THE RESEARCH PROMOTION FOUNDATION PROGRAMMES FOR RESEARCH, TECHNOLOGICAL DEVELOPMENT, AND INNOVATION

RESTART 2016 – 2020

Pillar	I. Smart Growth
Programme	CO-DEVELOP
Project Acronym	Green-HIT
RIF Project Number	CODEVELOP-ICT-HEALTH/0322/0135
Proposal Title	A Green - Holistic IoT platform for Forest Management and Monitoring
Project Coordinator	Frederick Research Center (FRC)
Work Package Number	WP7
Work Package Title	Green-HIT platform Integration and Pilot Studies
Deliverable Number	D7.1
Deliverable Title	Testing and Validation Methodology

Dissemination level		
PU	Public	X
CO	Confidential, only for members of the consortium (including RIF)	

Funded by the European Union NextGenerationEU

Cyprus tomorrow RECOVERY AND RESILIENCE PLAN

Republic of Cyprus

AUTHORS

Author	Institution	Contact (e-mail, phone)
Giorgos Tsapparellas	**CyRIC**	g.tsapparellas@cyric.eu
Antonis Hadjiantonis	**CyRIC**	a.hadjiantonis@cyric.eu

DOCUMENT CONTROL

Document version	Date	Change
v0.1	15/01/2024	Draft
v1.0	31/01/2024	Pre-Final
v2.0	28/02/2024	Final Version

Executive Summary

This document presents the development of a robust testing and validation methodology for the Green-HIT platform. Through collaborative efforts, the methodology outlines systematic procedures, tools, success criteria, and reporting mechanisms essential for thorough evaluation. It encompasses testing of the sensing end-nodes (including custom), UAVs, LoRaWAN gateways, LoRaWAN network server, cloud platform, back-end system (including APIs), web dashboard, smartphone application, and intelligence modules, addressing critical aspects such as accuracy, performance, usability, and interoperability. By adhering to this methodology, Green-HIT ensures the reliability and effectiveness of its environmental monitoring and management platform, laying a strong foundation for successful deployment and utilization.

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1. Introduction

The success of the Green-HIT platform hinges on its robustness, functionality, and user-friendliness. To ensure these vital aspects, a concrete testing and validation methodology must be established. This document outlines the task aimed at defining such a methodology, which will serve as guidelines for technical partners and enable thorough evaluation from both technical and user perspectives. It entails creating a testing plan focusing on various platform components and selecting appropriate testing approaches, considering Green-HIT as a holistic platform.

2. Testing and Validation Methodology

Developing a methodology involves creating a structured approach for testing and validation. This document serves as a comprehensive guide detailing the step-by-step process for conducting tests. It outlines specific techniques, tools, and criteria to be utilized, ensuring consistency and reliability throughout the testing phase. The methodology defines the scope of testing, delineating which aspects of the platform will undergo evaluation and the methodologies to be employed for each. Clear success criteria are established, providing measurable benchmarks for determining test outcomes—whether they pass or fail. Additionally, the methodology specifies robust reporting mechanisms to document test results, track identified issues, and facilitate necessary follow-up actions. This ensures that the testing process is well-documented and transparent, enabling effective communication and collaboration among project stakeholders.

3. Technical and User-Oriented Evaluation

Ensuring both technical and user-oriented aspects are evaluated is crucial for a comprehensive assessment of the Green-HIT platform. Technical evaluation focuses on assessing the platform's functionality, performance, security, and compatibility. This involves rigorous testing to verify that the platform operates as intended, exhibits optimal speed and efficiency, safeguards data against vulnerabilities, and seamlessly integrates with other systems and devices such as sensing end-nodes and intelligent modules. On the other hand, user-oriented evaluation delves into aspects such as usability, accessibility, satisfaction, and inclusivity. Through user feedback, usability testing, and accessibility assessments, the platform's ease of use, suitability for diverse user needs, and overall user satisfaction are gauged. By considering both technical and user-oriented evaluation criteria, the testing process ensures that the Green-HIT platform meets the needs and expectations of all stakeholders.

4. Testing Plan Establishment

Formulating a testing plan involves developing a detailed strategy to systematically test each component of the platform. This plan outlines the types of tests to be conducted, such as unit testing, integration testing, system testing, and acceptance testing. It identifies the specific methodologies and tools to be utilized for each type of test, ensuring comprehensive coverage and accurate evaluation. The testing plan also defines the test environments, including development, staging, and production environments, to simulate real-world scenarios. Additionally, it specifies the data sets to be used for testing, ensuring that test scenarios represent a diverse range of conditions and use cases. By establishing clear expected outcomes for each test scenario, the testing plan provides a roadmap for conducting tests and evaluating the platform's performance against predefined criteria.

