the area of Education. In addition, these products must be replicable in other contexts to make their use possible by other institutions that so wish (Capes, 2013; 2017; Gonçalves et al., 2019; Silva et al., 2019).

The first product was developed by Oliveira (2019) and consisted of a portfolio of extension courses for the Itaituba Campus of the Federal University of Western Pará (UFOPA). The study by Oliveira (2019) prospected 506 companies in the city of Itaituba to understand the demand of these companies about the qualification of their respective employees. To this end, a survey based on statistical calculations was carried out to obtain a maximum precision during data collection (Barbetta, 2017; Matos & Trez, 2012). Of the 506 prospected companies, 272 provided the requested answers during the stages of the research protocol (Silva et al., 2020b).

This survey by Oliveira (2019) made it possible to identify the preferences of the selected population sample. The results that showed the highest prevalence were: a) courses with a maximum load of 40 hours; b) courses offered in face-to-face mode and the night shift;

c) semester offering of the courses. Armed with this information, Oliveira (2019) proceeded with the generation of the prototype of his portfolio. A virtual page was created to publicize the product made on the internet. Figure 3 shows the visual characteristics of the first version of UFOPA's portfolio of extension courses (Itaituba Campus).

Figure 3

First version of the portfolio of extension



Source: Oliveira (2019, p.61).

Oliveira (2019) clarifies that the suggestions obtained during the tests were aimed at changing the structure and aesthetics of the portfolio. Thus, a new version was generated, which was well accepted by the public participating in the prototype test. This study obtained 25 responses referring to the new portfolio version, all complimentary and emphasizing the virtual page's more objective and didactic character. This first version of the portfolio page was available in a repository for 15 days. Because of this return, the portfolio was considered approved in the performance tests to which it was submitted, as shows the figure 4.

Figure 4*Second version of the portfolio of the extension courses*

Source: Oliveira (2019, p. 65).

The second product that integrates this part of the study was developed by Silva (2019) and consisted of elaborating a proposal for self-training for undergraduate coordinators. This product motivated the creation of this product due to the changes in the criteria for authorization and recognition of undergraduate courses in Brazil, as of Ordinance No. 1,383 (Brasil, 2017). As a result, Brazilian universities faced the challenge of accurately meeting the indicators of the three analytical dimensions that integrate the evaluation of courses in national higher education: a) Didactic-Pedagogical Organization, b) Faculty and Tutorial Body, and c) Infrastructure (Inep, 2017a; 2017b).

To this end, a MOOC was created, an acronym for Massive Online Open Course (Silva et al., 2020). The course was designed to explain to its users aspects related to the four essential functions of the science of Administration: planning, organization, direction, and control, in addition to the logic of evaluating undergraduate courses in Brazil (Inep, 2017a; 2017b; Silva, 2019). The didactic material chosen for disseminating this knowledge was the e-book (Silva et al., 2020c).

The population sample consisted of 8 education professionals, including higher education professors and graduate evaluators from the National Institute of Educational Studies and Research Anísio Teixeira (INEP). The course was divided into four modules: a) Management Process, b) Didactic-Pedagogical Organization, c) Teaching and Tutorial Body, and d) Infrastructure, each with its corresponding digital book (Silva, 2019). The materials were organized in a modular system in a virtual learning environment (Biancamano & Flores, 2019).

The first part of the prototype test sought to know the respondents' perception of the components that make up the course's e-book. The following evaluation parameters were defined: a) Cover art, b) Size of the texts, c) Content of the texts, d) Division of modules, e) Didactic sequence of e-books, f) Quality of the e-book pictures, g) Number of pages per e-book, and h) Quality of the texts of the e-books. For evaluation purposes, a scale from 1 to 5 was adopted: 1 represents unsatisfactory performance, 2 means partial attendance, 3 satisfactory means performance, 4 is related to very good performance, and 5 is outstanding performance. Each respondent, represented by the letter P followed by a numeral, evaluated each proposed item and launched their response in the prototype evaluation instrument (Silva, 2019). Table 1 demonstrates the results of this prototype test.

Table 1

Self-training course e-book test for undergraduate coordinators

Attributes	P1	P2	P3	P4	P5	P6	P7	P8	Results
Cover art	5	5	3	2	4	3	3	4	To repair
Size of texts	4	5	4	4	5	3	5	5	Adequate
Text content	4	5	4	4	3	5	4	5	Adequate
Division of modules	5	5	5	4	4	5	5	5	Adequate
The didactic sequence of e-books	5	5	5	5	4	5	5	5	Adequate
Quality of figures present in e-books	5	5	1	2	3	2	3	4	To repair
Number of pages per e-book	5	5	3	4	4	5	4	5	Adequate
Quality of e-book texts	5	5	3	3	4	5	4	5	To repair

Source: Silva (2019, p.73 - 74).

As can be seen, three items scored below 3, correcting each topic whose performance was below expectations. In the specific case of Silva (2019), there were improvements in the quality of the texts in the e-books and in the quality of the figures that make up the content of these didactic materials, as well as the creation of a new cover for the digital books of the proposed course. The results of this test were essential for realizing the topics of the teaching materials that needed rectification, and the necessary improvements were made (Paraschivescu & Cotîrlet, 2015).

The third product highlighted in this part of the study is an extension course whose thematic core was Industry 4.0, created and implemented by Souza (2020). The idea of this course was to develop material capable of responding assertively to this world-class event and its impacts on people's lives. An execution logic similar to that seen in Silva (2019) was used, but with the difference that the population participating in the prototype test was larger and composed of an audience directly impacted by this revolution: employees of factories in the Zona Franca de Manaus (Igrejas, 2017).

