Lessons Learned from a Lean R&D Project

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Abstract: In a partnership between academia and industry, we report our experience in applying the Lean R&D approach in the IAGO project, an oil and gas machine-learning-based dashboard. The approach is grounded in continuous experimentation through agile development, beginning with a Lean Inception workshop to define a Minimal Viable Product. Then, after technical feasibility assessments and conception phases, Scrum-based development begins, continually testing business hypotheses. We discuss our experiences in following the approach, and report developers' perceptions gathered through interviews and user evaluations of the final product. We found that the Lean Inception works well for aligning expectations and objectives among stakeholders, but it is not enough to level the domain knowledge among developers. The participation of end users in the workshop and throughout the project, as well as constant communication among all stakeholders, is very important to deliver appropriate solutions.

1 INTRODUCTION

In September 2019, the *Pontifical Catholic University of Rio de Janeiro* and *Petrobras*, a large publicly-held company that operates in the oil, gas, and energy industry in Brazil, established a partnership through an initiative called *ExACTa (Experimentation-based Agile Co-creation initiative for digital Transformation)*. The goal is to develop several Research & Development (R&D) solutions, with a focus on Digital Transformation (DT). We follow an approach named Lean R&D, which has the following building blocks: (i) Lean Inceptions, to allow stakeholders to jointly outline a Minimal Viable Product (MVP); (ii) early parallel technical feasibility assessment and conception phases, allowing to "fail fast"; (iii) Scrum-based development management; and (iv) strategically aligned continuous experimentation to test business hypotheses (Kalinowski et al., 2020).

The first solution in the partnership is called IAGO (Artificial Intelligence (AI) for Odor Management, in Portuguese). It is an AI-powered visual analytics dashboard that helps to diagnose and forecast odoriferous compound, which eventually can be felt by nearby communities. The underlying goal of IAGO is to enhance the good relationship with these communities. IAGO was conceptualized and developed in eight months. Its kick-off event was a modified, in-person Lean Inception (LI) workshop in December 2019. LI is a five-day, collaborative workshop proposed by Caroli (2018), whose objective is the definition of an MVP. However, due to time constraints, we had to conduct the workshop in 2.5 days. We kept all the activities, but reduced the time in which they were conducted.In this paper, we report our experience of co-creating a DT solution with an R&D focus, following the Lean R&D approach (Kalinowski et al., 2020). We report difficulties and obstacles we encountered in the first iteration of the approach, which includes a mismatch of expectations from the customer side to participate in conception phases, as they were eager to start the development stage. Indeed, we failed to set the expectation that end users should be present during the LI, the definition of the product backlog, and the design of the prototype user interface. We also report results from questionnaires about the quality and usability of the final software product, as perceived by its users.

The remainder of this paper is structured as follows: in Section 2, we describe related work. Section 3 describes the methodology used to develop IAGO. In Section 4, we discuss positive and negative

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experiences we had throughout the design and implementation process. In Section 5, we conclude with our final remarks, lessons learned, and future work.

2 RELATED WORK

Currently, there are no reports on applying the Lean R&D approach in industry-academia collaborations. In this section, we cover related work and studies that feature similar approaches and methods.

Sandberg et al. (2011) developed 10 action principles for industry-academia collaboration: (i) address activities to ensure results, as the ultimate goal is to provide industrial benefits and innovation; (ii) ensure management engagement; (iii) embrace research negotiations, as industry and academia have different objectives; (iv) organize get-togethers to facilitate collaborations; (v) communicate both progress and results; (vi) attend to both needs and goals; (vii) be agile; (viii) fund small research projects; (ix) allow innovation to emerge from needs; and (x) realize that collaborative practice research involves learning – researchers must learn to be agile toward industry needs and practitioners must learn to appreciate research rigor (Sandberg et al., 2011).