5. Holistic Platform Approach

Adopting a holistic platform approach involves considering Green-HIT as a unified entity rather than a collection of disparate components. This approach emphasizes the interconnectivity and interoperability of different modules and components to ensure seamless integration and overall performance. By assessing how various parts of the platform interact and complement each other, potential issues or bottlenecks arising from component interactions can be identified and addressed proactively. The holistic platform approach also enables a comprehensive evaluation of the platform's overall effectiveness in achieving its objectives. By evaluating the platform as a whole, rather than in isolation, the testing methodology ensures that all components work seamlessly together to deliver value to stakeholders and effectively address environmental and forest management challenges.

6. Testing and Validation Metrics

As stated in the previous sections “2. Testing and Validation Methodology”, “3. Technical and User-Oriented Evaluation”, “4. Testing Plan Establishment” and “5. Holistic Platform Approach”, this section outlines possible evaluation metrics that will be investigated for assessing the performance and functionality of the sensing end-nodes (including custom), UAVs, LoRaWAN gateways, LoRaWAN network server, cloud platform, back-end system (including APIs), web dashboard, mobile application, and intelligence modules within the Green-HIT project.

Sensing end-nodes evaluation metrics:

1. **Sensor Measurement Accuracy:** The precision and reliability of sensor measurements in capturing environmental data such as temperature, humidity, co2, etc.
2. **Power Consumption:** The energy efficiency of the sensing end-nodes to ensure prolonged operation without frequent battery replacements or recharging.
3. **Bidirectional Communication:** The effectiveness of communication between the sensing end-nodes and the cloud platform, ensuring seamless data transmission and reception.
4. **LoRaWAN/Satellite Signal Reception:** The ability of the sensing end-nodes to transmit/receive LoRaWAN/Satellite signals reliably, considering factors such as signal strength and interference.

LoRaWAN gateways evaluation metrics:

1. **Gateway Range Coverage:** Evaluate the coverage area of LoRaWAN gateways by measuring the signal strength and range in different environments (urban, rural, indoor, outdoor).
2. **Gateway Reliability:** Assess the reliability of LoRaWAN gateways by monitoring the uptime and availability of gateway connections over a specified period.
3. **Gateway Interference Resistance:** Test the resistance of LoRaWAN gateways to interference from other wireless devices or environmental factors, ensuring uninterrupted communication.
4. **Gateway Throughput**: Measure the data throughput of LoRaWAN gateways to determine their capacity for handling simultaneous transmissions from multiple end-nodes.
5. **Gateway Scalability:** Evaluate the scalability of LoRaWAN gateways by testing their ability to support an increasing number of connected end-nodes without degradation in performance.
6. **Gateway Security**: Assess the security features implemented in LoRaWAN gateways to safeguard against unauthorized access and data breaches.

LoRaWAN network server evaluation metrics:

1. **Network Reliability:** Evaluate the reliability of the LoRaWAN network server by monitoring the successful delivery of messages between end-nodes and the cloud platform.

2. **Network Latency:** Measure the latency of the LoRaWAN network server in processing and routing messages, ensuring timely delivery of data.
3. **Network Security:** Assess the security protocols implemented in the LoRaWAN network server to protect against unauthorized access, data tampering, and denial-of-service attacks.
4. **Network Scalability:** Evaluate the scalability of the LoRaWAN network server by testing its ability to handle an increasing number of end-nodes and messages without degradation in performance.
5. **Network Integration:** Assess the compatibility and ease of integration of the LoRaWAN network server with other components of the Green-HIT platform, such as the cloud platform and data analytics modules.
6. **Network Monitoring and Management:** Evaluate the monitoring and management capabilities of the LoRaWAN network server, including real-time status updates, performance metrics, and remote configuration options.

UAVs evaluation metrics:

1. **Flight Ability:** Assessment of both manned and autonomous flight capabilities, including manoeuvrability, stability, and responsiveness to commands.
2. **Power Supply:** The adequacy and reliability of power sources ensuring uninterrupted operation during flight missions.
3. **Environmental Protection:** Protection mechanisms to safeguard the UAVs from environmental factors such as weather conditions, temperature variations, and physical obstacles.

