Interreg Sudoe
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Report on THE END-USER participation process

Partner Responsible
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UNIVERSITÉ TOULOUSE III PAUL SABATIER · POLITÉCNICA INTERNATIONAL CAMPUS OF EXCELLENCE · Ciências ULisboa · cise Electromechatronic Systems Research Centre · UNIVERSIDADE BEIRA INTERIOR · La Rochelle Université · Funseam Fundación para la Sostenibilidad Energética y Ambiental · circe RESEARCH CENTRE FOR ENERGY RESOURCES AND CONSUMPTION · CTA

The A2.5 “Users energy behaviour” consists of:

- Development of applications to communicate with users
- Implementation of participatory protocols
- Definition of user cohorts
- Data collection (does not require any activity from participants)
- Analysis of results and recommendations

1. Introduction

The objective is to study how users' behaviour can change in relation to their consumption and, consequently, to involve users in the co-design of solutions.
On the one hand, we conducted a study to collect the views of campus users on the basis of innovative equipment and, *on the other hand, the implementation of a system to predict user behaviour for better energy efficiency in intelligent b*uildings.

This activity was carried out at ULR and UT3. It is divided into several sequential tasks:

- Task 1: from T0 to T10 Development of applications to communicate with users, Implementation of participatory protocols.
- Task 2: from T11 to T14 Configuration of user cohorts
- Task 3: from Q15 to Q22 Data collection
- Task 4: from Q23 to Q29 Analysis of results and recommendations.

Stakeholders and how they are involved in this activity:

Campus end-users, such as students and staff working on campus, will participate in this experiment with the support of specific equipment dedicated to this activity. Researchers are involved in the analysis of the results. Campus managers will be involved in sharing the results.

This report is the second report of this activity. While the first report concentrated on Tasks 1 to 3 and stated the first analysis and recommendations in Task4, the current reports extend ends the previous one by proposing and designing the tool that would be used in order to detail and implement the foreseen recommendations to influence user behavior for better energy efficiency in intelligent buildings.

2. Task 4: Analysis of results and recommendations

The analysis of the results shows us that several types of end-users are in the university. Some of them which are in majority: students are not aware of the university functioning and they don't take care of the energy consumption in the campus. The other type of users includes students and university staff who are, on the contrary, well aware of the issues related to energy consumption in the university's missions.
They strongly ask to have more information about the university.
In this part of the report, we suggest a recommendation system with an application layer for user interaction, in order to predict and influence the user behaviour for better energy efficiency in intelligent buildings. To get started, we define a set of objectives based on the insights from previous tasks. Then, following a UX design approach, we clarify the product vision, targeted user personas, and the possible usage scenarios for each of them. Finally, we conclude with the implementation aspect of the project, and some screenshots of the final products.

Key goals and considerations

Our system's main objectives are threefold:

1. Improve tenants' comfort and well-being: The main goal of the project is to improve the collective well-being of tenants of university buildings and offices. The idea is to determine a consensus of behaviors to increase overall user satisfaction, which is determined by how close users come to their desired comfort levels.
2. Reduce energy consumption: A tradeoff with the first objective is energy consumption, as most forms of user comfort usually result in an excess of energy consumption (e.g., being too warm in winter or too fresh in summer). The system aims to achieve a moderate comfort level with minimal energy consumption.
3. Ensure data protection and privacy: As with any component of IT, there is no exception to the rule of data protection and security. The clearest example is the case of heating and ventilation management. For such a system, it is necessary to track the presence, absence or long-term absence of the people occupying the university's offices. This data is in fact sensitive, and that requires protection of its access with an authentication system that only allows its corresponding entity to access it.

Requirements identification & analysis

Starting from the objectives above, we identify any functional constraints related to the project. We indeed opted for classical methods for this phase of collecting information. In particular, survey forms were sent to the laboratory employees, the objective is to have a clear vision of potential needs that our system should take into consideration.

Functional specifications

The answers from the conducted survey provided us with key insights on the expectations of our potential users. Essentially, we figured that our front-end layer would consist of multiple applications targeting three possible user profiles: tenant, maintainer, and manager.

First, a mobile app will be needed for office tenants to monitor the collected data from their workplace in real-time and to receive relevant recommendations to achieve comfort with minimal energy consumption. The same application should allow tenants to report any anomaly or failures regarding the physical sensors of their office. The reported failures from tenants will be received through a second application, dedicated to maintenance technicians to keep track of physical devices health and their intervention tasks. Lastly, we must provide a dashboard for management, allowing them to have control over the system. By managing different user types, permissions, sensors, offices, and buildings.

User stories

For a better understanding of our system, we dive into the details of the aforementioned specifications by formulating them into a set of user stories according to the agile SCRUM methodology.

Management

- The system must allow the manager to accept new occupants registered in the system. The system shall allow the manager to delete an occupant.
- The system shall allow the manager to block an occupant. The system shall allow the manager to add technicians.
- The system shall allow the manager to add buildings.
- The system must allow the manager to add rooms in buildings.
- The system shall allow the manager to add sensors in a given room.
- The system shall allow the manager to update sensors of a given room.
- The system shall allow the manager to add tenants to a given room.
- The system shall allow the manager to change tenants of a given room.
- The system shall allow the manager to view reports made by tenants.

Tenant

- The system shall provide real-time recommendations to tenants.
- The system shall allow tenants to provide feedback on the received recommendation.
- The system shall provide real-time temperature and humidity statistics.
- The system shall allow the tenant to report any failures in the system and its sensors.
- The system shall allow the tenant to report anomalies related to the integrity of data.
- The system shall allow the tenant to modify their profile.
- The system shall allow the tenant to change their password.
-

Maintainer

- The system shall allow the technician to update the status of a sensor (from failure to working).
- The system shall send notifications to technicians in the event of sensor failure.
- The system shall allow the technician to register a newly added sensor.
- The system shall allow the technician to view buildings and their rooms.
- The system shall allow the technician to change their password.

Functional Design

For the design of the different applications of our system, we relied on flow diagrams to have a clear idea of how the user experience should be.

Manager dashboard

The manager's dashboard gives control over the different settings of the app. After successful login with the provided admin credentials, the manager will be able to perform several actions on the different entities of the system. The typical process starts by visiting the page of the entity (e.g., sensors, users, buildings), from that page they may visualize the list of the existing items, add others, update an item's detail, or archive/delete one or more items. Furthermore, some actions may subsequently lead to others; when trying to add an office for instance, the manager will be prompted with a page to add potential tenants to the office if there exist any. The manager will also be able to update system

settings through a dedicated page and may finally choose to disconnect and end the process [Figure 2].