The course proposed by Souza (2020) was designed into 5 modules: a) Industrial Revolutions, b) Industry 4.0: what is it?, c) Characteristics of Industry 4.0, d) Pros and Cons of Industry 4.0, and e) Impacts of Industry 4.0 on people's lives (Souza, 2020). Each extension course module had a digital book associated with it. As seen in Silva (2019), the didactic material chosen for the course was the e-book (Silva et al., 2020c).

The dynamics of the test adopted to measure the quality of the didactic material of the Souza (2020) course differed from what was observed in Silva (2019). The scores adopted to evaluate the proposed items ranged from 0 to 10. The public participating in the test was formed by 20 industrialists working in companies in the Manaus Free Trade Zone (Igrejas, 2017). A research protocol was adopted to evaluate this material (Silva et al., 2020b).

Participants in the study by Souza (2020) were suggested the following affirmative sentences:

- a) The text of the e-book follows the objectives of the course;
- b) I was satisfied (a) with the spelling and grammar of the e-book text;
- c) I found the size of the letters (fonts) in the e-book adequate;
- d) The e-book figures are visible;
- e) The figures in the e-book help in understanding the course content;
- f) The number of paragraphs in each part of the e-book is adequate;
- g) I found the number of pages in the e-book sufficient to present the course content;
- h) The didactic sequence facilitates the understanding of the course content;
- i) The sequence of chapters allows the fulfillment of the logic of each subject addressed in the course.

Table 2

Test Results of the e-book components (N=20 respondents)

e-book components test	Frequency %
The sequence of chapters allows the understanding of the logic of each subject covered in the course	98%
The didactic sequence facilitates the understanding of the course content	96%
The number of pages of the e-book is sufficient to present the course content	90%
The number of paragraphs in each part of the e-book is adequate	89%
E-book pictures help in understanding the course content	85%
The e-book figures are visible	87%
I found the size of the letters (fonts) of the e-book adequate	86%
I was satisfied with the spelling and grammar of the e-book text	89%
The text of the e-book is in line with the objectives of the course	94%

Source: Souza (2020, p. 73).

Respondents should demonstrate their degree of agreement with the sentence suggested in the prototype test, which mentioned the main aspects of the e-book. The participants had to respond to the prototype evaluation instrument by attributing scores from 0 to 10. Once the scores were completed for each evaluated item, the results were transformed into percentages and displayed in a graph format to identify prototype items needing revisions and improvements (Graban, 2013; Paraschivescu & Cotîrlet, 2015; Salunke & Hebbar, 2015). Table 1 demonstrates the results obtained in this prototype test.

Souza (2020) provided corrections in the size of the letters, the figures' quality, and the teaching materials' spelling and writing. Because the results are shown in Table 1, the items that obtained low scores were promptly corrected. Carrying out this test can facilitate the visualization of the respondent public's perception of the technological artifact presented to them, making it possible to make the necessary improvements (Graban, 2013; Paraschivescu & Cotîrlet, 2015; Salunke & Hebbar, 2015).

5 DISCUSSION OF THE RESULTS

Prototype testing is necessary for three reasons. The first one is to know if the technology generated works (Nascimento-e-Silva, 2020). Although it seems simple, this check is essential to prevent any defect or problem from happening after a product is launched on the market, which compromises its reputation with potential consumers. For example, an air conditioner should be noted for making the temperature of a specific environment colder. Therefore, this is the primary function that the prototype of this product must present. This is also applicable to intangible products such as software and applications.

The second reason for carrying out prototype tests is to know how the technology works (Nascimento-e-Silva, 2020). Here the logic is as follows: the fact that an artifact works does not necessarily mean it is efficient and effective. If an air conditioner manages to make the temperature of an environment colder, but its components demonstrate an abnormal level of heating, the risk of a short circuit occurring is high, which in turn jeopardizes the integrity of both the product and the also of its users, such as, for example, the risk of electric shock (Kuiava et al., 2020).

The third factor that justifies prototype tests is detecting items whose performance is below expectations. As seen in Peukert and Vilmaier (2021), the generation of prototypes is associated with an unknown since, during the initial phase of product development, it is still

not possible to know precisely whether a product works. This is why tests are necessary to have credibility and quality in the product engineering project (Ketokivi & Choi, 2014; Slack et al., 2009). Thus, defects can be detected and resolved on time by providing the necessary repairs (Graban, 2013; Nascimento-e-Silva et al., 2013; Paraschivescu & Cotîrlet, 2015; Salunke & Hebbar, 2015).

Improvement refers to the Japanese word Kaizen (Dönmez & Yakar, 2019). It is considered that the construction of technological products represents an effort by all stakeholders to determine if each prototype attribute is at a minimally acceptable level of performance. Among the aspects to be evaluated in the tests, the functionality of each component, the speed of response of each triggered command, and the visual elements relevant to the design stand out (Siregar, 2020). These properly evaluated items make technology generation processes more assertive and, therefore, more consistent and improve product engineering.

6 CONCLUSION

The present study showed the significance of prototype tests in developing technological products, emphasizing three cases that occurred in the Teaching area. The study highlighted the need to carry out tests that can prove the effectiveness of each functionality that integrates the configuration of the prototypes. It is estimated that given the magnitude that affects the prototypes, the national scientific literature relevant to this topic still needs reinforcement. It is understood that science transformed into technology represents a process that must stand out for its assertiveness and credibility.

In this sense, prototype tests represent not only a mandatory step for the success of product engineering projects but also a management tool that can provide the necessary support for creating and developing technological solutions. The cases presented demonstrated that carrying out tests helps product creators perceive low points detected from the point of view of their potential users. It should be noted that the more improved the prototype tests are, the more assertive the products resulting from these tests will be. This assertiveness is a sine qua non-condition for human needs to be met effectively and efficiently through technological products whose prototypes have been duly tested and approved.

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