

# Insights from the application of Exploratory Tests in the daily life of distributed teams: an experience report

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## Abstract

The Exploratory Testing (ET) approach has been adopted in the context of agile development due to the effectiveness of its application. Due to these benefits, the need arose to train agile professionals based on the practical application of this type of test to contribute to its incorporation into the daily work of teams. In this sense, the objective of this article is to investigate the contributions and limitations of adopting Problem-Based Learning (PBL) and Just-in-Time Teaching (JiT) in ET teaching-learning, and the main aspects that favor or limit the incorporation of ET into the day-to-day of agile teams. For this, we conducted a course in remote teaching format with agile professionals from a software development company, distributed geographically. At the end of the course, data were collected through an online questionnaire and examined with quantitative and qualitative analysis. Then, the ET activities performed by the participants in their daily lives were monitored and a brainstorming session was conducted to evaluate this experience. Our main findings are that (1) the collaboration between participants and the adoption of a real problem, along with (2) activities and resources made available before the class, and (3) the existence of specific tool support for ET sessions optimized learning in the context of remote teaching. Other main results refer to the planning and registration of ET and the need for guidelines to guide the execution of ET. Therefore, integrating theory and practice in ET is necessary for a better understanding of the effects of tests in the agile environment. Additionally, it is necessary to investigate specific approaches and tools that contribute to the execution of the ET and, consequently, to the incorporation of this test into the daily lives of the teams.

**Keywords:** *Software testing, Exploratory Testing, Testing Education, Testing Learning and Teaching, Active Learning, JiTT, Just-in-Time Teaching, PBL, Problem Based Learning*

## 1 Introduction

Aligning theory and practice regarding the teaching of Software Engineering (SE) is a persistent challenge, both in the academic context and in the industry (Leite et al., 2020). Providing and stimulating experiences that contribute to the technical and non-technical training of students and professionals in this area requires actions to plan the curriculum and curricular components, articulate new teaching methodologies, and include innovative pedagogical elements (Cheiran et al., 2017).

In this context, the teaching of Software Testing (ST) also stands out. For Cheiran et al. (2017), ST is one of the areas of SE that presents challenges for teaching. It may be difficult and inefficient to teach ST through lectures and lectures. Additionally, the simplicity of the criteria is a factor that makes it possible for ST contents to be part of non-specific subjects, such as SE (Paschoal and Souza, 2018). Moreover, ST contents may be part of the training provided by companies when their employees do not know a given ST practice or technique.

Among the existing ST practices, we have Exploratory Testing (ET). ET emphasizes the responsibility and freedom of the tester to explore the system, allowing the tester to acquire knowledge of the program in parallel with the execution of the tests (Costa et al., 2019; Hendrickson, 2013; Bach, 2003; Whittaker, 2009), as there is no script planning or the

definition of test cases defined in test plans (Hendrickson, 2013). For Bach (2003), ET is learning, designing, and executing tests performed simultaneously.

As a way to meet the need for management and measurement of ET, Bach (2003) proposed (1) to divide the testing activities into sessions, which would be the basic unit of work, (2) to stipulate a mission for each session, and (3) adopt time metrics related to testing activities (Castro, 2018), thus giving rise to the Session-Based Test Management (SBTM) approach.

Although the problem associated with ST teaching is being discussed with greater visibility by the academic and scientific community (Paschoal and de Souza, 2018; Garousi et al., 2017, 2020; Scatalon et al., 2019; Aniche et al., 2019) and is producing more specific developments (Cheiran et al., 2017; de Andrade et al., 2019; Martinez, 2018; Coutinho and Bezerra, 2018; Paschoal and Souza, 2018; Paschoal et al., 2017; Queiroz et al., 2019), few studies investigate the possibilities of streamlining the teaching and application of ET in practice (Costa et al., 2019; Ferreira Costa and Oliveira, 2020).

Adopting more dynamic strategies that bring theory and practice closer together to provide academic-professional training in the real scenario of the software industry is not a trivial task, especially when this experience is conducted with geographically distributed teams that work in an agile environment.

When conducting experiences like this, some challenges

emerge, such as (1) integrating the team that works in a cross-functional way, due to the adoption of agile practices; (2) creating conditions for the flow of knowledge to develop, considering the different ways in which people assimilate information; and, (3) dealing with contextual challenges, such as communication, time, internet connection, among others.

There is a need to investigate ways to conduct ET teaching for agile teams working with Distributed Software Development (DSD). Therefore, our research question is: *How to encourage practical ET learning with geographically distributed agile teams, seeking integration among members, and promoting active learning, in order to encourage their insertion in the daily work?*

In these circumstances, learning in a participatory way, from real problems and situations, can contribute to learning evolution. Problem-Based Learning (PBL), is an active learning approach (Bonwell and Eison, 1991; McConnell, 1996) that, from problem-solving, enables students to live experiences that portray the reality of the professional context in the academic environment (Cheiran et al., 2017) and aims to encourage the collaborative resolution of challenges through research, reflection and development of solutions.

In an associated way, Just-in-Time Teaching (JiT) (Novak, 2011) also aims to contribute to student learning. Based on activities carried out before class, JiT encourages the development of prior knowledge of students (Novak, 2011; Martinez, 2018) so that we can further develop discussions about a given content during class.

This study aims to investigate the contributions and limitations of adopting PBL and JiT in ET teaching-learning with agile DSD teams in a remote learning context, in order to encourage the incorporation of ET practices in the daily lives of these teams. Thus, it is expected to contribute to the mitigation of the main challenges - mentioned above - faced in the execution of courses conducted in a DSD context, and encourage the adoption of ET in the ST practices developed by agile teams.

For this, we carried out an ET course with agile professionals from a software development company, distributed geographically. At the end of the course, data were collected through an online questionnaire and examined. Then, the ET activities performed by the participants in their daily lives were monitored and a brainstorming session was held to evaluate this experience.

It is worth noting that this paper is an extended version of the award-winning paper "Teaching Exploratory Tests through PBL and JiT: an experience report in a context of distributed teams", published in the proceedings of the 35th Brazilian Symposium on Software Engineering (SBES 2021), Education Track (Coutinho et al., 2021).

In addition to this introductory section, this paper is structured as follows: Section 2 discusses an overview of ST Teaching. Section 3 describes the methodological procedure used in this study. Section 4 presents the results obtained, in response to the defined research questions. Section 5 discusses the perspectives, challenges, and limitations of this study, based on the results obtained. Section 6 discusses the threats to the validity of this study. Section 7 exposes the analysis of some related works. Finally, Section 8 presents the final considerations and perspectives for future work.

## 2 Background

In this section, we discuss important aspects related to Teaching Software Testing and Exploratory Testing. We then present and discuss some relevant concepts about two main approaches to active methodologies, PBL and JiT.

### 2.1 Teaching Software Testing

ST is an essential activity to guarantee the quality of software. Seeking to meet the need to use teaching methods that make the learning of this activity more effective, some studies have been dedicated to investigating systematic approaches to contribute to the teaching in this area of SE (Paschoal and de Souza, 2018; Garousi et al., 2017, 2020; Scatalon et al., 2019; Aniche et al., 2019).

One of the most significant difficulties for teaching ST is the need to apply the process in practice (Paschoal and de Souza, 2018; Coutinho and Bezerra, 2018). At university, sometimes, the teaching of ST is distributed in disciplines in the SE area and does not provide an opportunity for the ST learned in depth. This aspect causes students to graduate with deficiencies in software testing skills (Scatalon et al., 2019).

On the other hand, the industry needs professionals with formation and more solid training in testing. In practice, testing professionals (test analysts, test engineers, or testers) have been looking for options to improve the effectiveness and efficiency of testing (Garousi et al., 2017) both to perform a more effective job and to find better positions in their professional career.

Thus, university graduates and SE professionals self-learn (self-train) ST through books or online resources or by participating in industry training and obtaining certification in the ST area (Garousi et al., 2020), such as those provided by International Software Testing Qualifications Board (ISTQB), for example.

### 2.2 Exploratory Testing

One type of testing that has become widespread in the agile environment is ET. In this method, test professionals can interact with the system the way they want and explore, without restriction, its functionality (Suranto, 2015). In layman's terms, it can be said that ET allows professionals to learn quickly, adjust their tests, and, in the process, encounter software problems that are often not anticipated in test plans or *scripts*.

For Bach (2003) ET is the learning, design, and execution of tests performed simultaneously. Thus, the test professional adapts to the system being tested, creates, and improves the tests based on the knowledge acquired during the exploration of the system, without the aid of instructions about the system (Castro, 2018).

In ET, test design and execution are performed at the same time (Whittaker, 2009). However, we can perceive some disadvantages in the application of this test. For instance, the lack of preparation, structure, and guidance can lead to many unproductive hours (Suranto, 2015). Also, we can test the same functionality more than once while others are not tested (Castro, 2018), especially when multiple testers or test

teams are involved. Moreover, it can be not easy to track the progress of testing professionals (Suranto, 2015; Castro, 2018); among others.

To overcome some of these disadvantages and as a way of meeting the need for ET management and measurement, Bach (2003) proposed (1) to divide the testing activities into sessions, which would be the basic unit of work, (2) to stipulate a mission for each session and (3) adopt time metrics related to testing activities, originating the SBTM strategy.