Cloud platform evaluation metrics:

1. **Payload Decoder Optimization and Functionality:** The efficiency and accuracy of payload decoding algorithms to process and interpret sensor data received from the sensing end-nodes.
2. **Bidirectional Communication:** The reliability and responsiveness of communication between the cloud platform with the sensing end-nodes (and LoRaWAN gateways), facilitating real-time data exchange and command execution.

Back-end system evaluation metrics:

1. **Scalability:**
    - The system's ability to handle increased load and data volume without significant degradation in performance.
    - The ease of scaling API endpoints to accommodate growing application demands. This includes evaluating the ability to handle concurrent requests and maintain consistent performance.

2. **Performance:** The speed and responsiveness of database queries, API responses, and CMS interactions. This can include metrics like response time, throughput, and latency under different load conditions.
3. **Reliability:** The system's reliability in terms of uptime and availability. Metrics can include mean time between failures (MTBF), mean time to recovery (MTTR), and overall system uptime percentage.
4. **Security:** The effectiveness of security measures implemented, including encryption, access controls, and protection against common vulnerabilities like SQL injection and cross-site scripting (XSS).
5. **Usability of CMS:** The ease of use and intuitiveness of the CMS interface for managing content and configurations. This can include metrics related to user satisfaction, task completion time, and error rates during content management tasks.
6. **Interoperability:** The ability to integrate with other systems and services. This includes assessing compatibility with different programming languages, data formats, and communication protocols.
7. **Compliance:** Adherence to relevant industry standards, regulations, and best practices for data privacy, security, and accessibility. This can include compliance with standards like GDPR.

Web dashboard and smartphone applications evaluation metrics:

1. **User Interface (UI) and User Experience (UX):** The overall usability and user satisfaction, measured using the UEQ (User Experience Questionnaire) approach to gather insights into users' perceptions and experiences with the platform. The corresponding questionnaire is included in ANNEX 1.
2. **Responsiveness and performance:** Speed and responsiveness across different devices and screen sizes. This includes measuring loading times, rendering performance, and responsiveness to user interactions.
3. **Security**: The effectiveness of security measures implemented to protect sensitive data and prevent unauthorized access. Metrics can include compliance with security standards, encryption of data in transit and at rest, and access controls.
4. **User Engagement:** User engagement metrics such as active users, session duration, and retention rate. This provides insights into how effectively the platform retains and engages users over time.
5. **Battery and Resource Usage**: The impact of the smartphone application on device battery life and resource usage. Metrics can include CPU and memory usage, as well as battery drain rate during typical usage scenarios.

Intelligence modules evaluation metrics:

1. **Accuracy**: The proportion of correctly classified instances among all instances evaluated. It provides a general measure of the model's correctness.

2. **Precision**: The proportion of true positive predictions among all positive predictions made by the model. It measures the model's ability to avoid false positives.
3. **Recall (Sensitivity):** The proportion of true positive predictions among all actual positive instances in the dataset. It quantifies the model's ability to identify all relevant instances.
4. **F1 Score**: The harmonic mean of precision and recall, providing a balanced measure of a model's performance. It helps evaluate a model's overall effectiveness.
5. **Inference Time**: The time taken by the model to make predictions on new, unseen data. It reflects the efficiency of the model during deployment.
6. **Resource Consumption:** The amount of computational resources, such as memory and CPU utilization, required for inference tasks. It helps assess the scalability and practical feasibility of deploying the model in production environments.

A reporting template for the Testing and Validation (Table 1) of the Green-HIT platform is provided below. This template should be duplicated and used by all project partners for each "Testing Component".

	Testing Component	Type of test	Test environment	Other Components	Pass/Fail
1	Sensing end-nodes	Unit Testing/ Integration Testing/ System Testing/ Acceptance Testing	Development/ Staging/ Production	LoRaWAN gateways/ LoRaWAN NS/ Cloud platform/ Back-end system/ Web dashboard/ Mobile application/ Intelligence modules	Pass/Fail
2	LoRaWAN gateways	Unit Testing/ Integration Testing/ System Testing/ Acceptance Testing	Development/ Staging/ Production	Sensing EN/ LoRaWAN NS/ Cloud platform/ Back-end system	Pass/Fail
3	LoRaWAN network server	Unit Testing/ Integration Testing/ System Testing/	Development/ Staging/ Production	Sensing EN/ LoRaWAN gateways/ Cloud platform/	Pass/Fail