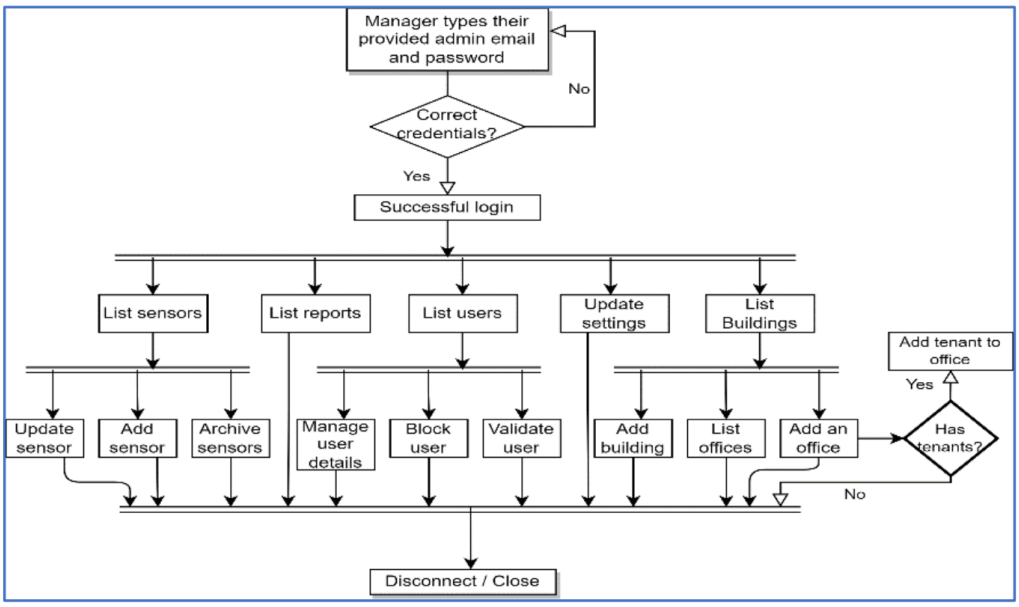


Figure 2. Flow diagram for manager app

Tenant application

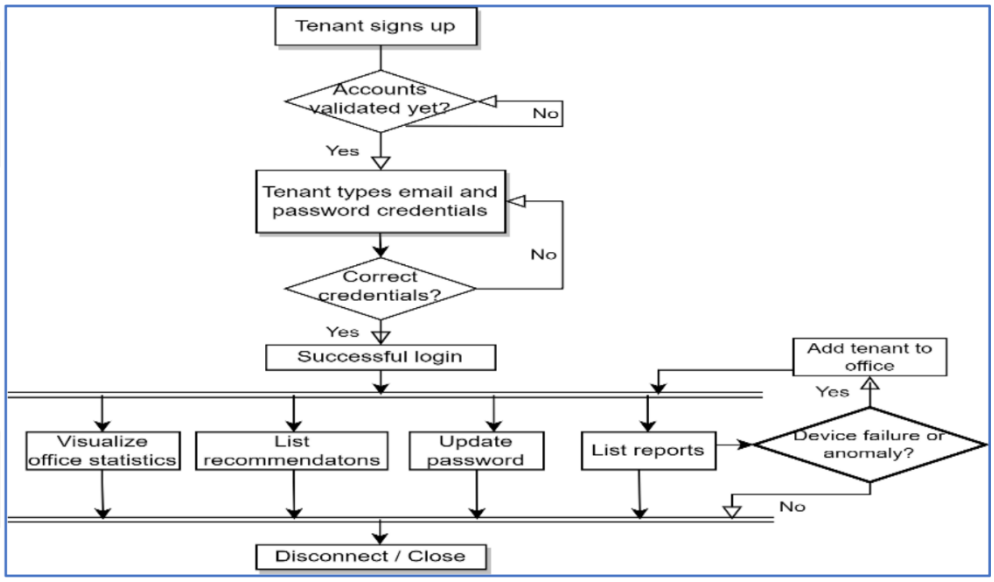


Figure 3. Flow diagram for tenant's app

As illustrated in [Figure 3], A standard workflow of a tenant using their dedicated application must start with a sign-up and a validation process (from the admin side). Once an account is created and validated, the user will be able to connect to the application

using their email and password. This will allow the user to access the application features; like check received recommendations, checking usage statistics, report anomalies, or to disconnect again from the app.

Maintainer application

After successful login, the user (maintenance agent) will be presented with a list of all user reports sorted by date of creation. From that list, the user can see the necessary details about the anomaly so they can plan their intervention. A second process concerns the management of sensor deployment operations, it can be accessed from a second page where the user can see information about existing sensors and register new ones that they have successfully deployed [Figure 4].

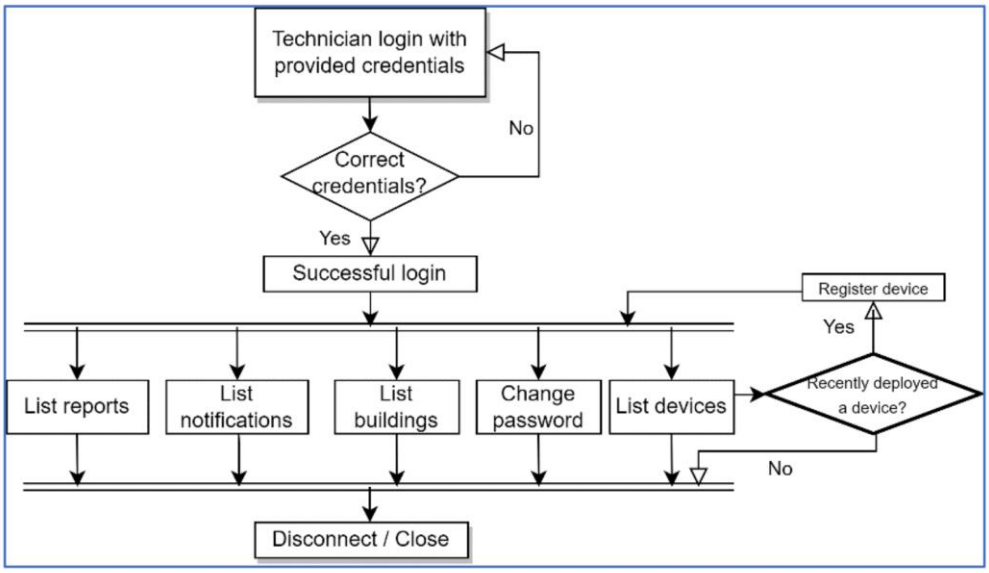


Figure 4. Flow diagram for maintainer's app

Implementation

This final part of this task concerns the implementation aspect of the application layer.

Technology choice

There's a myriad of modern technologies to build user frontends. In order to choose, we had to keep in mind our business constraints. Mainly, we want a technology that allows rapid development and prototyping, must be easily maintainable, and that doesn't require a paid license to use.

We ended up choosing Flutter, which is an open-source framework created by Google, and which we found very adequate for these key reasons:

- **Underlying language:** Flutter is based on Dart, which is a programming language that is designed and optimized for front-end development, code written in this language can be easily compiled into any of the popular platforms (Web, Android, IOS). Dart is a robust language; it supports null safety, which reduces errors, speeds development time, and reduces application crashes.
- **Development time:** this becomes significantly reduced compared to coding the same UI components several times with each device's particular languages (Swift for IOS, Kotlin for Android, and HTML/CSS/JS for web apps).
- **Community:** Flutter is an open-source software, which means that it's free to use, but also means it's made, maintained, and adopted by a huge community of developers from around the globe, it's in fact one of the most active developer communities online and that makes finding documentation, solving bugs, or suggesting improvements very straightforward.

Final Product

In this section, we present some screenshots from the final products, taken respectively from the manager's dashboard [Fig 5-7], tenant's application [Fig 8-10], and finally the maintainer's application [Fig. 11-12].