The SBTM strategy is used to make ET is more effective and with clearer goals (Castro, 2018). For these reasons, too, ET has gained greater popularity in the agile industry (Suranto, 2015; Raappana et al., 2016; Garousi et al., 2017), requiring testing professionals to display a little knowledge, experience, and skills with ET. Thus, although Garousi et al. (2020) highlight that most courses have trained little about ET, it also recommends more ET coverage in ST education.

Ghazi (2017) highlights that an ET session should start with a document, called a Charter, which contains the mission described in a succinct way. The purpose is to ensure that the tester remains focused only on executing the session described in the Charter.

Some guidelines are indicated to define the mission, in the Charter: (i) the mission must not be too specific, nor too generic; (ii) the mission determines what is to be tested (not how the test is to be carried out); (iii) at the end of the ET session, new ideas, opportunities or problems, found by the tester, can be used to create new missions; (iv) after completion of the mission, it is important to have an evaluation of the session in order to discuss the results found.

For Hendrickson (2013) the mission format should be based on the following premise: define the mission and what should be explored. The mission of an ET, can be defined with the estimation of Test Points. A Test Points is related to each test job performed on the ET mission. Each mission can contain one or several Test Points that must be investigated during the time of the ET session. It is important to note that the Test Points list is dynamic, that is, new points can be added, based on errors found and corrections (Ghazi, 2017); and, they must be tested according to risk (high, medium or low), being the most at risk first.

## 2.3 Active Learning

As a way to streamline teaching and offer students differentiated strategies that lead to effective learning, active methodologies emerge as an alternative proposal to traditional teaching-learning approaches (Bonwell and Eison, 1991; McConnell, 1996).

Currently, active methodologies are being adopted in teaching-learning from different areas of knowledge as a way to improve current techniques and involve students in this process (Paiva et al., 2016), not limiting their learning only during class.

Active learning is characterized by stimulating students' autonomy and continuous participation in the learning process (Bonwell and Eison, 1991), through different teaching approaches such as Problem Based Learning (PBL), Team-Based Learning (TBL), the Flipped Classroom, Just-in-Time Teaching (JiT), among others. Some other trends in ac-

tive methodologies have emerged such as Peer Instruction (PI) (Crouch and Mazur, 2001), Design Thinking (Brown and Katz, 2011), Storytelling (Andrews et al., 2009) and Maker Culture (Milne et al., 2014), for example. Among these modalities of active methodologies, PBL and JiTT were adopted in a complementary way during the course of Exploratory Tests (ET). As the course was conducted remotely, PBL contributed to initiating and motivating participants to learn through real-life problems and encouraging group work skills and autonomous learning (Bonwell and Eison, 1991; Coutinho and Bezerra, 2018; de Andrade et al., 2019). JiTT influenced active participation in different activities before and during classes, encouraging participants to read the material and perform online tasks. For these reasons, these active methodology modalities were selected and applied in this study. Next, we describe PBL and JiTT separately.

### 2.3.1 Problem Based Learning - PBL

PBL is a teaching method that is characterized by the use of problems to initiate and motivate the learning of concepts and promote skills and attitudes necessary for their solution (Figueroa et al., 2011). In addition, PBL also aims to include the acquisition of an integrated and structured knowledge base around real-life problems, as well as promoting group work skills and autonomous learning (Figueroa et al., 2011; de Andrade et al., 2019; Cheiran et al., 2017), through collaboration and ethics.

PBL is considered a methodology strongly oriented to processes and accompanied by instruments that can assess its effectiveness (Figueroa et al., 2011). Therefore, the practical immersion promoted by PBL requires a teaching plan. This plan includes well-defined learning objectives, the structuring of a practical environment, the determination of roles for the subjects involved (teacher and student), and result evaluation strategies (Figueroa et al., 2011; Cheiran et al., 2017).

In summary, PBL starts with the proposition of a problem and ends with the resolution of this problem. For this, some steps are indicated: (1) clarify terms that are difficult to understand; (2) list the problem(s); (3) discuss the problem(s); (4) summarize the discussion; (5) formulate learning objectives based on the problems; (6) seek information; and, (7) integrate the information gathered to resolve the case. To carry out the PBL steps, the participation of a group of 10 to 12 students is indicated (with the figure of a coordinator and a secretary), a tutor and the definition of a script, with a description of the problem and a recommended bibliography or material support, if necessary.

PBL is suggested as a teaching-learning practice when there is a need to encourage the participation of students or professionals in the learning process, placing them as protagonists in this process, and consequently removing them from the condition of receiver of knowledge.

### 2.3.2 Just-in-Time Teaching - JiTT

JiTT is a pedagogical strategy developed by Novak (2011), whose essence is to connect activities inside and outside the class through warm-ups (Martinez, 2018). In this approach,

students are encouraged to read material about the content of the class and complete a small task online, a few hours before the class takes place (Martinez, 2018). This activity allows the teacher to plan the next class or make considerations in class according to the student's expectations or doubts (answers).

JiTt also aims to encourage students to participate actively in different classroom activities, through greater control over their learning, motivation, and engagement (Novak, 2011). With JiTT, class time is used more effectively because less time is spent on material that students have learned from reading, and more time is spent on more difficult subjects (Martinez, 2018).

In summary, the development of JiTT encompasses three basic stages, centered on the student: (1) WarmUp exercise, where the student is encouraged to read support materials and answer conceptual questions - from there, the teacher prepares the class; (2) class discussions on Reading Tasks (RT), through the re-presentation of questions and (some) answers from some students, maintaining anonymity; and, (3) group activities involving the concepts worked in the TL and in the class discussion, which can be expository, fixation exercises, among others.

JiTt is indicated when you want to stimulate, in the student or professional, the construction of prior knowledge about the content that will be discussed in class. And also to create the habit of studying before class. Other factors involve oral and written communication skills, maximizing effectiveness and class time, among other factors. JiTT is mainly suggested for the execution of short courses or for content taught in a short class time.

### 3 Methodology

This research examines the contributions of the use of active methodologies, PBL and JiTT, used in association, to assist in the teaching-learning process of ET, during the application of a course conducted remotely with members of agile teams distributed geographically. Thus, the research is classified as an experience report (Wohlin et al. (2012)), as it precisely describes: the planning, in Section 3.1.1; the execution, in Section 3.1.2; and, the analysis procedures, in Section 3.1.3, as a way to contribute with relevant considerations for the ST teaching area, as well as to allow the replication of this experience in other SE teaching contexts.

In order to learn more about ET, a bibliographic research was initially conducted to understand the main approaches and tools that have been used to support the practice of ET in the agile environment. This study culminated in a ET course, aimed at agile professionals, to validate the practical application of the SBTM approach. To understand the development phases of the experiment conducted, Figure 1 illustrates the activities developed, from planning to evaluation.

#### 3.1 Study Design

##### 3.1.1 Planning

The goals of this experience were defined following the guidelines of the Goal Question Metric (GQM) paradigm.

Thus, we seek to **analyze** the PBL and JiTT approach in teaching Exploratory Tests, **with the purpose of** realizing their contributions, **concerning** collaboration and integration between participants of a remotely conducted course, from the researchers' **point of view in the context of** geographically distributed agile teams.

To achieve this goal and conduct this research, we defined the following Research Question (RQ): "*How to encourage practical ET learning with geographically distributed agile teams, seeking integration among members, and promoting active learning, in order to encourage their insertion in the daily work?*".

Thus, RQ aims to identify the main contributions and limitations of the implementation of active learning PBL associated with JiTT in an ET course in remote format, about content learning, integration, the collaboration between participants, practical activities, and other aspects inherent in solving problems based on real scenarios. Thus, to answer this RQ a course on ET was planned and executed (see Section 3.1.2) with an agile DSD team. And, in the end, an online questionnaire was applied to collect the participants' feedback on the adopted teaching-learning methodology.

As shown in Figure 1, the planning phase of the ET course consisted of four well-defined steps, described below.

**Step 1. Define the Course Plan.** In this stage, we defined the course syllabus, the number of hours to be taught, the date of the course, the target audience, the objectives to achieve, the materials needed, and classes to be produced in a detailed manner according to the adopted methodology. It is important to remark that the definition of this Course Plan was widely discussed, reviewed, and evaluated by two specialists in the ST field. Moreover, we defined the tools to be used in the course, considering the context of remote learning as the following: *Google Meet*, for video communication during classes; *Discord*, for communication between participants during practical activities; *Google Drive*, for storing and sharing class materials and resources (in documents, spreadsheets, and presentations); *Google Forms*, for the elaboration and availability of the evaluation questionnaire, after the course; and, the *Xray Exploratory App*<sup>1</sup>, for ET planning and execution, only in the last practical activity. It is important to highlight that the contributions of the XRay Exploratory App tool were as follows: (i) it has desktop and mobile versions; (ii) it is possible to integrate it with Jira Software - although it was not possible to apply it in this study; (iii) assists in bug detection, while ET sessions are recorded in video, audio and/or screen capture format; (iv) ET sessions are detailed and executed directly in the tool; (v) when closing the session, a report is automatically attached to the test run - this strategy provides quick feedback to testers. In summary, the XRay Exploratory App assists in the test report and in the documentation produced.