		Acceptance Testing		Back-end system	
4	UAVs	Unit Testing/ Integration Testing/ System Testing/ Acceptance Testing	Development/ Staging/ Production	Sensing EN/ Cloud platform/ Back-end system/ Web dashboard/	Pass/Fail
5	Cloud platform	Unit Testing/ Integration Testing/ System Testing/ Acceptance Testing	Development/ Staging/ Production	Sensing EN/ LoRaWAN gateways/ LoRaWAN NS/ Back-end system/ Web dashboard/	Pass/Fail
6	Back-end system	Unit Testing/ Integration Testing/ System Testing/ Acceptance Testing	Development/ Staging/ Production	Sensing EN/ LoRaWAN gateways/ LoRaWAN NS/ UAVs/ Cloud platform/ Web dashboard/ Mobile application/ Intelligence modules	Pass/Fail
7	Web dashboard	Unit Testing/ Integration Testing/ System Testing/ Acceptance Testing	Development/ Staging/ Production	Sensing EN/ UAVs/ Back-end system/ Cloud platform/ Intelligence modules	Pass/Fail

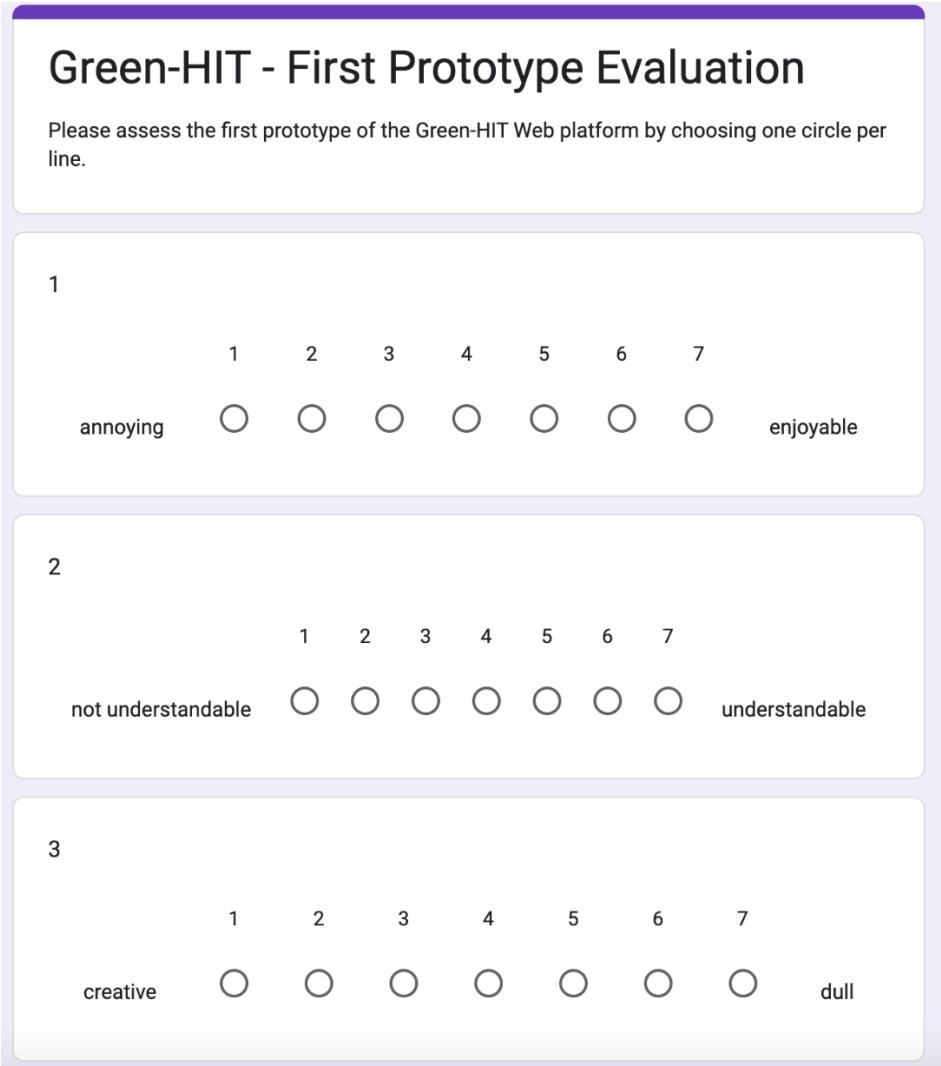
8	Smartphone application	Unit Testing/ Integration Testing/ System Testing/ Acceptance Testing	Development/ Staging/ Production	Sensing EN/ Cloud platform/ Intelligence modules	Pass/Fail
9	Intelligence modules	Unit Testing/ Integration Testing/ System Testing/ Acceptance Testing	Development/ Staging/ Production	Sensing EN/ Back-end system/ Cloud platform/ Web dashboard	Pass/Fail