Manager's dashboard

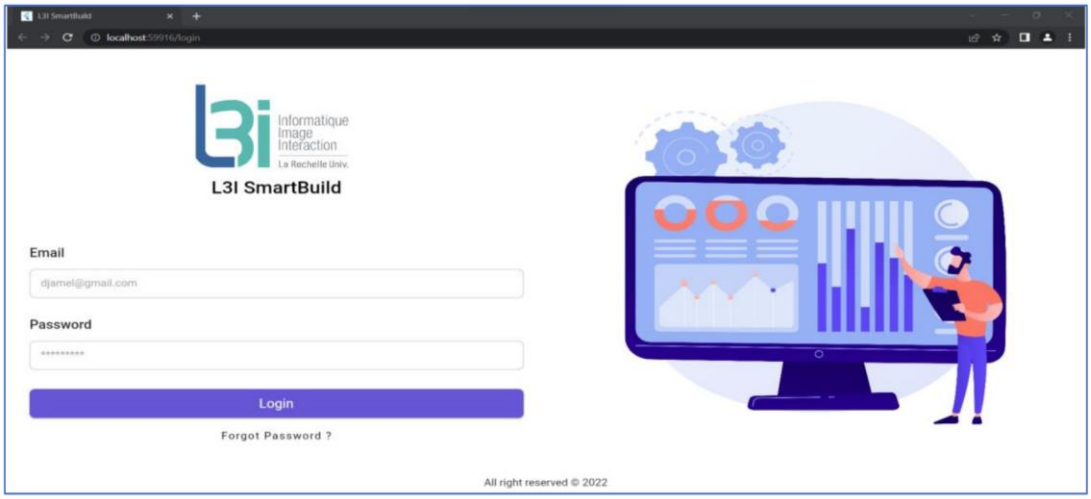


Figure 5. Manager's dashboard - login page

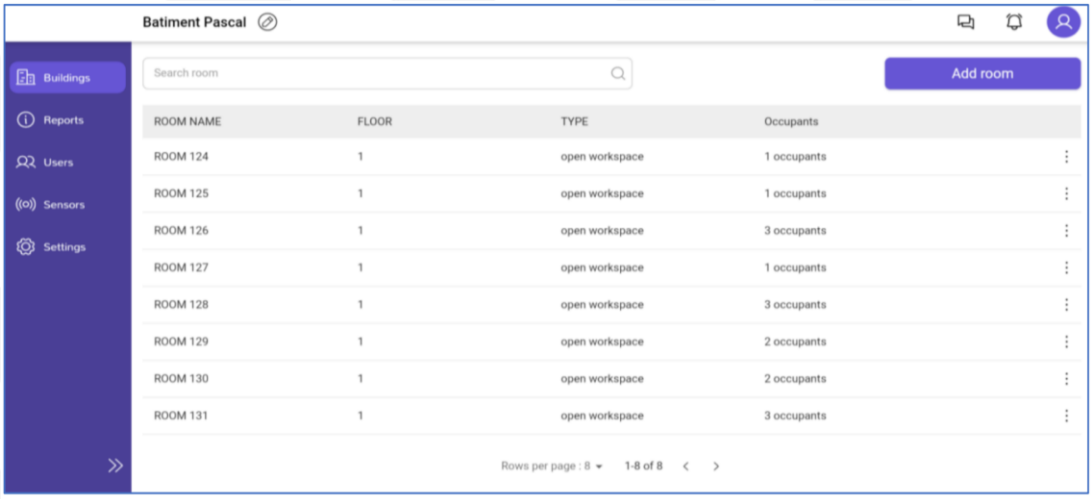


Figure 6. Manager's dashboard - offices list

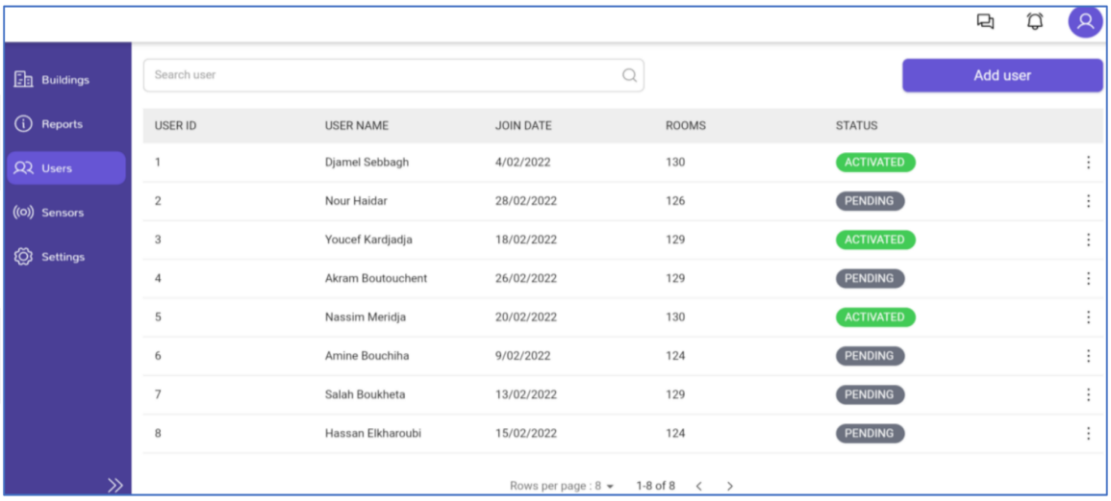


Figure 7. Manager's dashboard – User's list

Tenant's application

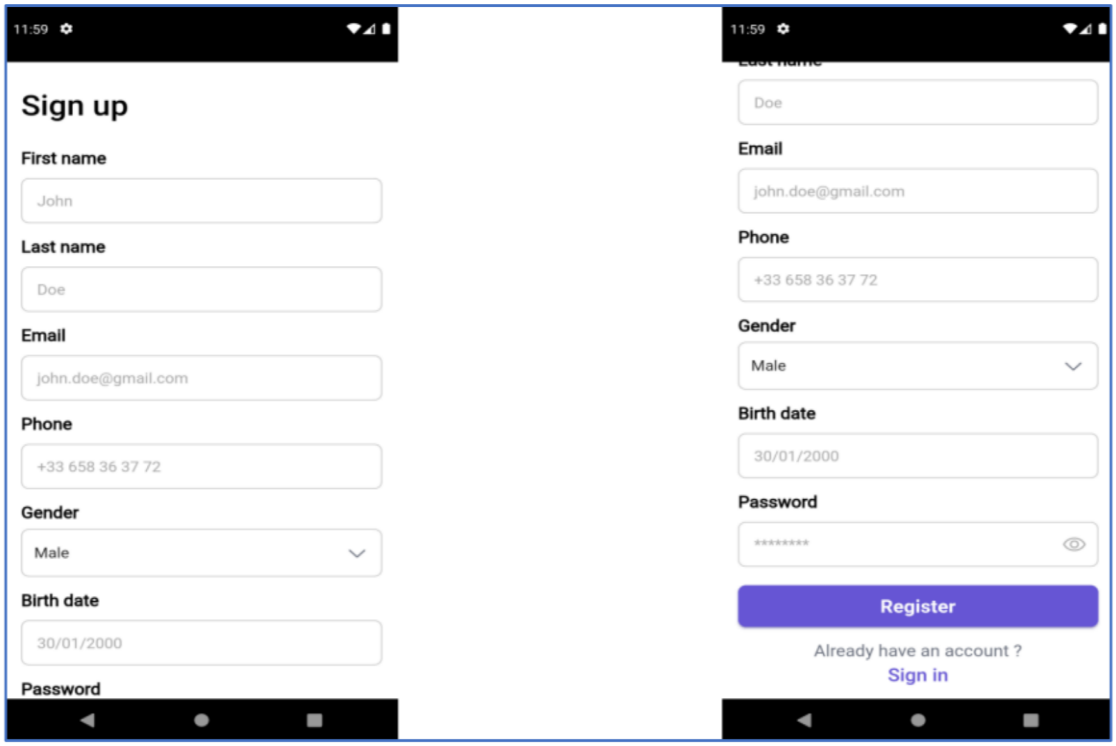


Figure 8. Tenant's app - sign up pages.

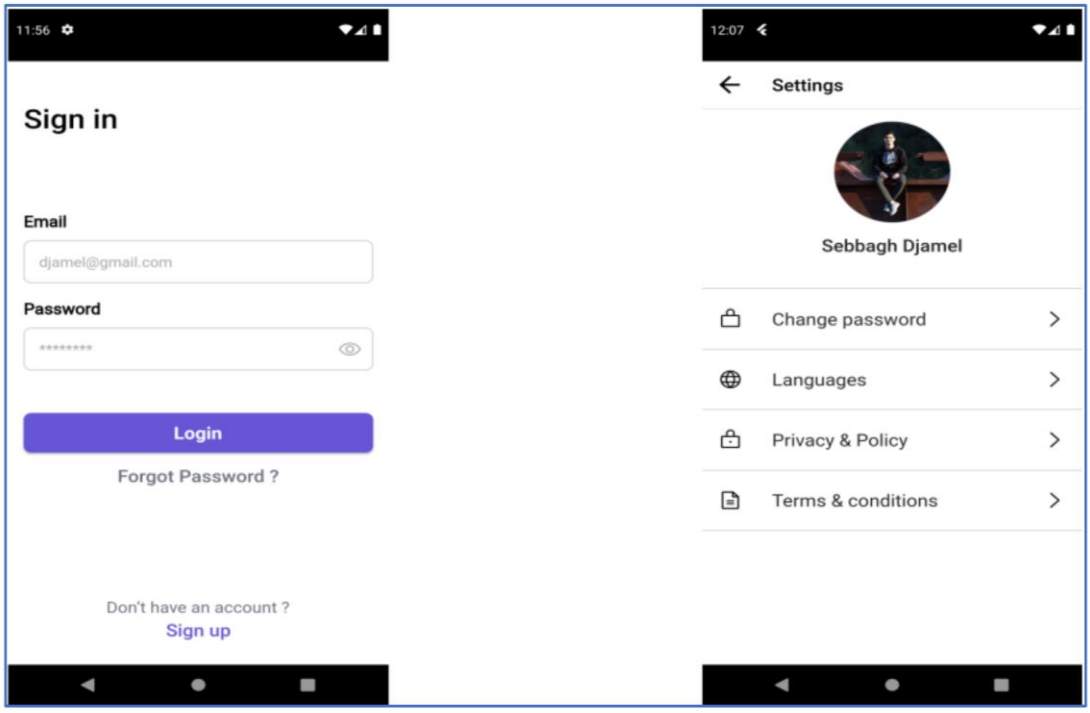


Figure 9. Tenant's app - Login page and main menu.