**Step 2. Develop class materials.** The classes in this course are intended to train participants on the subject of ET in the agile context and balance the level of knowledge among all

<sup>1</sup>Xray Exploratory App: <https://www.getxray.app/exploratory-testing-app/>

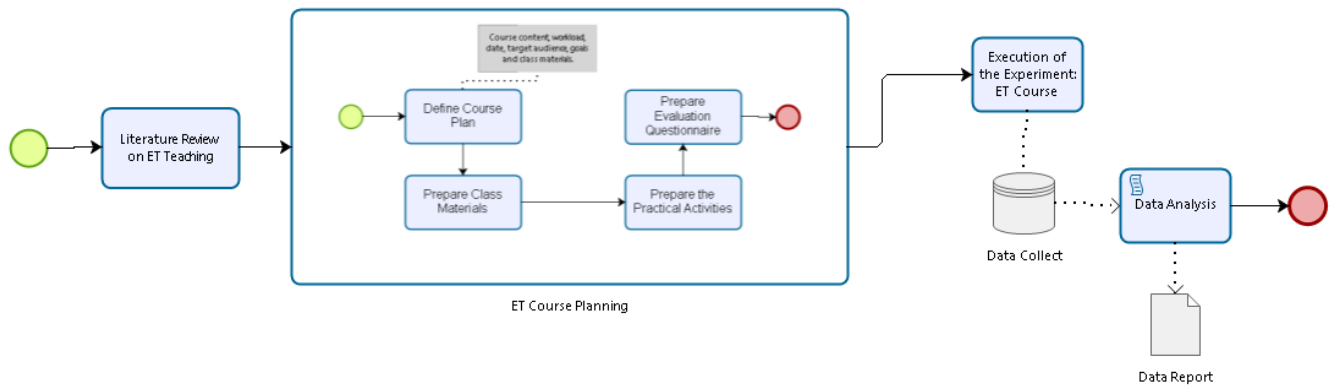


Figure 1. Development phases of this experience.

Table 1. Relation of questions addressed in the questionnaire with the purpose of each section.

Section	Goal	Questionnaire Questions	Question format
I	Identify the profile of the professional participating in this research and their experience in the ST area.	01, 02, 03, 04, and 05	All questions are objective.
II	Identify the organizational procedures and practices in relation to the practice of ST in the Sprints of the projects developed by the agile teams, before the course is offered.	06, 07, 08, 09, 10, 11, and 12	All questions are objective, except question 12 - it was subjective. Questions 09 and 10 follow the response format based on the Likert scale.
III	Identify the participants' perceptions about the teaching-learning obtained with the ET course.	13, 14, 15, 16, 17, 18, 19, 20, 21, and 22	All questions follow the response format based on the Likert scale, except for question 22. Question 22 is objective.
IV	Identify the contributions of the PBL and JiTT approach, used in an associated way, in the ET course.	23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, and 41	All questions follow the response format based on the Likert scale, except for question 41. Question 41 is subjective.

agile professionals participating in the course. In this context, the content covered in the class materials was based on Bach (2003); Castro (2018); Hendrickson (2013); Whitaker (2009); Crispin and Gregory (2009); Ghazi (2017) and on current lectures, conducted by renowned experts in the field of ET. It is important to highlight that (1) lecture notes (slides) with theoretical content and practical examples on ET were prepared and (2) a handout with a detailed synthesis of the content covered in the course; as well as, we selected (3) a list of tools that support ET planning and execution, (4) a list of videos (tutorials and lectures) available on the web, and (5) a list of technical articles and books on ET in the agile context. The class material adopted in the ET course can be accessed at <https://bityli.com/pUEhUgFN>.

**Step 3. Develop practical activities.** To exercise and reinforce learning about the content taught in each module of the course, examples and practical activities were prepared, based on the guidelines provided by the PBL and JiTT methodologies. At this stage, the materials and resources needed to carry out these activities were defined and elaborated, for example, the selection of the web system to be tested; a guide with basic guidelines for each practical ac-

tivity; templates of the test artifacts (such as Charters, Test Points, and Session Report) to optimize the time devoted to each activity; requirements artifacts (such as a System Requirements Specification Document and a Use Case Diagram); and, selecting an installation manual for the *Xray Exploratory App* program. Some of these materials and resources needed to be improved during the course, to meet the doubts and needs of the students, diagnosed in advance (ie, before the class) through the application of the JiTT methodology. It is important to highlight that it was possible to follow all the stages of PBL and JiTT in full (Figueiredo et al., 2011; Novak, 2011), even though the course was carried out in a remote teaching format.

**Step 4. Elaborate on the evaluation questionnaire.** To collect information about the experience and learning of the participants, a questionnaire was created online<sup>2</sup>, with objective and subjective questions. A total of 41 (forty-one) questions were included, distributed between 39 (thirty-nine) multiple-choice questions and 02 (two) open questions, whose answer was optional for the participant.

The questionnaire was designed in *Google Forms* and or-

<sup>2</sup>Access to the evaluation questionnaire: <https://cutt.ly/Ym5vEk2>

**Table 2.** Structure of the Exploratory Testing Course

Topics	Contents	Practical Activity (PA)	Course Workload (h)
Module I - Introduction	1.1. What is ET? 1.1.1. ET Characteristics 1.2. What is not ET? 1.2.1. Randomness and Testing Ad Hoc 1.2.2. Scripted tests 1.3. When to use ET?	PA1 Goal: Understand the product, create hypotheses, and plan test scenarios.	02h
Module II - ET in practice	2.1. ET Heuristics 2.2. ET planning 2.3. Writing ET Cases: Charters 2.4. Introduction to SBTM 2.5. Running Tests Based on Sessions 2.6. Evaluation of a session	PA2 Goal: Investigate Heuristics, run tests, and log failures. PA3 Goal: Apply Task Breakdown Structure (TBS) metrics.	04h
Module III - A little more about ET	3.1. Problems, Challenges, Solutions 3.2. ET good practices 3.3. ET Support Tools	PA4 Goal: Practice using the XRay Exploratory App tool through the execution of an ET Session.	02h

ganized into four sections. So, the first section aimed to briefly characterize the professional profile of respondents. The second section sought to identify the organizational procedures and practices about the ST practice in the Sprints of the projects developed by the agile teams before the course was offered. The third section sought to identify the respondent's perceptions about the teaching-learning obtained during the ET course. Finally, the fourth section aimed to identify the contributions of PBL and JiTT in conducting the ET course. Table 1 relates the questions addressed in the questionnaire with the goal of each section (see Section 3.1.1).

It is important to highlight that to answer the questionnaire, participants should: (1) have participated in all modules of the course; (2) have carried out the practical activities developed in each module; and, (3) right at the beginning of the questionnaire, have agreed to a Free and Informed Consent Form (FICF) for the research.

In Table 2 the structure of the course is presented, together with the description of the topics and contents covered in the syllabus, and the practical activities planned for the end of each class module. Additionally, the workload defined for each module of the course is informed.

### 3.1.2 Execution

The population of this study included twelve professionals from the software development industry who work with agile methodologies, in the same organization. Currently, these professionals work in geographically distributed locations, due to the *Corona Virus Disease* (Coronavirus Disease) or *Sars-CoV-2* pandemic, which specifically affects the Brazilian population since February 2020. For this reason, too, the ET course was conducted in a completely remote teaching context. It is important to highlight that 50% of the course participants have already performed ET, even without knowing the definition of the practice in detail.

In general, the execution of the experience took place as internal training with agile teams of that organization and as

planned, in four virtual meetings, with a duration of 02 hours each meeting, on the dates of 06, 07, 12, and 13 April 2021. It is important to highlight that Module II was divided into two meetings, due to the extent of the content taught.

At each meeting, the content was taught and participants were able to ask questions and resolve their doubts throughout the class. Then, to exemplify the discussed theory, a demonstration was made with real examples. And then, participants were instructed to exercise the knowledge obtained through a practical activity based on a real web system. For this, some guidance on the activity was provided.

Participants were distributed in teams and encouraged to interact and collaborate, through the dynamics of each activity. The resolution of a real problem also sought to encourage participants to research, reflect and develop ET relevant to the context analyzed in the activity. This strategy was based on the guidelines provided by the PBL.

At the end of each meeting, class materials and resources were made available to participants so that they had prior knowledge of the next content to be discussed in the course. This strategy, based on JiTT, sought to encourage interaction between the teacher and the course participants, in addition to enabling more in-depth discussions during the class and anticipating feedback on the materials and resources adopted for the next meeting.

To solve the proposed problem, the participants were monitored for approximately 40 to 50 minutes. The time was stipulated according to the complexity of the activity proposed in each module. For that the activities were defined in order to build knowledge about the execution of ET sessions and each activity involved a practice related to the content studied in the respective course module (see Table 2). In each activity, a set of practices was defined that served as guidance for the execution of the ET sessions (see the course material).

At the end of the course, participants were instructed to fill out a questionnaire online, whose purpose was to collect information about the experience and learning about ET

through PBL and JiTT practices.

### 3.1.3 Analysis Procedures

After data collection, through the online questionnaire, individual reports were generated, according to the objective of each section investigated in the questionnaire. It is worth noting that the information in these reports was anonymized to preserve the identity of the participants.

Thus, to analyze the data extracted from the content of the responses provided by the participants, a quantitative analysis was conducted (Wohlin et al., 2012), mainly in the responses provided through the Likert Scale, with options from 1 to 5 (being: 1 - Totally Disagree; 2 - Partially Disagree; 3 - Neither Agree nor Disagree; 4 - Partially Agree; 5 - Totally Agree). In this sense, the answers were analyzed by class: disagreement, indecision, and agreement. Additionally, a qualitative analysis was conducted on the answers to the subjective questions in total, alone two questions - 12 and 41), but as they were optional or complementary answers to the objective questions, there was little need to apply this type of analysis. Thus, when necessary, we synthesize and analyze the responses from open, axial and selective coding oriented in the Grounded Theory (Corbin and Strauss (2014)).