Lárusdóttir et al. (2014) conducted interviews with information technology (IT) professionals regarding customer involvement in an agile context. They found that developers value a close relationship with the customer, which can lead to a better understanding of software requirements. However, because agile does not distinguish between customers and real users of the system, it can blur the real involvement of system users. Also, the IT professionals in their study found it important that the customers integrate the agile process into their organizational culture, which can prove to be a challenge, as some prefer to follow a waterfall process. As one of the study participants said, “It is difficult to be Agile in a non-Agile environment” (Lárusdóttir et al., 2014).The study results indicate that it is easier to be agile in smaller, more flexible companies. Because *Petrobras* is a large, traditional company, some of these obstacles were found in the IAGO project.

Kuusinen (2014) conducted a study in a large software development company that follows agile R&D practices to investigate the relationship between the UX and the developers. They found that problems in Agile UX were mostly related to process and communication: little or no cooperation between the UX team and the developers, and not enough time for the UX design to be concluded before being implemented by the developers, as the UX team was rarely included before the product backlog was created. Consequently, as the amount of work done by the UX/UI team was usually rushed, they lacked a big picture of the software product, which hampered their work.

3 METHODOLOGY

We now describe the Lean R&D methodology used to develop IAGO. Figure 1 shows the development process. It started with a brief study of existing solutions regarding odor detection in oil refineries, which then led to the requirements and MVP definition during an LI workshop. The resulting requirements were then documented through User Stories (US) in Azure DevOps. The next step was the creation of low-fidelity wireframes, which were validated and drove the creation of high-fidelity prototypes. Then, we investigated different Business Intelligence (BI) platforms to host IAGO. Next, we implemented simple dashboards, which were evaluated and generated new investigations of different BI platforms. Once we settled on a platform, we continued the implementation and development process and concluded the IAGO project with a usability evaluation questionnaire.

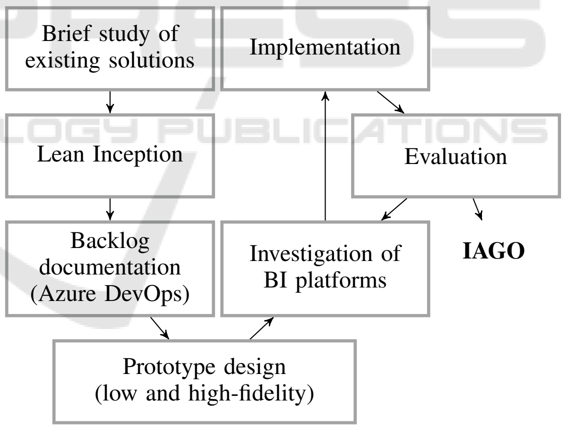

Figure 1: Development process.

3.1 Brief Study of Existing Solutions

We started with a brief study of existing solutions. *Petrobras* first presented an existing, internal dashboard, which provides diagnosis for odoriferous compound measurements in oil refineries. However, the dashboard users mentioned problems with the user interface, which lacked important information, such as meteorological data, a log of the complaints and testimonies by the communities around the refineries regarding strong odors, and usage data for management purposes. The system was also too slow and the machine learning model needed improvement, as the results were not accurate enough. A migration to a cloud platform was also desired, as well as the adoption of a robust BI system like Power BI to build the dashboard, to make the product faster and more usable.

As related work, Bashir Shaban et al. (2016) describe a model to predict concentrations of O_3, NO_2, and SO_2, whereas Du et al. (2019) present a model to predict the landfill odor of H_2S. Nonetheless, neither of the studies present dashboards to monitor these results. Yousif (2016) presents a model to predict H_2S concentration and implemented a real-time forecasting system for catastrophic conditions, which sends a suitable warning alarm to the controller. However, it is unclear how the alarm reaches the users because there are no mentions of its user interface.

Cadei et al. (2019) developed a real-time, end-to-end tool to monitor H_2S emissions in an oil and gas field, using machine-learning and data mining techniques to raise alarms and then provide prescriptive information. Their solution also features a dedicated dashboard to monitor the risks of high H_2S levels and model performance.

We were unable to find other solutions that would be of value to our case. Oil, gas, and refinery plants have very specific inner workings, and each has its own unique processing scheme (Groysman, 2017). Although similar solutions to similar problems can be adopted, a further study into each specific plant is necessary. Therefore, the next step of this work comprises an LI workshop used to provide more information on the specifics of the IAGO project.