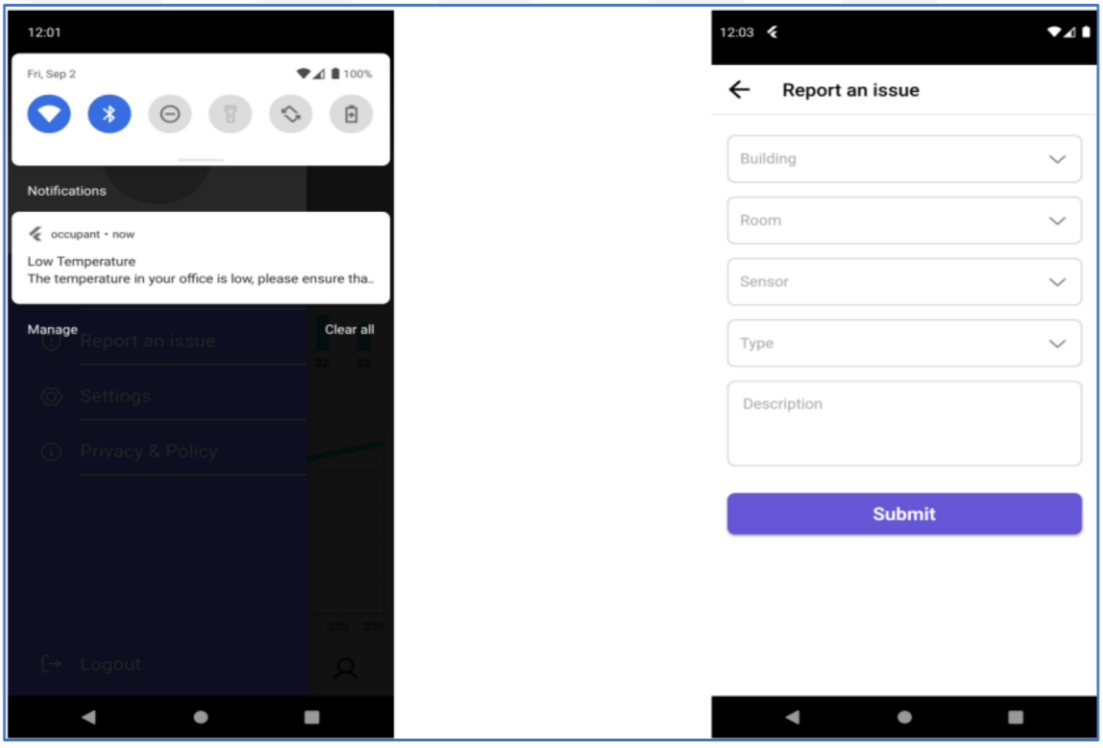


Figure 10. Tenant's app - Notifications and Reporting

Maintainer application

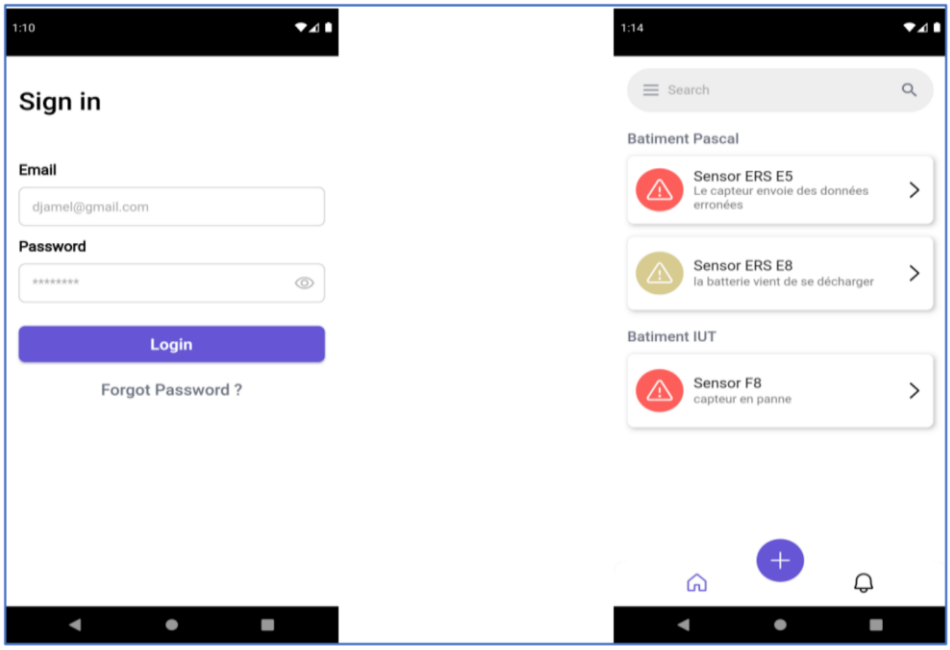


Figure 11. Maintainer's app - Login and Reports

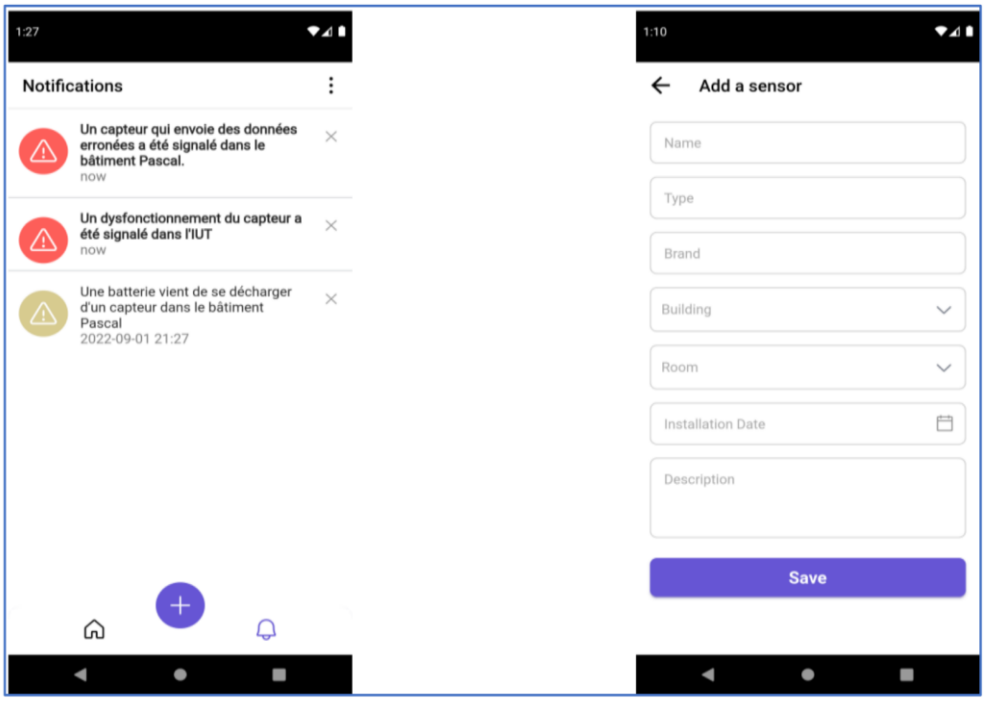


Figure 12. Maintainer's app - Notifications, Device registration

Experiments and evaluation

Our objective is to evaluate the acceptability, the acceptance, the user experience and the ergonomics of the HMI. Through this study we aim to:

1. Assess the adoption of the product (its rejection or use) and obtain an estimate of the acceptability of the system.
2. Evaluate the user experience (UX) and the ergonomics of the HMI

Definitions

- Acceptability (before use): prospective judgment towards a technology or tool before usage.
- Acceptance (after use): judgment and behavioral reactions towards a product after usage.