## 3.2 Checking the Use of ET in Practice

After the execution of the ET course, the activities performed by the participant were monitored during their daily work with agile development. Based on the guidelines learned in the course, the ET sessions were planned and executed. Then, a brainstorming session was conducted with the professionals to understand the real advantages and difficulties experienced in this context.

### 3.2.1 Brainstorming Planning

Brainstorming is a technique used in groups to generate innovative ideas or insights into a particular topic (Bonnardel and Didier, 2020). Overall, brainstorming should (i) generate as many ideas as possible, (ii) extend the interpretation of ideas, (iii) present original ideas, and (iv) perform the combination and improvement of existing ideas.

To conduct the brainstorming, the main question was defined, that is, a problem to be solved, and a set of activities to be followed. Thus, the following question was defined: "What to do to be able to integrate Exploratory Tests, as a test practice, in the team's daily life?". From this main question, other specific questions were presented to guide and contribute to the generation of ideas (see Table 3).

Regarding the set of activities followed in brainstorming, the following were planned (see Figure 2):

1. *Activity 1. Brainstorming in silence.* This activity consists of generating ideas, individually, to try to solve the presented problem. Thus, participants must write their ideas on Post-its.
2. *Activity 2. Sharing Ideas.* This activity consists of presenting the ideas that were generated and transcribed in the Post-its. Other participants are allowed to ask questions or add any new information or ideas.

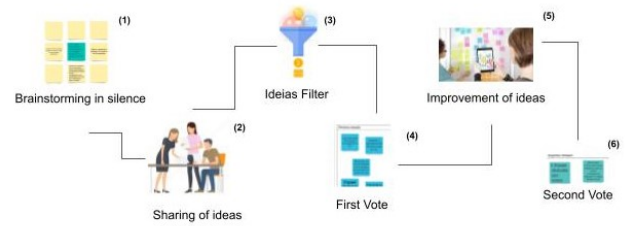


Figure 2. Activities performed in brainstorming.

3. *Activity 3. Filtering ideas.* The objective of this activity is to discard ideas that are not aligned with the context of the problem or that generate disagreements.
4. *Activity 4. First vote.* In this activity, all participants must select the ideas that best solve the exposed problem. Only the 6 most-voted ideas are listed for the next activity.
5. *Activity 5. Improvement of Ideas.* The objective of this activity is to improve the most voted ideas, adding important new information, through more post-its, with details of artifacts, testing activities, documentation, platforms or TE tools, and team organization, among others.
6. *Activity 6. Second vote.* Finally, the participants vote for the second time on the most applicable idea to solve the presented problem.

### 3.2.2 Execution of Brainstorming

After the execution of the TE course, the participants were led to apply TE sessions in projects they develop. In total, nine TE sessions were held, divided into two specific moments of the project. Then the brainstorming took place.

The brainstorming took place in a completely remote context, with the participants distributed locally. For this reason, the online tool Lucidspark<sup>3</sup> - was adopted to facilitate the transcription of ideas and collaboration between physically distant participants.

After some initial orientations, the participants were led to the brainstorming activities. In total, the brainstorming lasted a period of seventy-nine (79) minutes. It is important to note that the brainstorming lasted longer than anticipated in the initial planning. Figure 3 illustrates the execution of post-its brainstorming, presented by the Lucidspark online tool. The results are discussed in Section 4.2.

## 4 Results

After the experience was carried out, data were collected and analyzed. In total, the information provided by the twelve-course participants was considered, as they all agreed to participate in this study, followed the discussions during classes, and performed all the practical activities provided for at the end of each module. Thus, these results are discussed in Section 4.1. Then, the results of the Brainstorming carried out with the participants, after ET insertion with agile teams, in Section 4.2.

<sup>3</sup>Lucidspark: <https://lucidspark.com/pt>

Specific questions
1. How did the Session-based Testing strategy get in the way of ET execution?
2. Does something prevent ET from being routinely practiced by the team? What actually prevents it? (process, tool, team, project, time, etc.)
3. What can we do to improve the execution of ET?
4. Which requirements strategy or artifact is most useful to assist in the realization of ET?
5. What can be done to make these requirements clearer to the team?
6. What information is important to record/plan before performing the ET, in addition to what was indicated?
7. What information is important to record during the execution of the TE, in addition to those indicated?
8. What information is important to record after performing the ET, in addition to what was indicated?
9. Which practices were most interesting?
10. What practices did you not find interesting?
11. What benefits for the team's day-to-day activities were observed in the course?
12. In light of what was learned, what was the most difficult thing to implement on a day-to-day basis?
13. Has anything changed in the team's testing practice after the course? What has changed?
14. What do you see that would change in test practice after the course?
15. Did the ET course influence the incorporation of testing practices? What really influenced you?
16. Is ET useful as a testing practice in the context of remote work? What could be incorporated to contribute to remote work?

**Table 3.** Brainstorming specific questions.



**Figure 3.** Execution of Brainstorming.

## 4.1 Results of Experiment

Next, sections 4.1.1 to 4.1.4 present the characterization of the participants, the most common Agile ST practices adopted by the participants before the course, the perception of ET after the course, and the main contributions of PBL and JiTT to the teaching-learning ET.

### 4.1.1 Characterization of participants

Initially, to characterize the participants' professional profiles, an analysis was made regarding each team member's attributions and professional experience.

Considering that the composition of agile teams is multidisciplinary, that is, each team member can perform different functions during the developed software project, among the participants in this study, we identified different attributions distributed among the team members (see Table 4), among them are Developer Back-end and Developer Front-end, played by 50% of participants; Software Engineer, 41.7%; Project Manager, 25%; Database Administrator and Tester or Quality Analyst, 16.7% each; Software Architect, Scrum Master, Designer, Mobile Developer, and Infrastructure Engineer, with 8.3% each. Other attributions such as Analyst

or Business Leader, Analyst or Requirements Engineer, and Product Owner (PO), among others, were not informed.

**Table 4.** Assignments of participants in agile teams.

Assignments	Answers (N <sup>o</sup> )	Answers (%)
Database Administrator	2	16.7%
Architect	1	8.30%
Back-end Developer	6	50%
Front-end Developer	6	50%
Designer or Human-Computer Interaction Specialist	1	8.30%
Project or Product Manager	3	25%
Scrum Master	1	8.30%
Software Engineer	5	41.70%
Quality Tester or Analyst	2	16.70%
Mobile Developer	1	8.30%
Infrastructure Engineer	1	8.30%

Regarding the level of academic education of the participants, 58.3% have completed graduation, while 33.3% have a *stricto sensu* post-graduation at the master's level, and only 8.3% are still attending graduation.

Another factor observed was the professional experience of the participants:

1. Working experience in the industry software: 50% of them work in this context between 1 and 2 years; 16.7%, between 3 and 5 years; 25%, between 6 and 10 years; and, 8.3%, for more than 11 years. None of them reported little experience with software development, that is, less than 1 year of experience in the market.
2. Working time with agile methodologies: 50% work in this context between 1 and 2 years; 25%, between 3 and 5 years; 16.7%, between 6 and 10 years; and, 8.3%, for more than 11 years. None of them reported little ex-



perience (less than 1 year) or no experience with agile methodologies.

3. Working time with agile ST: 50% perform tests between 1 and 2 years; 16.7%, between 3 and 5 years; and, 16.7%, between 6 and 10 years. However, another 16.7% reported not working with testing at all.

#### 4.1.2 Common practices in Agile ST

Additionally, to identify how tests are commonly conducted by agile teams, an analysis of the main ST organizational practices performed in the Sprints of the projects was carried out.

Generally those responsible for testing the software or the software module developed are the Back-end Developer (41.70%), the Front-end Developer (25%), the Product Owner (PO) (16.70%), the Project or Product Manager (41.70%), Scrum Master (8.30%), the Engineer Software (16.70%), the Tester or Quality Analyst (25%) and, in some cases, everyone on the team (41.70%).

We also identified that tests are usually performed throughout the software lifecycle (41.7%). In some phases with more emphasis such as, during (33.3%) or after coding the software (58.30%); and, during (25%) or after the software integration phase (25%). In other phases the test takes place with less intensity such as, during (8.3%) or after the software verification phase (16.70%); during (8.3%) or after the production of software documentation (8.30%); or, during (25%) or after the software maintenance phase (16.70%).

In Agile ST the test types are categorized in Quadrants Crispin and Gregory (2009). Considering this categorization, we notice that the tests performed most frequently by the participants are Unit Tests (50%), Exploratory Tests (50%), Component/Integration Tests (41.7%), Functional Tests (41.7%), Usability Tests (41.7%), Performance and Load Tests (41.7%), Simulations (33.3%), Scenarios (16.7%), User Acceptance Tests (16.7%), Alpha/Beta (8.3%) and Examples (8.3%).

To assess the participants' perception of the types of tests performed on their teams, with regard to their professional activities, we expose the following questions:

- *Question 09*: "I believe that the software testing strategies adopted so far, and reported above, have been sufficient to detect bugs in the system".
- *Question 10*: "I believe we need to extend and improve the software testing practices used so far to try to ensure higher quality in whatever product we develop".

These statements contained multiple-choice items, according to the Likert scale, which is detailed in Section 3.1.3. Table 5 presents the result of the answers to Questions 09 and 10, and highlights the choices of the Likert scale as follows: (1) Totally Disagree, (2) Partially Disagree, (3) Neither Agree nor disagree, (4) Partially Agree and (5) Completely Agree.