3.2 Lean Inception

We conducted a 2.5-day LI workshop with client representatives of business areas, IT experts, potential users, and the *ExACTa* development team.

The main goal of an LI is to define the scope of an MVP. It includes the following activities: (i) definition of the product vision, following a specific template; (ii) definition of the scope of the product, listing what it is and is not, and what it does and does not do; (iii) creation of personas; (iv) brainstorm of product features, performed individually at first, and then unified; (v) business, technical, and user experience (UX) review, in which each participant has to provide a score for how well they understand each feature and how it will be implemented, and a score from one to three on each of three dimensions – the business, technical, and UX impact of each mapped feature –; (vi) creation of user journeys for each persona; (vii) definition of a sequence of the mapped features according to a set of rules based on their business, technical, and UX scores, which are then evaluated by the participants and broken into different MVPs; and (viii) finalizing the MVP canvas (Caroli, 2018).

The first three activities, although performed in groups, were mostly carried out by *Petrobras* representatives, because the *ExACTa* participants had not had any contact beforehand with the domain, business context, and requirements of the IAGO project. For instance, when creating personas, an in-depth knowledge of the system's users is necessary, and the *ExACTa* participants did not have that expertise. Although the LI workshop does encourage collaboration among teams, it does not mention the kinds of knowledge each participant needs to have about the problem domain beforehand. The problem is defined in the first two activities, but it proved to be hard to follow for those who had never even been to an oil refinery.

The fourth activity was a brainstorming of product features, performed individually. Because of the first three stages, by then the *ExACTa* team had a deeper understanding of the problem. Every participant was able to come up with a few features during the brainstorming session, but the *Petrobras* representatives proposed more complex and specific features, due to their expertise in the field of oil refineries.

The fifth activity took the longest time and generated the most hesitation and uncertainty among participants. In this step, each participant must provide a score of how much each feature impacts: business, technical, and user experience (UX) aspects. Because the IAGO project is grounded in Research & Development, some of the features identified were not fully clear. For instance, one feature that generated a lot of debate was "Real-time inference of environmental issues". It was clear to participants what that feature meant: to predict the possibility of a person feeling odoriferous compounds from the plant. However, it was not clear how this would be done and what effort it would require, as it entails a potentially long research and experimentation period, with testing of different AI models. Therefore, in the dimension of technical impact, it received a score of three – the maximum score. The uncertainty behind that feature made it challenging to estimate its effort, and the LI workshop does not go into detail regarding complex features, commonly found in R&D projects.

Then, in groups, participants drew the user journey for each persona. The idea was to see how the identified features would be included in the tasks performed by each persona in their daily routines. This step was performed without any problems.

The next activity was the definition of a sequence of the identified features. This sequence would also help define the scope of the MVP. Because of all the issues left unanswered in the fifth activity, this one was also challenging. Many participants had different views regarding what needed to be delivered as the first MVP, and what features could be delivered as a second or even third MVP, but we came to a conclusion that the first MVP would encompass 17 features. Once the MVP was defined, we filled an MVP canvas with all the knowledge generated from the workshop. The canvas aimed to guide the conception and development stages that would follow.

3.3 Backlog Documentation (Azure DevOps)

After the LI, the next step in the Lean R&D approach is usually a workshop called Product Backlog Building (PBB) (Aguiar and Caroli, 2020). It helps to structure User Stories (US), which have a specific template for software requirements: “As a [role], I want [goal], so that [reason]” (Cohn, 2004). However, in the IAGO project, we were not able to conduct the PBB workshop because, as many hours had been spent in the LI workshop, the business representatives and potential users of the system were unable to participate in another workshop. Hence, the US definition was done by the *ExACTa* team, relying on the understanding and knowledge they had obtained in the LI workshop.