Framework

This experimental study will be done in two steps: the first one is essentially focused on the evaluation of the acceptability of the recommendation system by the building occupants. The goal is to have an estimation on their willingness to use the system. For this first step, we use a mock-up of the mobile application as it is not yet deployed. Furthermore, a second part of this study will focus on the evaluation of the usefulness, usability and aesthetics of the system's GUI (UX and ergonomics). It will be conducted using the real application after the first release.

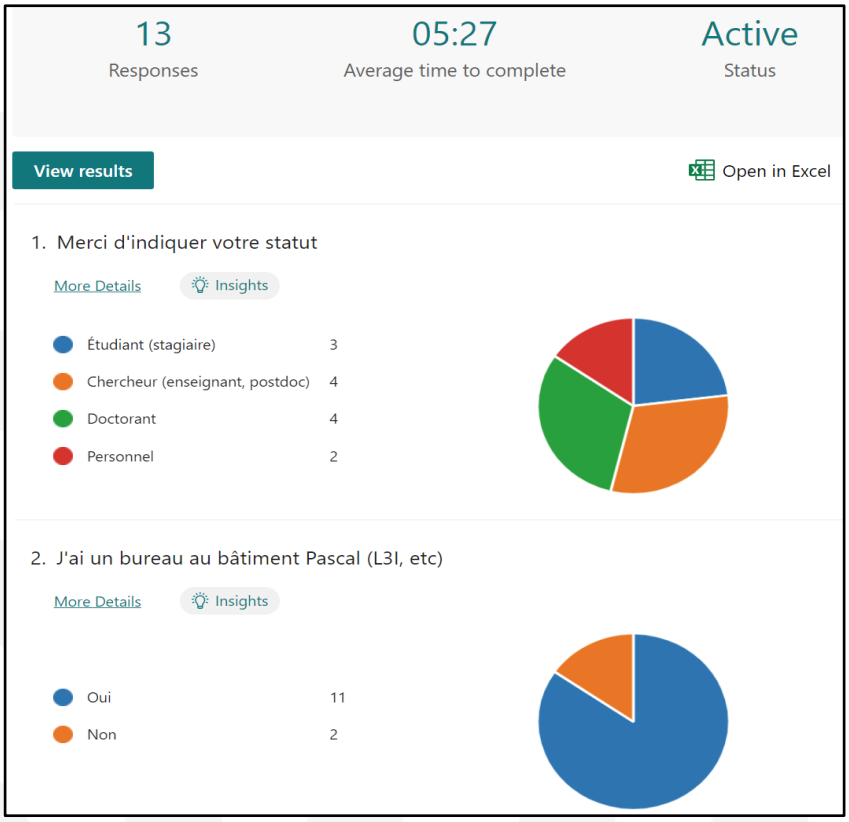
Experimental protocol #1 (first part):

We are interested in evaluating the acceptability of a mobile application that is never used before. The sensitive thing here is that the core operation of the system requires exploitation of sensory data collected from personal offices of the building occupants. The deployed sensors are :

- Window and door opening detectors
- HVAC (heating or air conditioning) temperature sensor
- Humidity sensor
- Brightness sensor
- Movement sensor (used to detect user presence).

We provide the participants with a brief presentation of the system and a video that shows its usage (a simulation). Furthermore, we present the participants with a mock-up of the application with an explanation of its content and operation. At the end, the participants will be able to take the questionnaire and give their opinions.

The participants of the survey are mostly office occupants in the La Rochelle University building “Pascal” Av. Michel Crépeau 17000 La Rochelle, France. These occupants can be professors, researchers/engineers, PhD students in research internships, or administrative staff.



The provided prototype to the participants was made with *Balsamiq Wireframes*. It represents the dashboard page of the recommendation system.

Videos scenarios

1. Too much humidity in the office.
    - User (office occupant) working inside their office.
    - Environment: blinds open, doors and windows closed, lights on, ideal temperature.
    - User receives notification on the phone: *"Caution! Room with high humidity, you need to air the room!"*
    - User follows the recommendation by opening windows and doors.
    - After a while, the app shows an improvement in humidity levels.
2. Light left open in absence of occupant.
    - User (occupant) shuts off the computer, and prepares to leave their office.
    - Environment: blinds open, doors and windows closed, lights on, ideal temperature.
    - User leaves the office and closes the door.
    - New environment: empty office / blinds open, doors and windows closed, lights on, ideal temperature.

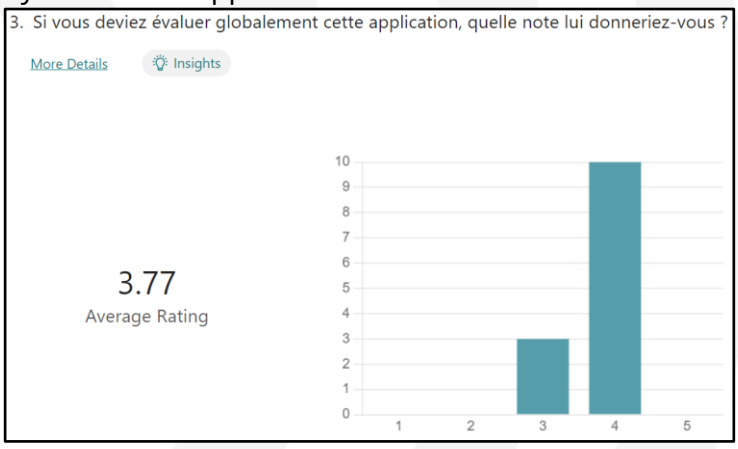
- User receives notification on the phone few moments after leaving the office:
  "Caution! Lights were left ON, you need to turn them off!"
- User follows the recommendation by going back to the office and turning the lights off.

Questionnaire

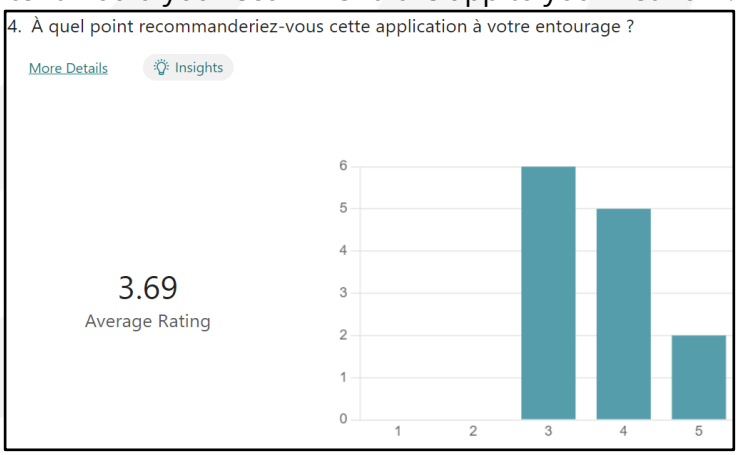
The questions set up are based on TAM and UTAT questionnaires. These are established models that aim to explain the factors of the adoption of technological products and to have better explanations of the usage intentions.
For this evaluation we will rely on the following variables: perceived usefulness, usability degree, overall appreciation, intention of use, motivation to use, social influence and trust.
The questions attempt to answer the following variables:

Overall appreciation (answers on rating-type scale)