Regarding question 09, it was possible to observe a predominance of responses following agreement, which may symbolize that the participants consider the ST strategies used to detect system bugs to be sufficient. Although, in question 10, they unanimously agree that the ST practices, un-

**Table 5.** Results of responses to Questions 9 and 10. ((1) Totally Disagree, (2) Partially Disagree, (3) Neither Agree nor disagree, (4) Partially Agree and (5) Completely Agree

	(1)	(2)	(3)	(4)	(5)
Question 09	8.3%	25%	8.3%	50%	8.3%
Question 10	0%	0%	0%	8.3%	91.7%

til then adopted by the teams, need to be improved and expanded. These results indicate that although the participants consider the agile testing practices adopted by the team to be sufficient, they also perceive the need to add other ST practices to try to ensure greater quality in the developed projects.

To understand the main problems related to the execution of tests in the projects developed by the participants in the daily work of their teams, we also expose assertions as response options, with multiple-choice items, according to the Likert scale. These assertions can be consulted in the Evaluation Questionnaire (see Section 3.1.1) and are described below. The results of the answers obtained can be seen in Table 6.

Thus, the assertions 'a' to 's', presented below, belong to question 11 of the questionnaire and comprise the participants' perception of the problems encountered in the practice of ST. These assertions were represented by letters of the alphabet so as not to be confused with individual questions or statements in the questionnaire.

- *Assertive a*: "A weak relationship between the client and the project leader".
- *Assertive b*: "A weak relationship between the leader and other team members".
- *Assertive c*: "Constantly changing objectives, business process and/or requirements during Sprint".
- *Assertive d*: "Lack of collaboration between test analysts and developers (programmers)".
- *Assertiva e*: "Failure to communicate within the development team (programmers) of the project".
- *Assertive f*: "Software requirements are purposely expressed in general terms, omitting specific implementation details".
- *Assertive g*: "Hidden, incomplete or inconsistent requirements".
- *Assertive h*: "Sprints too short".
- *Assertive i*: "Lack of knowledge about software testing practices and techniques".
- *Assertive j*: "Lack of training on specific software testing practices and techniques".
- *Assertive k*: "There is no time to test as it should".
- *Assertive l*: "There is no specific professional to run the tests within the team".
- *Assertive m*: "Trainings are time consuming and tiring".
- *Assertive n*: "There is too much effort to plan/design the tests".
- *Assertive o*: "There is an effort to run the tests".
- *Assertive p*: "Finding defects during production causes rework, delaying the completion of the Sprint".
- *Assertive q*: "Use of traditional testing practices in the agile environment does not favor the work developed during the Sprint".

- *Assertive r*: “A programmer tests their own code or the development team tests their own project”.
- *Assertive s*: “Test cases are written only for valid and expected inputs”.

The assertions that were most in the agreement were those referring to the constant change in objectives, business process, and/or requirements during the Sprint (*Assertive c*); the existence of hidden, incomplete, or inconsistent requirements (*Assertion g*); lack of knowledge about software testing practices and techniques (*Assertive i*); lack of training in specific software testing practices and techniques (*Assertive j*); insufficient time to perform the tests as it should (*Assertive k*); inexistence of a specific professional, on the team, to perform the tests (*Assertive l*); and, the effort to perform the tests (*Assertive o*). Most of the problems highlighted are typical results of teams that work in an agile context Alliance (2016) and can explain, for example, the need pointed out by the participants to expand and improve the adopted ST practices.

**Table 6.** Results of responses on problems in ST practice. ((1) Totally Disagree, (2) Partially Disagree, (3) Neither Agree nor disagree, (4) Partially Agree and (5) Completely Agree

	(1)	(2)	(3)	(4)	(5)
Assertive a	50%	25%	16.7%	0%	8.3%
Assertive b	58.3%	16.7%	8.3%	8.3%	8.3%
Assertive c	16.7%	8.3%	8.3%	50%	16.7%
Assertive d	58.3%	0%	16.7%	16.7%	8.3%
Assertive e	58.3%	16.7%	0%	16.7%	8.3%
Assertive f	25%	16.7%	16.7%	25%	16.7%
Assertive g	33.3%	8.3%	0%	33.3%	25%
Assertive h	33.3%	25%	16.7%	16.7%	8.3%
Assertive i	0%	16.7%	25%	25%	33.3%
Assertive j	0%	8.3%	25%	33.3%	33.3%
Assertive k	0%	25%	8.3%	41.7%	25%
Assertive l	0%	0%	8.3%	25%	66.7%
Assertive m	25%	25%	16.7%	16.7%	16.7%
Assertive n	25%	16.7%	25%	8.3%	25%
Assertive o	25%	8.3%	16.7%	16.7%	33.3%
Assertive p	50%	8.3%	8.3%	25%	8.3%
Assertive q	33.3%	25%	16.7%	16.7%	8.3%
Assertive r	25%	8.3%	33.3%	16.7%	16.7%
Assertive s	25%	16.7%	33.3%	16.7%	8.3%

Some participants reported how the ST process occurs on your team. Figure 4 highlights some of the reports made.

#### 4.1.3 Perception of ET after the course

We also investigate the learning gained by participants during the course by analyzing the information collected on some key topics in the ET content covered.

For this, we exposed the following questions to the participants and asked that the answers be assigned according to the multiple-choice options, according to the Likert scale.

- *Question 13*. “I have come to understand the importance of using Heuristics in Exploratory Testing”.

“The developer tests the code while developing. Another developer tests the integration of the developed code when analyzing a “merge request”. Team leaders test the entire application at the end of each sprint. All tests performed are exploratory tests, but without documentation.”  
(Participant X)

“Tests are carried out throughout the lifecycle in an exploratory and manual manner. These are slow and tiring tests that demand most of the team’s effort even during requirements development. But, given the context worked, it is something natural.”  
(Participant Y)

“Usually the developer tests his own code during and after coding. When development is complete, a second person tests this code. Finally, before delivery to the customer, a general test is carried out by all team members in the delivery environment of the application installed or available in the test environment, similar to the production environment. If an error is encountered, the process is restarted.”  
(Participant Z)

**Figure 4.** ST process executed in team projects agile described by the participants Question 12).

- *Question 14*. “I was able to understand that a list of heuristics to be adopted in Exploratory Tests helps in deciding how to test the functionality/module/system”.
- *Question 15*. “I have come to understand the usefulness and importance of Test Letters in Exploratory Tests”.
- *Question 16*. “I was able to realize that although it is not necessary to prepare a detailed Test Plan, simple planning helps with the execution of the Exploratory Test”.
- *Question 17*. “I managed to learn how to plan the Exploratory Test”.
- *Question 18*. “I was able to see that requirements artifacts, even if not very detailed, can contribute significantly to the planning (Setup) of the Session”.
- *Question 19*. “I was able to see those test artifacts (Mission Letter, Test Point, and Session Report) generated while conducting the SBTM were useful for the execution of the Exploratory Test”.
- *Question 20*. “From the explanation about SBTM I was able to apply this approach with ease in the Practice Activity”.
- *Question 21*. “I was able to understand the importance of the Alignment Meeting between the team to register possible failures, create possible formal test cases, create new missions, register possible requirements, and register new test points”.

The results associated with questions 13 to 21 demonstrate a predominant agreement on the learning of all content and practices taught during the course. Among the questions presented in this evaluation criterion, the following stood out with more emphasis: the importance of simple planning for the execution of the ET (*Question 16*); that requirements artifacts, even less detailed, can contribute to Session Setup (*Question 18*); the importance of the Alignment Meeting as a strategy to register possible failures, create possible formal test cases, create new missions, register possible requirements, and register new test points (*Question 21*); the usefulness and importance of simple ET artifacts generated in conducting the SBTM are useful for the execution of (*Question 19*); the relevance of defining Heuristics in ET (*Question 13*); among other relevant questions presented in the Table 7.

The performance of practical activities provided participants with a real experience with challenges common to ET, such as little domain knowledge and necessary qualities of

**Table 7.** Results of answers from Questions 13 to 21. ((1) Totally Disagree, (2) Partially Disagree, (3) Neither Agree nor disagree, (4) Partially Agree and (5) Completely Agree

	(1)	(2)	(3)	(4)	(5)
Question 13	0%	0%	8.3%	33.3%	58.3%
Question 14	0%	0%	25%	25%	50%
Question 15	0%	0%	16.7%	33.3%	50%
Question 16	0%	0%	0%	25%	75%
Question 17	0%	8.3%	8.3%	50%	33.3%
Question 18	0%	8.3%	8.3%	16.7%	66.7%
Question 19	0%	0%	25%	16.7%	58.3%
Question 20	8.3%	0%	25%	50%	16.7%
Question 21	0%	8.3%	0%	25%	66.7%

testers in the application of ET (91.7%) makes it difficult to carry out the tests; the absence of an ET plan results in the same functionality being tested several times or an important functionality may not be tested or a serious error may go undetected (91.7%); the lack of a definition of test cases makes it difficult to reproduce the tests performed, if necessary, such as in regression tests (75%); an incorrectly interpreted output can lead to defects that may remain in the system or be eventually detected in future tests (5%); as there is no detailed test guide or plan, and no more complete artifacts are produced other than the crash report, it is difficult to know what has been and has not been tested (50%); and, ET is not suitable for real-time systems (8.3%).