***Table 1**: Testing and Validation for Green-HIT project.*

7. Conclusions

In conclusion, the development of a robust testing and validation methodology for the Green-HIT platform is crucial for ensuring its reliability, functionality, and effectiveness. Through collaborative efforts, the methodology provides a structured framework encompassing systematic procedures, tools, success criteria, and reporting mechanisms for thorough evaluation across various components, including sensing end-nodes, UAVs, LoRaWAN gateways, LoRaWAN network server, cloud platform, back-end system, web dashboard, mobile application, and intelligence modules. By addressing critical aspects such as accuracy, power consumption, communication effectiveness, signal reception, reliability, scalability, security, and usability, the project ensures the platform's reliability and effectiveness, laying a strong foundation for successful deployment and utilization. With a holistic approach that considers both technical and user-oriented evaluation criteria, the methodology facilitates thorough assessment from various perspectives, contributing to the development of a robust and effective platform that meets the diverse needs of stakeholders and supports sustainable forest management practices and environmental conservation efforts. Continued adherence to the testing and validation methodology will be essential as the project progresses to ensure the platform's continued reliability, functionality, and effectiveness.

ANNEX 1



Green-HIT - First Prototype Evaluation

Please assess the first prototype of the Green-HIT Web platform by choosing one circle per line.

1

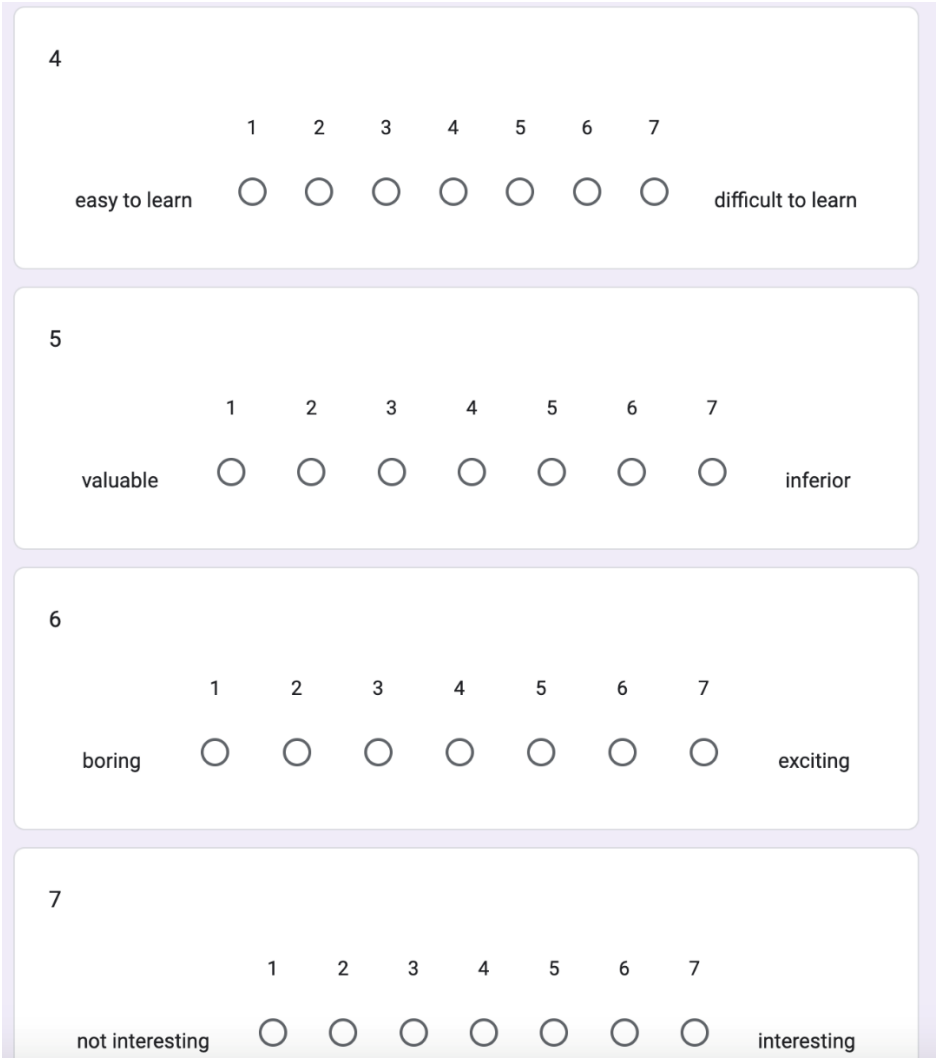
	1	2	3	4	5	6	7	
annoying	○	○	○	○	○	○	○	enjoyable