1. How would you rate the application overall?

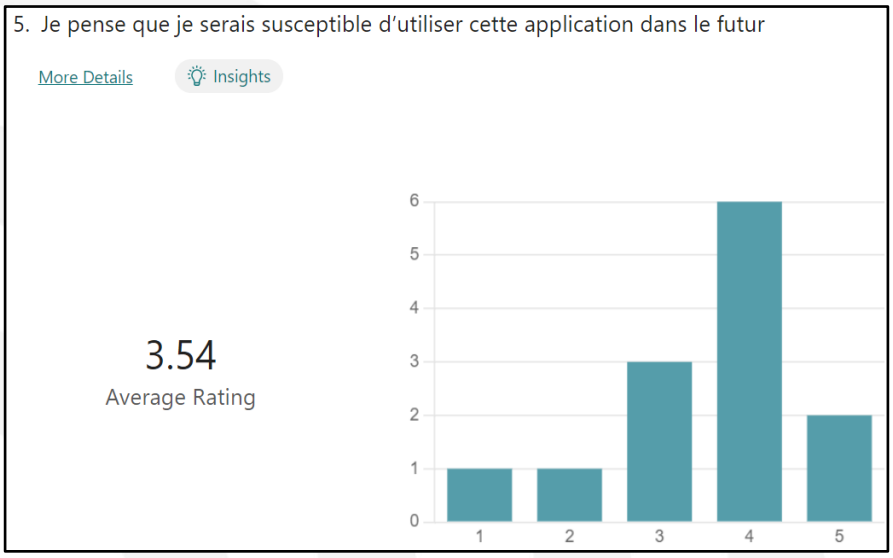


2. To what extent would you recommend the app to your network?



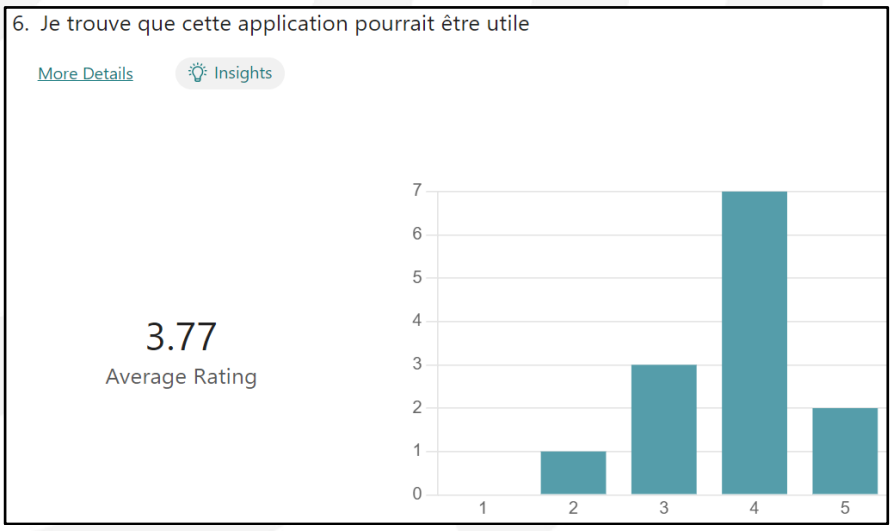
Intended use (answers in a Likert-type 5 points scale going from "strongly disagree" to "strongly agree")