#### 4.1.4 Contributions from the PBL and JiTT approach

To identify the contributions of PBL and JiTT in the teaching-learning process applied in the ET course, an analysis of the characteristics of these methodologies was carried out. In this perspective, a set of eighteen questions (23 to 40) were exposed to the participants to be analyzed and answered through multiple-choice options, also following the Likert scale. Questions are listed below:

- *Question 23.* “The scenario (web system) worked on in the practical activities represented a real scenario of software development.”
- *Question 24.* “The scenario (web system) worked on in the practical activities had a high level of complexity.”
- *Question 25.* “Practicing the theoretical content with a real web system helped me to better understand the concepts of Exploratory Testing.”
- *Question 26.* “Through practical activities with a real web system, the course made it possible to learn, autonomously and independently, the main methods and techniques of Exploratory Testing.”
- *Question 27.* “Through practical activities with a real web system, the course made it possible to work collaboratively in groups in order to broaden the discussions in the team about the theory learned.”
- *Question 28.* “Through practical activities with a real web system, the course made it possible to work collaboratively in groups in order to deliver the project activities on time.”
- *Question 29.* “Through practical activities with a real web system, the course made it possible to work collaboratively in groups in order to deliver the project activities with quality.”

- *Question 30.* “Although physically separated, interacting with the team during practical activities was not difficult.”
- *Question 31.* “The use of conversation tools (such as Discord) and collaboration (such as Google Sheets, Google Drive, and Google Docs) contributed to the team’s interaction in practical activities, decreasing the physical distance.”
- *Question 32.* “I realized that giving my opinion (feedback) about the class regarding the approach adopted, the exposed content, or the supporting material used (slides, pdf, artifacts, videos, etc. ), contributed to the organization of the class and the instructor’s practice in the next class.”
- *Question 33.* “I realized that giving my opinion (feedback) about the class regarding the approach adopted, the exposed content, or the supporting material used (slides, pdf, artifacts, videos, etc. ), helped the instructor to focus on the main difficulties that were expressed by the participants.”
- *Question 34.* “I realized that giving my opinion (feedback) about the class regarding the approach adopted, the exposed content, or the supporting material used (slides, pdf, artifacts, videos, etc. ), maximized efficiency and class time.”
- *Question 35.* “I realized that the practical activities were also aimed at stimulating my oral and written communication, through discussions with the team and elaboration of the test artifacts.”
- *Question 36.* “I realized that the practical activities were also aimed at stimulating group work skills, such as distributing the roles of each member, setting goals, understanding objectives, providing collaboration and communication, among other aspects .”
- *Question 37.* “I collaborated more with my team in practical activity 2 (investigating heuristics) and 3 (applying TBS metrics) than in practical activity 1 (creating hypotheses and planning test scenarios) because I felt more secure about the web system I was exploring, only in these activities, as I didn’t know the business scenario well before.”
- *Question 38.* “I felt more secure in carrying out the practical activities, only after the course instructor provided more specific guidance on the task, as the guidance in the support material (slides) was not clear enough .”
- *Question 39.* “I felt more motivated in practical activity 2 (investigating heuristics) and 3 (applying TBS metrics) after the course instructor made the test artifact templates available.”
- *Question 40.* “I had problems collaborating on practical activities because I couldn’t understand them.”

To more accurately classify the answers given, we grouped the questions correlated to the main practices of active methodologies, in general - perceived in Questions 23 to 25; PBL, in Questions 26 to 29, and 36; and, JiTT, in Questions 32 to 36. We highlight that Questions 36 to 40, characterized both practices common to PBL and JiTT. Questions 30 and

31 sought to understand the participants' perception of the dynamics of the course in the remote setting. Table 8 displays the answers given to the questions.

**Table 8.** Result of responses from Questions 23 to 40.

	(1)	(2)	(3)	(4)	(5)
Question 23	0%	0%	8.3%	16.7%	75%
Question 24	25%	25%	33.3%	8.3%	8.3%
Question 25	0%	8.3%	0%	25%	66.7%
Question 26	8.3%	16.7%	0%	33.3%	41.7%
Question 27	0%	0%	0%	25%	75%
Question 28	8.3%	16.7%	16.7%	25%	33.3%
Question 29	0%	0%	16.70%	16.7%	66.7%
Question 30	0%	0%	8.3%	25%	66.7%
Question 31	0%	0%	0%	8.3%	91.2%
Question 32	0%	0%	0%	16.7%	83.3%
Question 33	0%	0%	8.3%	25%	66.7%
Question 34	0%	0%	33.3%	16.7%	50%
Question 35	0%	8.3%	8.3%	8.3%	75%
Question 36	0%	0%	8.3%	16.7%	75%
Question 37	0%	16.7%	8.3%	33.3%	41.7%
Question 38	0%	8.3%	16.7%	25%	50%
Question 39	0%	0%	8.3%	33.3%	41.7%
Question 40	25%	33.3%	0%	25%	16.7%

About general practices guided by active methodologies, we investigated the participants' perception of the inclusion of real practical examples in the activities carried out in the course. It was possible to observe a predominance in the follow-up of agreement in the answers to questions 23 and 25, which refer respectively to "the scenario (web system) worked on in practical activities represented a real scenario of software development" and "practicing the content theory with a real web system helped to better understand the concepts of ET". However, in question 24 we identified a majority of disagreement with the "high level of complexity of the scenario worked on in practical activities".

The answers provided in questions 26 to 29 and 36, related to PBL practices, which deal with the inclusion of real problems as practical activities in the teaching of content, provide evidence of the efficiency of using this methodology, especially about: learning autonomously and independently about ET (Question 26); collaborative group work to expand team discussions on the theory learned (Question 27), deliver project activities on time (Question 28) and with quality (Question 29); encouragement of group work skills, such as distributing roles for each member, setting goals, understanding objectives, providing collaboration and communication, among other aspects (Question 36).

About statements 32 to 36, which deal with information about practices common to JiTT, the results provided by the participants express a majority of agreement on the contributions and feedback given to the class from the access of the contents and materials of the class. Thus, from the point of view of the participants, this strategy: contributed to the organization of the class and the instructor's practice in the next class (Question 32); helped the instructor to focus on the main difficulties that were expressed by the participants (Question 33); and, maximized efficiency and class time (Question 34). Another JiTT characteristic observed

in the questions and which showed a predominance of the agreement was related to the objective of practical activities, namely: the encouragement of oral and written communication, through discussions with the team and preparation of test artifacts (Question 35) and the encouragement of group work skills (Question 36).

Otherwise, we investigated how collaboration between the team in practical activities stimulated the participants' learning. Agreement in questions 37, 38, and 39 prevailed, which referred, respectively, to security in collaborating more in the final practical activities than in the initial ones, as it is already better adapted to the business scenario provided as a real example in the activity; security in performing the activities after more specific instructions from the instructor; and, motivation after the instructor provides templates for the test artifacts. A positive aspect was the predominant disagreement in statement 40. A large part of the participants disagreed that they had "problems in collaborating in practical activities because they could not understand them". This result can be explained by the aspects already confirmed in statements 37 to 39.

Finally, the benefits and difficulties of participating in the theoretical and practical activities of the course were investigated, given its implementation in a completely remote teaching context. Table 9 presents the main testimonies of the participants regarding the perceived benefits and difficulties.

According to the statements reported in the responses, we identified that the content, the main approaches, and the ET tools were not known by some of the participants, as well as the usefulness of this test in agile methodologies. These aspects were pointed out as a benefit of the course for the work developed by the teams. Regarding the reported difficulties, we found that the practices could have been conducted with products developed by the teams themselves as a way to facilitate the understanding of the business scenario, and the course load was also considered short for the extension of the content and developed practices.

## 4.2 Results of ET insertion with agile teams

The six activities planned for brainstorming were conducted. There was no maximum or minimum limit of ideas to be expressed by the participants. Thus, participants were encouraged to present their ideas within the time interval defined for each activity (see Section 3.2.1).

In *Activity 1*, 37 answers were obtained to the specific questions listed in the preparation of the Brainstorming. Then, in *Activity 2* some questions were asked in order to clarify doubts related to the exposed ideas. In *Activity 3*, some ideas had to be grouped together, and others discarded. Thus, a total of 29 ideas that were not aligned with the main Brainstorming context were disregarded. It is important to highlight that not all the answers obtained were considered viable ideas to be applied, as some were repeated, complemented each other, or were outside the research context. In *Activity 4*, 06 ideas were voted on to be included in the next phase. In *Activity 5*, the most voted ideas were briefly discussed and improved, with the aim of favoring the vote to be carried out in the next activity. Finally, *Activity 6* resulted in a single

**Table 9.** Benefits and Difficulties of participating in an ET course in remote format.

Benefits
<i>Participant B:</i> “The ET scope and planning to deliver quality software.”
<i>Participant H:</i> “Learn how to document the execution of exploratory tests.”
<i>Participant I:</i> “Learning about the topic. Although the team, which also works together on development, somewhat adopted what was proposed in the classes, it was clear how we could improve.”
<i>Participant J:</i> “The theoretical content and practical activities were of great importance for a more solid understanding of the ET... The requirements document should also be detailed enough to enable the planning of the ET by the responsible team ... In addition, the ET technique presented in the training can contribute a lot to the quality of the developed artifacts.”
<i>Participant K:</i> “Through the course, I had my first contact with ET, and participating in it made me learn a lot... What was seen seemed very attractive for the context of agile methodology.”
<i>Participant N:</i> “I found the use of heuristics in the tests interesting, I didn’t know about it.”
Difficulties
<i>Participant B:</i> “Not having any type of ST course in my graduation.”
<i>Participant F:</i> “The guidelines of the support material, sometimes it was not clear what should be done, generating doubt in the group.”
<i>Participant H:</i> “Differentiate what information should be placed in each field of the template provided during ET planning.”
<i>Participant L:</i> “It was a little difficult to think of scenarios for an initially unknown system. I think it would be more beneficial if the practice of the course had used a system developed and well-known by the team/class.”
<i>Participant O:</i> “I had difficulty participating due to the course schedule, as it wasn’t my actual work schedule.”

viable idea to implement: the definition of a more viable approach to be implemented in the daily life of the team.