This generated a multitude of questions that needed to be answered. Although the PBB workshop was not conducted, daily informal meetings were held with customer representatives, who helped solve some of the emerging doubts. Still, new queries arose often, as the *ExACTa* team had no experience in the field of oil and gas refineries. Other issues were related to data gathering: to build a machine learning model, large amounts of structured data are necessary, and obtaining them took longer than first estimated when defining the MVP.

3.4 Prototype Design (Low and High-fidelity)

Once the product backlog was defined, the UX team started working on low-fidelity paper prototypes. Paper prototypes are fast and allow developers and designers to demonstrate the behavior of an interface very early in development (Rettig, 1994). We were only able to validate those prototypes with customer representatives from research and business areas, but not with real users. As real users work within refinery plants and are often occupied with surveying real-time environmental issues that may be happening, it is not practical to have frequent meetings with them. End-user participation occurred in two stages: to define the main features and characteristics of the first MVP; and to test and use the final product.

Hence, as other representatives from the customer side validated the proposed sketch of user interface (UI) and interaction design, the UX team moved on to designing high-fidelity prototypes to guide the developers involved in the IAGO project. This was done using Adobe XD[1], a UX/UI design collaboration tool.

The high-fidelity prototype was available online and was shared with the customers. Some of them left comments, which were then taken into account as new versions of the high-fidelity prototype were created. The UI was designed without a specific BI platform in mind, as no decisions had been made in that regard at that point.

3.5 Investigation of BI Platforms

Before the implementation stage, we had to choose a BI platform to host IAGO. Because of the experimentation nature of this project, we tested different platforms and found some limitations. We tried to replicate the high-fidelity prototype on these platforms, but encountered performance and usability issues.

We settled on Power BI, which was already used by *Petrobras*. The developers found its learning curve to be shorter than the other platforms’. We were able to reproduce the high-fidelity prototype with great similarity, which means that the UI had already been approved by the customer. The end users, however, had yet to test and evaluate the system. Their evaluation is described in Section 3.7.

3.6 Implementation

The implementation stage was performed in three simultaneous activities: (i) Data analysis and development of a machine learning model; (ii) Serverless architecture building; and (iii) Design and development of a dashboard. This paper focuses on the latter.

Figure 2 depicts IAGO’s user interface. IAGO supports two main goals: making decisions when dealing with an odor event, and preventing the odor event by analyzing historic data. With that in mind, we designed a 3-part dashboard: (i) the main visualization, which shows historic measurements of odoriferous compound; (ii) the “Cards” tab, which provides information about the possible causes for those measurements; and (iii) the “Inquiries” tab, which lists the registered inquiries or complaints from the community.

[1]https://www.adobe.com/products/xd.html

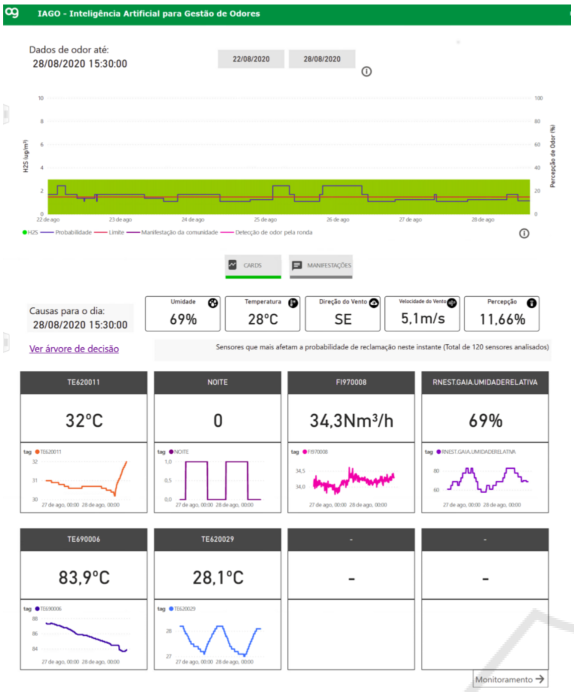

Figure 2: IAGO's interface.