3. I intend to use such an application in the future if available

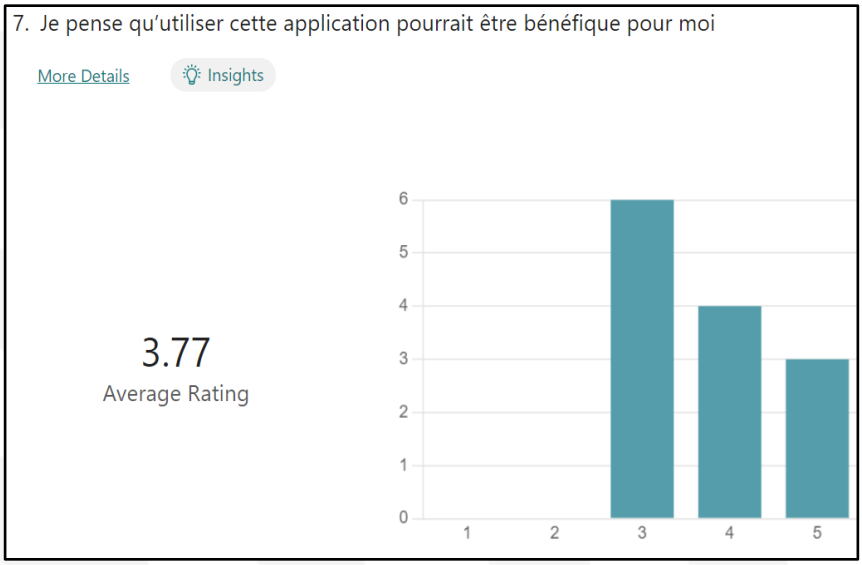


Perceived usefulness

4. I believe that this application can be useful for some people

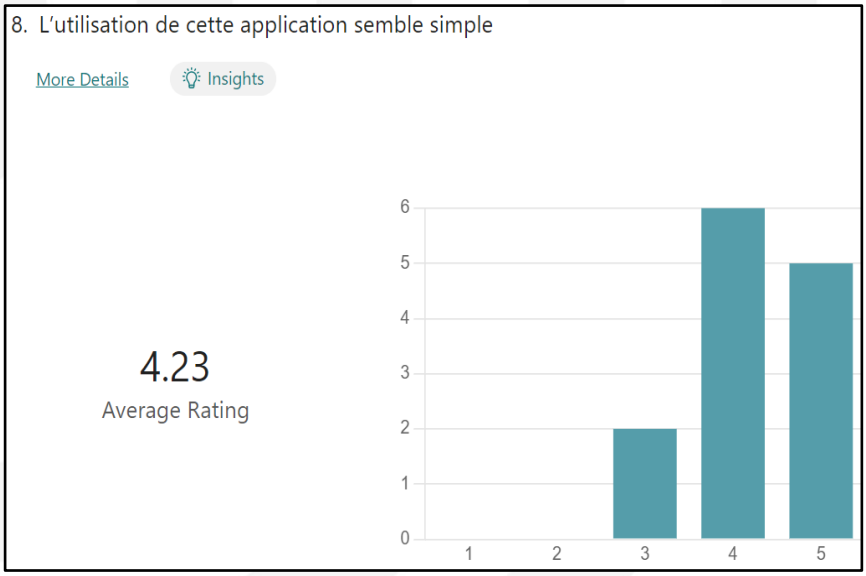


5. I believe that this application can be useful to me



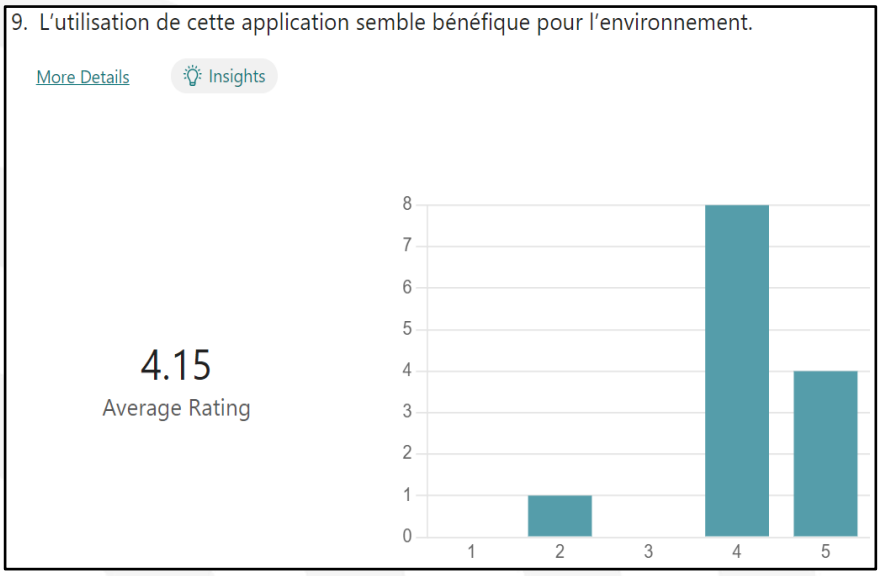
Perceived usability degree

6. Using this application seems simple to me

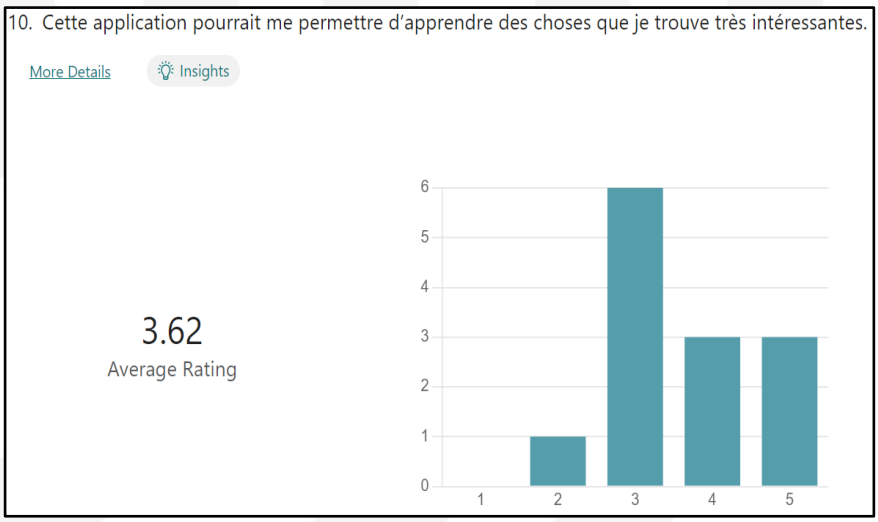


Motivation to use

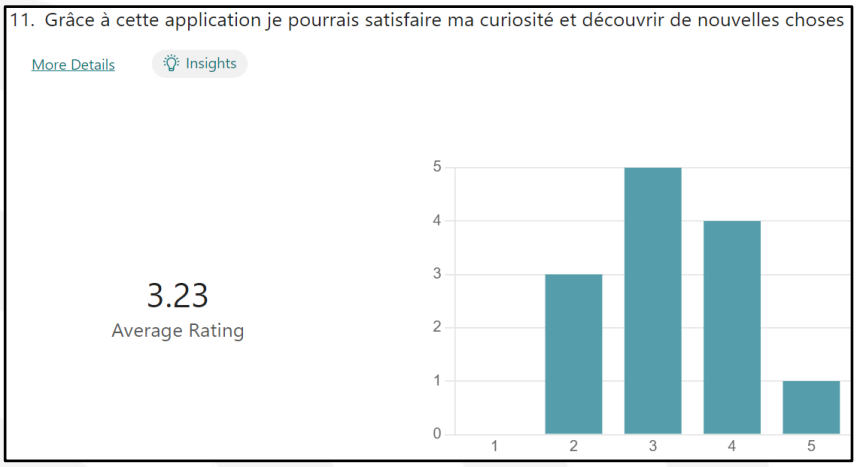
7. Using this application can be beneficial for the environment