The ideas presented in the Brainstorming were related to the implementation of ET in the participants’ daily lives, from the application of the ET course. Thus, the exposition of some ideas was crucial to understanding the effectiveness and usefulness of the practices exercised and the artifacts generated. We categorize these ideas to explain what actually applies and what does not apply to the daily lives of agile teams. The following is a summary of the ideas exposed in the brainstorming that favored the incorporation of ET in the daily life of agile teams:

- The registration of Test Points and the Test Report were considered important for the planning and execution of the ET.
- Regarding the benefits for the team’s day-to-day activities, the importance of recording the ET made was highlighted, in order to highlight the points that were tested and their pending issues.
- The registration of TestPoints was seen as a significant contribution of the TE Sessions because, in practice, there was an improvement in the activity of registration of the test to be done.
- Considering the context of distributed work, adopting files or artifacts with permission for simultaneous collaboration, and online tools contributed to the TE performed remotely.

Below is a summary of the ideas exposed in the brainstorming that stood out as limiting factors to the incorporation of ET in the daily life of agile teams:

- The minimum and maximum time limit for executing an ET Session does not apply in practice, as this factor is relative to the tested functionality. As well as recording the complete execution of an ET session.

- The unavailability of time to plan ET sessions was defined as a difficulty in implementing TE in practice.
- Having a well-defined TE process could contribute to the insertion of TE as a test practice in the team’s daily life.
- The minimum time reserved for an ET Session, in SBTM, could be smaller for small features.
- The lack of experience with the ET makes the professional who performs the test, dedicate a significant effort to the preparation of the TE Session as a whole.
- The absence of a well-defined process that optimizes the preparation time of an ET Session limits the insertion of the ET in the team, as well as the organization and commitment of the entire team to find a common moment to perform the ET.

In a complementary way, some other ideas emerged to facilitate the insertion of ET in the daily lives of teams, such as:

- Include a description and examples in the attributes of each artifact of the ET Session, to facilitate the understanding of the artifact, or to exemplify the description of a Test Point.
- Set the Test Points in advance.
- A document or a Use Case model could contribute as an artifact of base requirements for the planning of ET Sessions.
- Providing a brief description of the functionality to be tested in the ET Session could facilitate the planning and execution of the test.
- Capturing the print screen or screen recordings that contain the functionality defects identified in the ET Session contributes to the record of the test performed.
- After running the test, it would be interesting to record the test execution step by step, the scenario tested and any impediments or difficulties encountered by the tester.

## 5 Discussion of Results

In this section, we discuss the results obtained and presented in Section 4, in order to expand the considerations about the ET course applied with agile professionals 5.1 and the monitoring of the incorporation of ET in the daily work of these professionals 5.2.

### 5.1 Overview on using PBL and JiTT

To promote active learning and integration among geographically distributed participants during an ET course in a remote learning format, PBL and JiTT approaches have proven to be useful in stimulating hands-on learning in this context. According to the agreement of information and reports from the participants, some characteristics of PBL and JiTT stood out, such as:

1. *The use of a real scenario* of software development contributed to the practice of the ET concepts covered in the course. The actual scenario practiced encouraged the participants to further investigate the possible failures of the analyzed system from the Heuristics and planned ET scenarios. This strategy allowed the quick identification of some bugs implemented in the system's functionalities - in total, there were 6 bugs in three different missions (test scenarios) tested in practice 2, and 4 bugs in three distinct missions tested in practice 3. We highlight that each mission was executed in a 30-minute session. The low level of complexity of the adopted web system also contributed to the understanding of its operation, since there were - in the first practical activities - more detailed requirements or business artifacts.
2. *Autonomous learning* was stimulated through practical activities, simulating the participants' daily situations through the exploration of the web system; studying or reading classroom material and resources in advance; the discussion of content and activities during classes; the elaboration of questions about the understanding of practical activities; and, the construction of the generated ET artifacts.
3. *Collaborative work* stimulated different learning styles among the participants, such as: distributing the roles of each member, setting goals, understanding objectives, and providing communication. It also contributed to the expansion of discussions in the team, with the different points of view of the participants, and with the delivery of the activity on time - although, in some cases, additional time to complete the activity was necessary - and with quality - meeting the requirements of the activity. The use of online conversation and collaboration tools contributed to the team's interaction, narrowing the physical distance.
4. *Stimulation of additional skills*, such as reading materials, using logical reasoning to understand the features of the web system during practical activities, discussions between teams, and exploring the system, among others. Teamwork was also an encouraging practice, although the participants already act in this way in their daily work.
5. *The motivation*. Some clarifications about technical terms, expressions, or ET artifacts were useful to keep the participants motivated in carrying out the practical activities. As well as the availability of ET artifact templates and the socialization of the generated artifacts at the end of each practical activity.
6. *Feedback* provided before, during, and after classes about the content, materials, resources, and methodology used, contributed to the organization and practice of the instructor in the following class; help the instructor focus on the main difficulties that were expressed by the participants; and, maximize the effectiveness and time of the class.
7. *The examples shown*, as well as the way to present them, contributed to improving the understanding of TE, as all the examples also referred to contexts of real systems. Exemplifying the theory in this way helped the participants in the understanding and applicability of ET, especially during the performance of practical activities.

It is important to highlight that the Likert Scale helped to identify both the benefits and limitations of the PBL and JiTT approaches, through assertions that represent their main characteristics. However, the answers provided by the participants pointed to these (Question) characteristics more as benefits than as limitations to the use of these approaches in remote learning. Although guidance and some clarifications were provided during the practical activities, some participants agreed on the difficulty in collaborating in practical activities because they were unable to understand them well. Perhaps this is justified by the absence of face-to-face contact to facilitate communication.

In summary, it is also important to highlight that: (i) although during the course, the participants were geographically dispersed, we did not address any specific DSD process. The purpose of the course was to use strategies and tools that would make ET viable in the context of isolated and remote work; (ii) the use of a specific tool (Xray Exploratory App) for planning, executing and reporting bugs (with video recording, capturing and annotating screenshots, annotations, among other aspects) in ET sessions are benefits not found in other tools that aid the execution of ET; (iii) the experience of remote learning with geographically distributed participants is challenging and factors such as stimulating participation, collaboration and attention skills need to be considered for learning to actually happen; (iv) we noticed: the interest and engagement of the participants, when practicing the theoretical content through a real problem adopted in the activities and discussions during the classes, mainly due to the pre-constructed knowledge through prior access to the materials of the classroom; the quality of the answers in the exercises, as a good part of the test artifacts generated were in accordance with the criteria suggested in the description of the activities; a motivation to use the Xray Exploratory App tool, due to the ease in creating, executing and exploring the ET performed; among other aspects already discussed in this Section.

## 5.2 Overview of Insights in Practice

The ET course facilitated the participants' understanding of ET concepts and practices. In order to facilitate the incorporation of this test practice in the daily lives of the teams, the participants were motivated to apply ET sessions in their work context. Then, a brainstorming was conducted to evaluate the execution of the ET. Next, we discuss the information obtained from brainstorming from the questions listed in Table 3.

Therefore, some factors were perceived that favored the incorporation of ET in the daily lives of the teams, such as:

1. The *planning of Test Points*, and defining the degree of importance of each Test Point facilitated the understanding of what is a test priority for the moment.
2. *Documenting what was tested* also contributed to the conduct of the alignment meeting with the team, considering that all the information inherent to the test execution, such as bugs, suggestions for improvements, or pending issues, was recorded.

On the other hand, some limitations were also noticed in the implementation of ET Sessions:

1. The artifacts adopted in the ET Sessions - Charters, Tests Points and Test Report - proved to be complex (i.e. difficult to understand) or with underused fields for the test record. In this case, there is a *need to implement guidelines or examples to clarify the effective use of the artifact*.
2. There was a *need for adaptations in the artifacts* - of planning and recording the test - for a more specific adaptation to the agile context in which the ET was conducted.
3. *The orientation of minimum and maximum time* for the realization of the Sessions: sometimes, the minimum time (30 minutes, indicated by the SBTM) for the session was not used because the functionality tested was very simple, and the session that could have been done less time needed to be extended to reach the minimum time. In this case, a new orientation for situations like this needs to be considered.
4. *The absence of a well-defined process or approach that is compatible with the real work context of agile teams*. What is proposed in the literature, such as the SBTM, is not always applicable in its entirety in the real context of agile professionals.
5. *Experience of the professional who defines the Test Points* because when this activity is performed by professionals who are unaware of the application to be tested, there is a risk of specifying a Test Point in an inconsistent or incomplete, generating gaps in the ET planning and generating difficulties in its subsequent execution.