The main visualization comprises a bar chart and a line chart. The bars represent the measure of the odoriferous compound over time. The bar colors can be green, yellow, or red. Green means the value of the measure of odoriferous compound is below an estimated threshold, yellow means it is close to the threshold or slightly above it, and red means it is way over the threshold. The line represents the probability of a person feel odoriferous compound, as calculated by the AI model.

Power BI provides a "Filters" tab, where the user can pick a date and time range that affects the whole dashboard. It is also possible to select a relative date range. By default, IAGO shows the data from the last 7 days, as of the current day.

Below the main visualization, there are two possible visualizations: "Cards" and "Manifestation". The "Cards" tab shows meteorological data and possible causes for the odoriferous compound measurement in a given time. These causes are the most important features selected by the AI model. Each cause is represented by its name, its description, its value in that given time, and also an associated line chart that shows the history of that value in a recent period. The "Manifestation" tab shows a table of registered manifestations in that time range, with attributes like location, intensity of the odor, whether it is plausible or not, and others.

3.7 System Evaluation

The evaluation was performed using an online questionnaire based on the Technology Acceptance Model (TAM) (Davis, 1989) and the Questionnaire for User-Interaction Satisfaction (QUIS) (Harper et al., 1997), which are questionnaires widely used in the literature to evaluate interactive systems.

Four users evaluated IAGO after at least 3 weeks of usage. Figure 3 depicts their answers in the questionnaire. For most of our analysis, we contrast the answers provided by P3 and P1, depicted in boldface in the chart, as they often had opposite opinions.

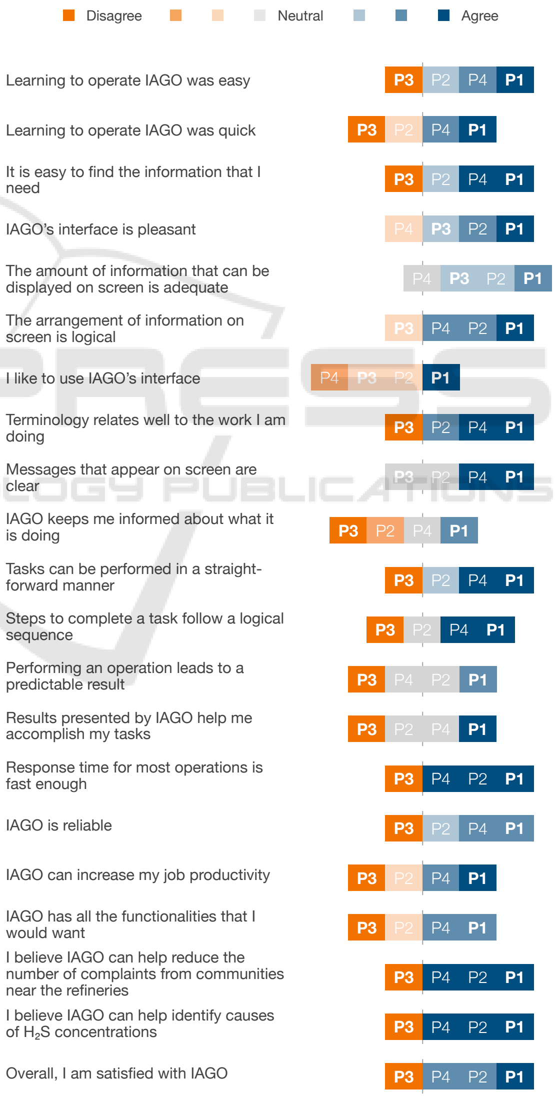

Figure 3: IAGO's evaluation.

Overall, it is clear that P3 had a negative standpoint, whereas P1 seemed to enjoy all aspects of the system. The questionnaire also featured open-ended questions, and we found that P3 will be working with system maintenance. P3 mentioned negative aspects regarding code documentation and lack of a manual to be used for maintenance. We believe P3's perspective may have been biased by their role, as they may had viewed dealing with IAGO as a burden.