8. This application could help me learn new interesting stuff

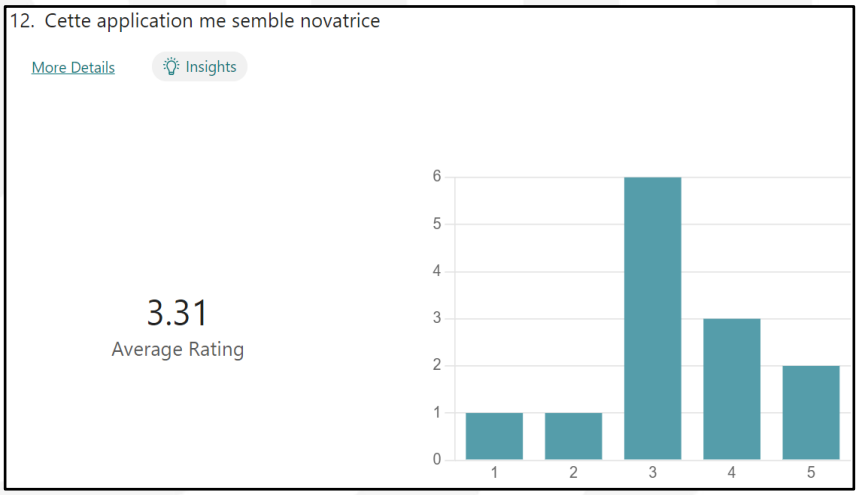


9. This application could help me discover things that I'm curious about in relation to my work environment



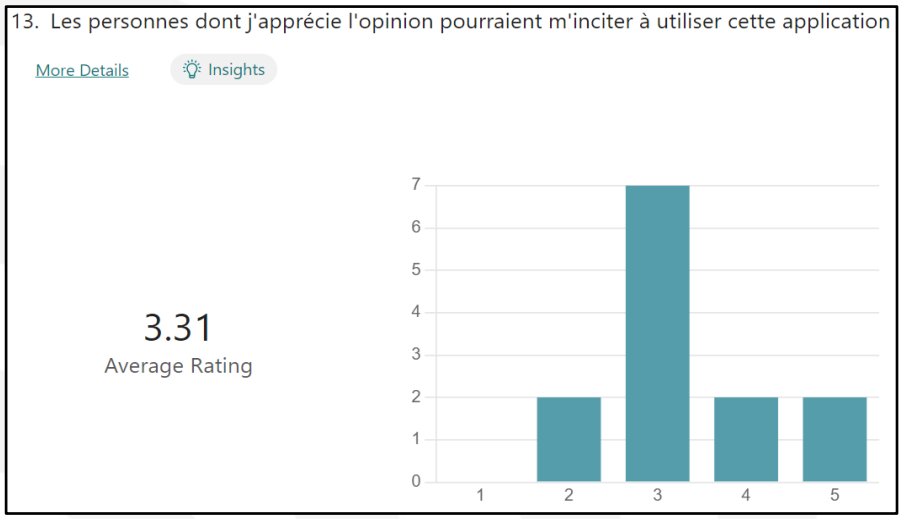
Enthusiasm

10. I find this application innovative



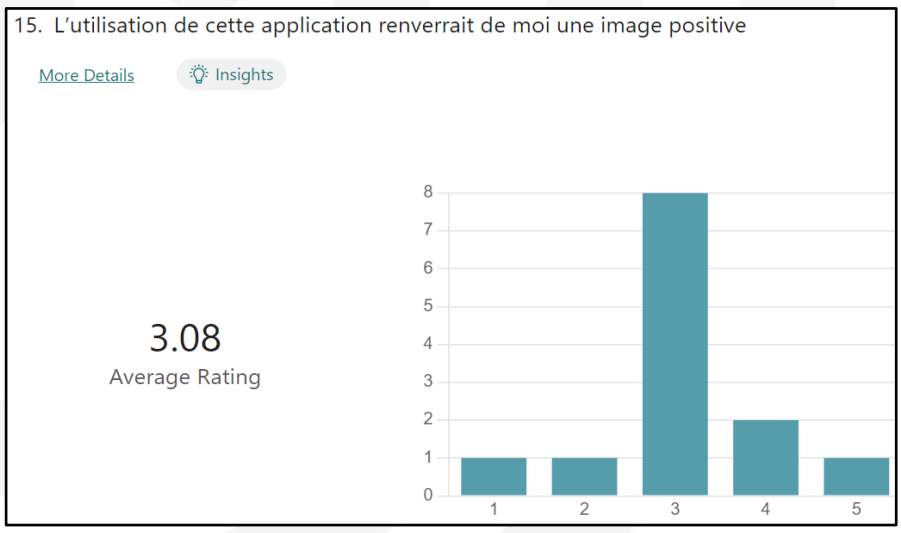
Social Influence

11. I think the people whose opinion I value would convince me to use this app

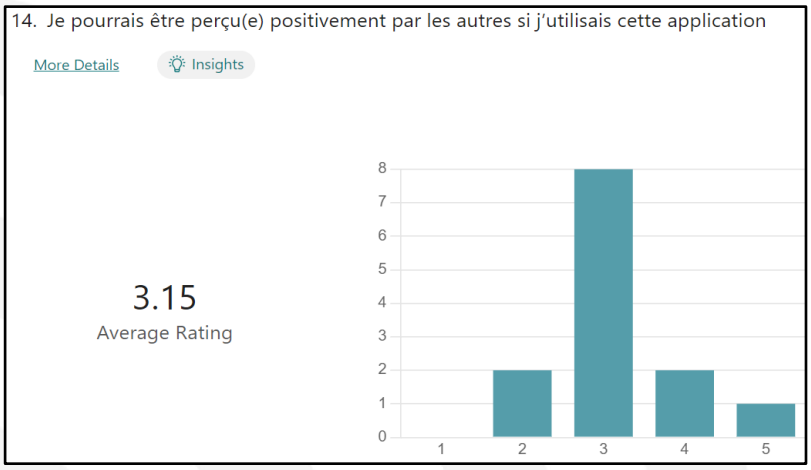


Personal image

12. Using this application would give me a more positive image about myself

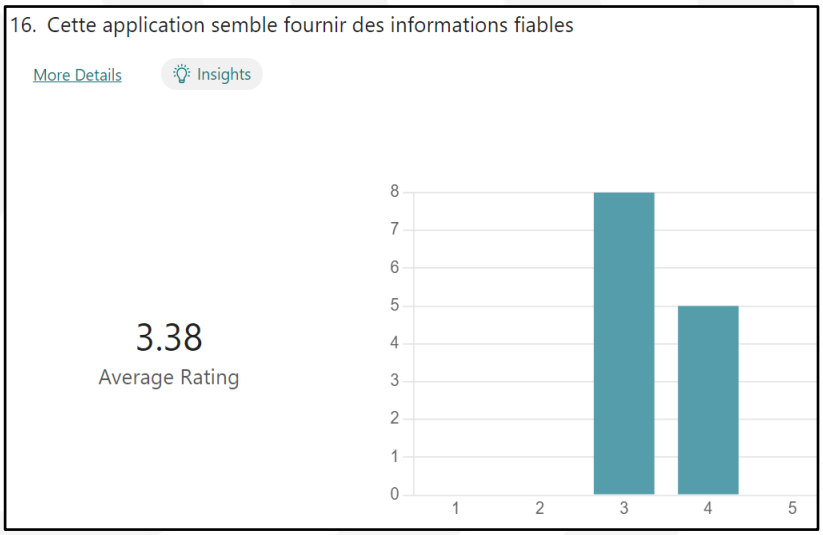


13. Using this application would make a more positive image of myself in other people's minds

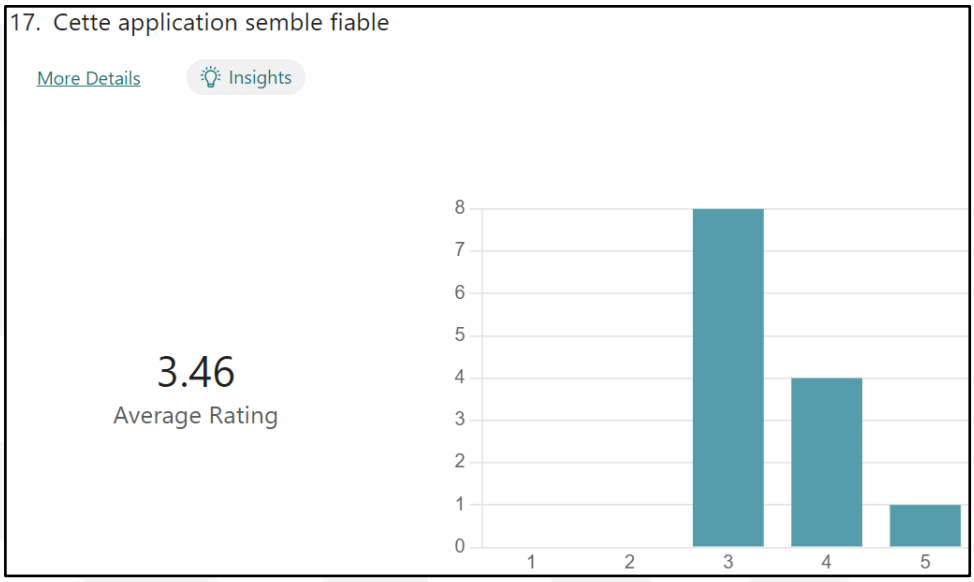


Trust

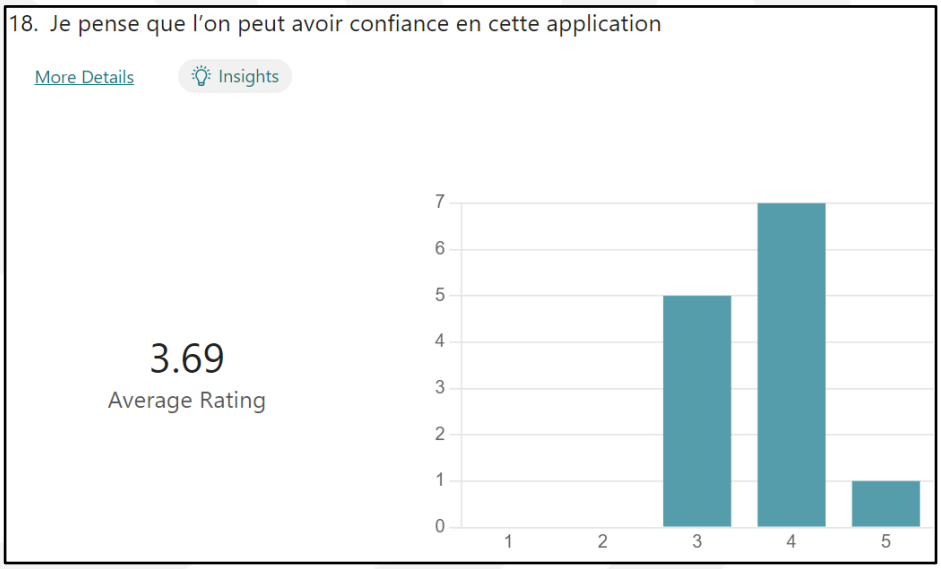
14. I think this application would give correct information



15. I think this application is reliable



16. I think that we can trust this application



Analysis

Overall, most survey participants seemed to share a good appreciation of the app (77% rated 4/5 in question 1). But tended to become slightly less enthusiastic when it comes to recommending it to their network (46% answering 3/5). A majority of participants also expressed that they might use this app in the future (61%*).

For the practical side of the app, many participants think it can be useful to them (54%*), but more of them are certain it can be useful for others (69%*). That being said, the majority still agrees that the application is simple to use according to the provided mockups (85%*). From an environmental perspective, all but one participant seemed to agree that the application can be useful for the environment. Furthermore, a portion of participants thought that such an application could help them learn interesting facts (48%*) or discover new things about their surroundings (39%*), but the majority seemed to be neutral on both questions, giving them both an average rating of 3.62 and 3.23 respectively.

More than half of the participants had divergent opinions about the innovative aspect of the app, and the other half remained neutral, which ended up giving that question a 3.31 rate on average. This applies as well to a similar degree for the following questions targeting social reputation and how they feel perceived after using the application.

Finally, most participants didn't seem to have strong opinions on the reliability or the correctness of the information provided by the app, but gave more positive opinions on how trust-worthy it is (62%*).

(*) aggregation of all opinions in range (e.g., sum of participants answering 4/5 and those answering 5/5).

Useful links

1. First scenario video (high humidity office): **https://youtu.be/_2FkG6iUxmA**
2. Second scenario video (Lights left ON): **https://youtu.be/q1OJOT6FXno**
3. Link to online form sent to (and to send to future) participants: **https://forms.office.com/e/13PViTjwPe**

Summary

In this report and based on the initial study conducted and reported in the previous report of this activity, we presented here an application layer of a recommendation system aiming to help the users in adapting their behaviors to reduce their energy consumption in intelligent campus buildings and offices while keeping their thermal comfort at a good level. Thanks to the insights from previous tasks, different user profiles were identified and presented, as well as their user stories, and potential activity flow within the application. An evaluation of the acceptability, the acceptance, the user experience and the ergonomics of the HMI related to this application layer had also been conducted in order to assess its usage within intelligent campuses.