To actually incorporate ET as a testing practice in agile teams, it is still necessary to define an approach that fits the context of these professionals, in order to consider practical application guidelines, more specific tools that consider the particularities of planning and ET execution, and simple,

clear and effective artifacts to be adopted. For this reason, there is a need for an approach that fits the needs of professionals working in agile development and that goes beyond the concept presented in the literature on ET.

## 6 Limitations and Threats to Validity

Some potential threats to the validity of this study were perceived, such as threats to internal, external, construct, and conclusion validity. For this reason, some measures were taken to minimize them. To mitigate *construct validity*, the course material and evaluation questionnaire were iteratively planned, updated, and validated by the authors. As well as, elaborated based on works related to the ET area, in the context of Agile ST (Bach, 2003; Hendrickson, 2013; Suranto, 2015; Whittaker, 2009; Castro, 2018). To mitigate *internal validity* and ensure the anonymity of responses, participant identification was optional - via email address. This allowed the data analysis to be performed in an impersonal way. Other aspects inherent to the selection of individuals and conduct of the experiment also contributed and are detailed in Sections 3.1.2 and 3.1.3. The *external validity* was attenuated with the availability of resources and teaching materials to facilitate the application of the active methodologies mentioned. Thus, the results can be valid for other course participants either in a remote or face-to-face teaching format. To mitigate the *conclusion validity*, only percentages were used to identify common patterns. Complementarily, the questionnaire validation answers were also discarded, regarding possible errors, such as answer format, and textual expressions used in the questions, among others. We tried to reduce bias using Likert scale data. Thus, all the conclusions we draw in this study are strictly traceable to the data.

## 7 Related Works

Although the literature shows interest in ST Teaching and is seeking strategies to boost practical teaching closer to the real context of the software industry through approaches based on active learning (Cheiran et al. (2017); de Andrade et al. (2019); Martinez (2018); Figuerêdo et al. (2011)) see Section 7.1 -, there are still few studies that present results on the teaching of ET (Costa et al. (2019); Ferreira Costa and Oliveira (2020)) - see Section 7.2.

Some other studies also have been dedicated to the investigation of ET in the context of the industry in order to understand the impact or effectiveness of this testing practice in real projects (Gebizli and Sozer, 2017; Mårtensson et al., 2019; Pfahl et al., 2014; Afzal et al., 2015) - see Section 7.3. A brief discussion of these works in relation to this study is presented in Section 7.4.

### 7.1 Teaching-learning of ST using active methodology

Cheiran et al. (2017) present an account of two experiences on the teaching of ST using PBL in an undergraduate course of SE at the Federal University of Pampa (UniPampa). In

total, 51 students participated - 25 in the 1st edition and 26 in the 2nd edition of the course. Data collection took place through questionnaires. To analyze the collected data, statistical and content analyses were adopted. The results point to evidence of students' maturity in the context of the curricular component and the benefits and problems faced by integrating PBL and gamification elements.

de Andrade et al. (2019) also conducts a study on ST learning using PBL practices, with students from Computer Science, at the University of São Paulo (USP), and Information Systems, of the Federal University of Juiz de Fora (UFJF). The results show that (i) classes with many students should have fewer presentations; (ii) courses with an average number of students can choose to keep weekly presentations more dynamic or with fewer presentations; (iii) the approach PBL is not as effective for students who have less time for extra classes. In summary, it was noticed that the successful adoption of an active approach is not directly linked to the infrastructural aspects.

Figuerêdo et al. (2011) apply PBL to train test engineers. For this, an empirical study was carried out with two groups, where each group was composed of five undergraduate students. The group should test a CASE tool to support functional testing using ET. Two evaluations were made with the participants - one before and one after the execution. Participants' knowledge, grades, and amount of bugs identified were evaluated. The results obtained highlight that the PBL provides the engagement of participants and obtaining experience in scenarios that simulate real ST situations.

Martinez (2018) describes the results of an experience with JiTT based teaching in a graduate course in ST over two semesters. The approach adopted was evaluated from the perspective of students, through a survey, and of teachers, from an assessment of strengths and limitations. The results show that a large majority of students (1) believe that their learning has improved when they prepare for class by reading the material in advance and (2) consider JiTT to be an adequate teaching strategy for the course. Teachers highlighted that students became more involved and participatory in discussions during class.

## 7.2 ET teaching

Costa et al. (2019) use gamification as a motivating strategy in teaching and learning ET. This dynamic consisted of practical activity to apply ET in the form of a game, which refers to the "Treasure Hunt". An experience was carried out with students from an SE discipline of an undergraduate course in Computer Science. The results indicate that the qualitative results converged with the quantitative results obtained, showing that gamification helped in the teaching and learning process of the students (forehead pains).

In another work, Ferreira Costa and Oliveira (2020) replicate a new experience with the gamification strategy for teaching ET discussed in Costa et al. (2019), with a group of undergraduate students in Computer Science and with graduate students in a Computer Technician course. As a result, students achieved good overall performance. Some reports highlight that gamification facilitated and significantly contributed to better performance, converging with the quantitative

data obtained. This can be evidenced mainly by the fact that both "runs" of the experience (classes) reached a percentage higher than 70% of achievement.

## 7.3 ET in the context of industry

Gebizli and Sozer (2017) evaluate the impact of the education and level of experience of testers on the effectiveness of the ET. For this, a case study was carried out with 19 industry professionals, with different educational backgrounds and levels of experience. A Digital TV system was tested, and detected failures were categorized according to their severity. Thus, the effectiveness of the ET was evaluated on two aspects: criticality of detected faults and efficiency in terms of the number of faults detected per unit of time. The results show that ET efficiency is significantly affected by training and educational experience.

Mårtensson et al. (2019) conducted a study based on interviews to understand the success factors in the application of ET in industry projects. For this, interviews were conducted with 20 professionals. Finally, a list of key factors that enable the efficiency and effectiveness of ET in large-scale software systems was presented. The nine factors identified are grouped into four themes: (i) Testers' knowledge, experience, and personality; (ii) Purpose and scope; (iii) Ways of working; and, (iv) Registration and reporting.

Pfahl et al. (2014) investigated how software engineers understand and apply the principles of exploratory testing, as well as the advantages and difficulties they experience. For this, an online survey was carried out among Estonian and Finnish software developers and testers. The main results indicate that the majority of testers, developers, and test managers who use ET, (1) apply ET to critical software for usability, performance, security, and security to a high degree; (2) use ET very flexibly at all kinds of levels, activities, and phases; (3) they perceive ET as an approach that supports creativity during testing and is effective and efficient; and (4) feel that ET is not easy to use and has few support tools. In addition, there was a need for more support for ET users, such as guidelines and tools.

Afzal et al. (2015) sought to quantify the effectiveness and efficiency of ET vs. tests with documented test cases (TCT). For this, four controlled experiments were carried out, with a total of 24 professionals and 46 students. Manual functional tests using ET and TCT were done. The number of defects identified in the 90-minute test sessions, the difficulty of detection, the severity and types of defects detected, and the number of false defect reports was measured. The results show that ET found a significantly higher number of defects. However, the two testing approaches did not differ significantly in terms of the number of false defect reports.

## 7.4 Discussion of related works

We could not find works that apply JiTT and PBL in ET. In general, the application of JiTT or PBL in ST, as reported in the literature (Cheiran et al., 2017; Figuerêdo et al., 2011; Martinez, 2018), achieved results that converge with ours in the sense that the adoption of these methodologies has provided positive gains, related to motivation, engagement,



collaboration, and content learning. We also emphasize that most of the works are developed in academic environments (with undergraduate students), others in practical environments (with industry professionals). Generally, the types of tests investigated are different, sometimes a more specific type of test or in a more general context, such as defect detection only. But, it is not always possible to identify in which development process the work was applied or which development methodology was adopted.

In this way, this paper differs from the others in that it identifies and discusses the contributions of the integration of active methodologies, PBL and JiTT, in teaching ET in a remote learning course with agile professionals from the software industry and distributed geographically. Some strategies and guidelines seeking to optimize teaching-learning with PBL and JiTT, as well as the discussion of some perceived challenges, were also highlighted. Another differential is the monitoring of ET execution in the daily agile development of industry professionals, in order to highlight the aspects that favor or limit the incorporation of ET in the daily routine of agile teams.

## 8 Conclusions

This work investigates the use of the PBL and JiTT methodologies to teach ET to a DSD team. Based on a literature review and evaluation of the resources available, we planned and performed a training course on ET and analyzed the results obtained. While teaching ST has been challenging, under the circumstances imposed by social distance, where each team member is working remotely and isolated, teaching such a subject becomes even more challenging. Next, we followed the incorporation of ET into the daily lives of the teams that participated in the course and made an analysis of the application of this practice in the context of agile development. Through brainstorming, ideas were raised about the characteristics that favored or limited the execution of ET.

The use of these methodologies significantly contributed to the success of the course. They provided the grounds for adopting a real problem, assessing the student's needs with resources available before the class, adjusting the course to meet students' expectations and needs, and promoting collaboration. Additionally, the existence of a support tool for ET was key to optimizing remote learning. These aspects also favored the application of ET by agile teams in their projects. So that both the practices and the artifacts were put to good use in the test execution. However, even with this support given in the course, some limitations were perceived such as the absence of more specific support for the planning and execution of the ET, such as guidelines and tools.

As future works, we intend to (1) propose an approach that facilitates the implementation of ET, considering the DSD scenario and the generation of simple and robust ET artifacts, for the effective insertion of this test practice in the daily life of agile teams. Next, we also intend to (2) validate the approach through experiments with professionals from the software development industry.

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