P3 also mentioned that IAGO's main calculation should be different, but this was a functional requirement for the system decided by *Petrobras*. As the questionnaire responses were anonymous, we do not know the identity of P3, but it appears that they did not participate in the LI. As their role as system maintainer is crucial to the future of IAGO, they should have been included in the early conception phases and their input should have been heard. It seems like IAGO did not meet their expectations, and their inclusion in the LI might have avoided this issue and possible resentment towards the system.

By contrast, P1 agreed to most of the provided statements, *i.e.*, had a positive view of IAGO, claiming that "the interface is easy, logical, and organized; the information presented is adequate; and it allows filtering by specific periods". Although we cannot be sure, we tend to assume that P1 was present in the LI, as most of their expectations seem to have been met.

P2 and P4 seemed mostly positive in their responses, but not as strongly. There was some variation between positive, neutral, and negative opinions. Because their responses were not intense like P1's and P3's, we argue that they can use the system without major issues.

An interesting disparity found in the scores is related to the UI. Most participants stated they found the UI 'pleasant', but when providing scores for the statement "I like to use IAGO's interface", most answers were negative. This shows that, even though a design can "look nice", it may not be fully functional and meet the users' expectations in terms of usability. We argue that the lack of user involvement is the most probable cause for this problem, since we were not entirely aware of the end users' perspectives, needs, and values.

In general, most answers were positive. Nevertheless, there are clear issues with certain users and certain aspects of IAGO, which might have been prevented with the inclusion of users in the early conception phases. The design team played a sort of "guessing game", which worked to an extent, but the questionnaire results show that it was not enough and generated some user dissatisfaction.

3.8 Lessons Learned by Developers

We interviewed three developers from the *ExACTa* team involved in the IAGO project. Each interview lasted about two hours. During the interviews, participants discussed negative and positive points, detailing what worked and what did not work in each LI activity, which is the foundation for identifying the project's requirements. Participants also provided observations about the Lean R&D process overall. After conducting the interviews, we performed a qualitative analysis adopting some Grounded Theory (GT) procedures, especially coding, *i.e.*, the process of assigning meaning to data (Corbin and Strauss, 2007). We identified the following categories of lessons learned: Expectation alignment, Collaboration between teams and stakeholders, Feature identification, Generated requirements, User interface conceptualization, and Importance of end-user participation.

Expectation Alignment. The developers agreed that, during the LI, the objective of aligning expectations was achieved. In addition, participants mentioned that several activities of the LI helped align the objectives about the software to be created.

Collaboration between Team and Stakeholders. Because of the informal nature of the LI, the participants felt comfortable to collaborate and to contribute to the discussions: "The process felt laid-back and people were comfortable to express themselves" - P1. The LI activity that most contributed to the collaboration between participants was the brainstorming of product features.

Feature Identification. This item is related to the previous ones, as the alignment of the expected objectives and the ability to speak freely felt by the participants allowed for efficient feature identification. The persona technique helps to see features from the point of view of end users. The user journey helps identify the context of use. After identifying the features, the LI has an activity to help prioritize them, which is the business, technical, and UX review. Despite the developers' perception that this step helps prioritize the features, some aspects of the activity are not clear. Participants have only a general idea of the features and of the product goal, so there is not enough information to provide an accurate estimate of needed effort. Therefore, to reduce the lack of detail, for future projects, we will plan thorough meetings to help the development team get more business knowledge before the LI workshop. This way, the workshop will focus more on aligning the project's goals and on prioritizing features than on understanding requirements.

Generated Requirements. After the LI, several meetings were conducted to elicit requirements and to perform validations with the stakeholders. To facilitate system maintenance, *Petrobras* decided that the dashboard platform should be low-code. This was settled after the LI in meetings with the customers, but no decisions were made regarding what specific tool should be used. As continuous experimentation suggests, different platforms were tested and we settled on Power BI. However, there were issues with the transition between platforms: "We had to migrate the entire database in the middle of the project, and the deadline was too tight. Some decisions were made without proper deliberation, because of time constraints." - P1.

User Interface Conceptualization. This step had positive and negative aspects, since the platform to be used for the UI had not been chosen when the UI was designed. Due to the low-code nature of BI platforms, the development team could not follow the UI design proposal created earlier by the UX/UI team. To work with the platform limitations, the UX/UI team proposed a new UI design that would work with the defined platform. The UI prototypes helped the developers understand the requirements, acting as a foundation for the software development. In future projects, when working with a low-code platform, it is imperative that both developers and designers know its potential and limitations.

Importance of End-user Participation. The developers' participation in the workshop helped them get an idea of how important end users are when understanding the problem to be solved by the final software product. However, because there were no actual end users in the LI, only end-user representatives – like their managers –, the team struggled to define the requirements. To help mitigate the lack of end-user participation in the LI, after implementing the UI, we held meetings with end users to validate the final software. The users were also asked to create, weekly, a list of adjustments that should be made to improve usability. To minimize rework after the software implementation, it is important to ensure that at least one end user participates in the LI workshop.

4 DISCUSSION

The Lean R&D approach leaves some aspects underspecified. In this section, we review these aspects, some of which were highlighted by the interviews with the development team.

Before the LI, which marks the beginning of the project, there should be a conversation with domain specialists. The IAGO project focuses on a very specific part of oil refineries, which were new to the *ExACTa* team working on the project. If there had been a knowledge-sharing event prior to the LI, the technical team would have been able to participate in the discussions much more efficiently.

The end users were also not present in most of the project, participating only in a few meetings and testing the final product. Although certain approaches and techniques such as User-Centered Design (Abras et al., 2004) state the importance of having the user involved throughout the design and development process, the Lean R&D approach does not clearly specify how and when the end user, or other stakeholders, should participate. As the IAGO project was one of the first projects using the approach, it became clear that end-user involvement should be non-negotiable in future projects when planning some workshops and meetings, especially during the LI, where the requirements start taking shape. Also, as discussed by Lárusdóttir et al. (2014), the lack of distinction in many agile processes between customers and end users can cause a false sense of user involvement: although customers were present in the LI, there were no actual users of the final product in the workshop and throughout most of the project. This problem became apparent in the system evaluation questionnaire results.

One of Lean R&D's building blocks is "strategically aligned continuous experimentation to test business hypotheses". We argue that, besides business hypotheses, it is also imperative to study and evaluate user needs so that the final product is valuable to both the company and the end user. With users involved from the start, their opinions, preferences, values, and feedback can help shape the product into something they can incorporate into their daily routine.

Lean R&D is grounded in agile, continuous experimentation, which allows solution options to "fail fast". However, it is important to make sure that the team views these "failures" as a natural part of the experimentation process, not as problems. In the IAGO project, when platform limitations were found and evaluated, the team felt discomfort in having to switch platforms, but this type of change is welcome and expected in Lean R&D. Thus, the team's mindset should be prepared for these types of situations, which are normal and acceptable in research and development projects which feature great deals of uncertainty.

Nonetheless, despite failures being a part of continuous experimentation, it is essential that changes be communicated and validated with the stakeholders. When there was a switch in BI platforms in the IAGO project, there had to be confirmation that the chosen platform would be approved for deployment within the company. This depends on a clear alignment between the technical team, the business representatives of the customer side, and the IT department on the customer side. This communication network is crucial for Lean R&D projects to work. For solutions to be delivered in an agile way, there must be an alignment among all stakeholders.

5 CONCLUSIONS

Through our experiences, interviews with developers, and usability data from questionnaires with end users, we have learned interesting lessons from applying Lean R&D in an industry-academia collaboration in the oil and gas field, specifically in the IAGO project.

We found that not only communication with all stakeholders is crucial for this type of agile collaboration, but also, in particular, end-user involvement is key to avoid misunderstandings and rework. Because of the short cycles with frequent deliveries and the experimentation nature of the process, it is important to continually evaluate the evolving solution with the end users and customers and keep all parties informed about changes in the project.

When following the Lean R&D approach in the future, we plan to schedule early knowledge-sharing meetings about the domain, so that all participants in the LI workshop will be able to make well-informed decisions and elicit features and requirements that are valuable to both the business and the end users.

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