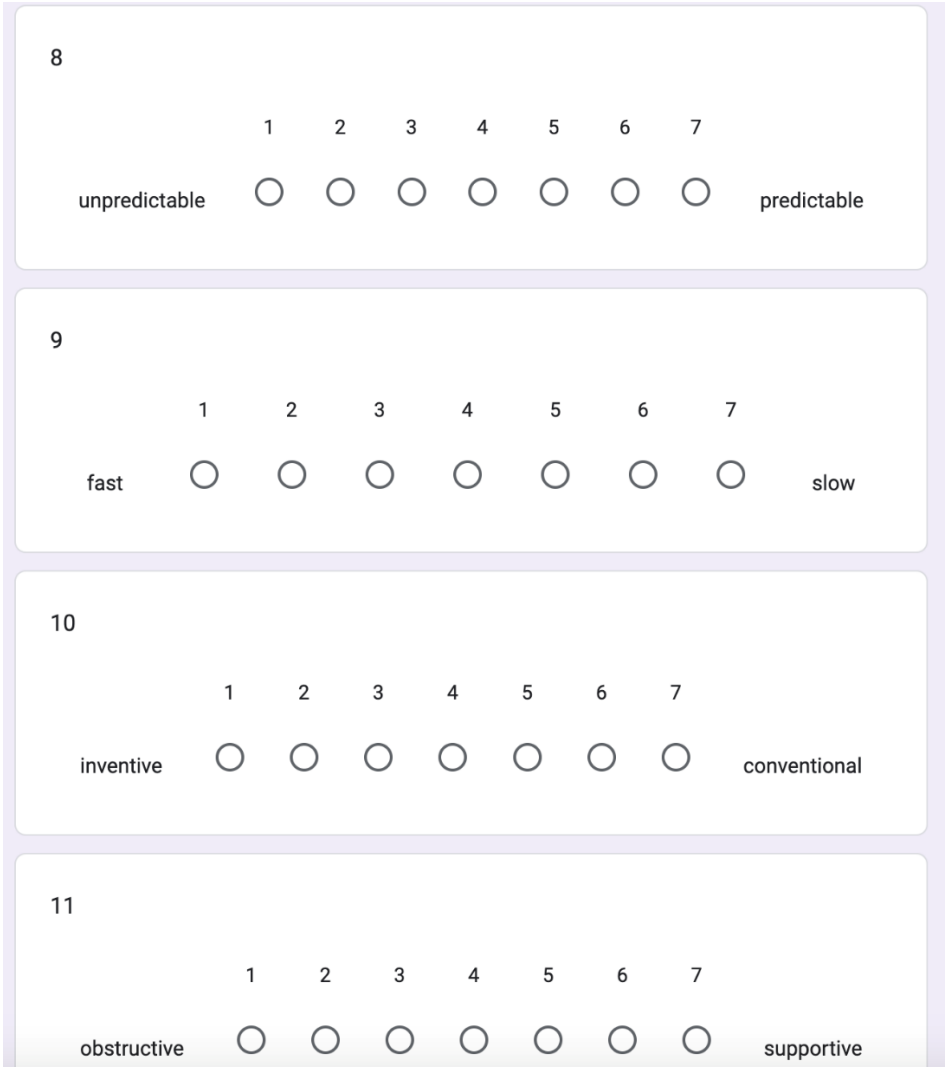
2

	1	2	3	4	5	6	7	
not understandable	○	○	○	○	○	○	○	understandable

3

	1	2	3	4	5	6	7	
creative	○	○	○	○	○	○	○	dull


4
1 2 3 4 5 6 7
easy to learn
difficult to learn
5
1 2 3 4 5 6 7
valuable
inferior
6
1 2 3 4 5 6 7
boring
exciting
7
1 2 3 4 5 6 7
not interesting
interesting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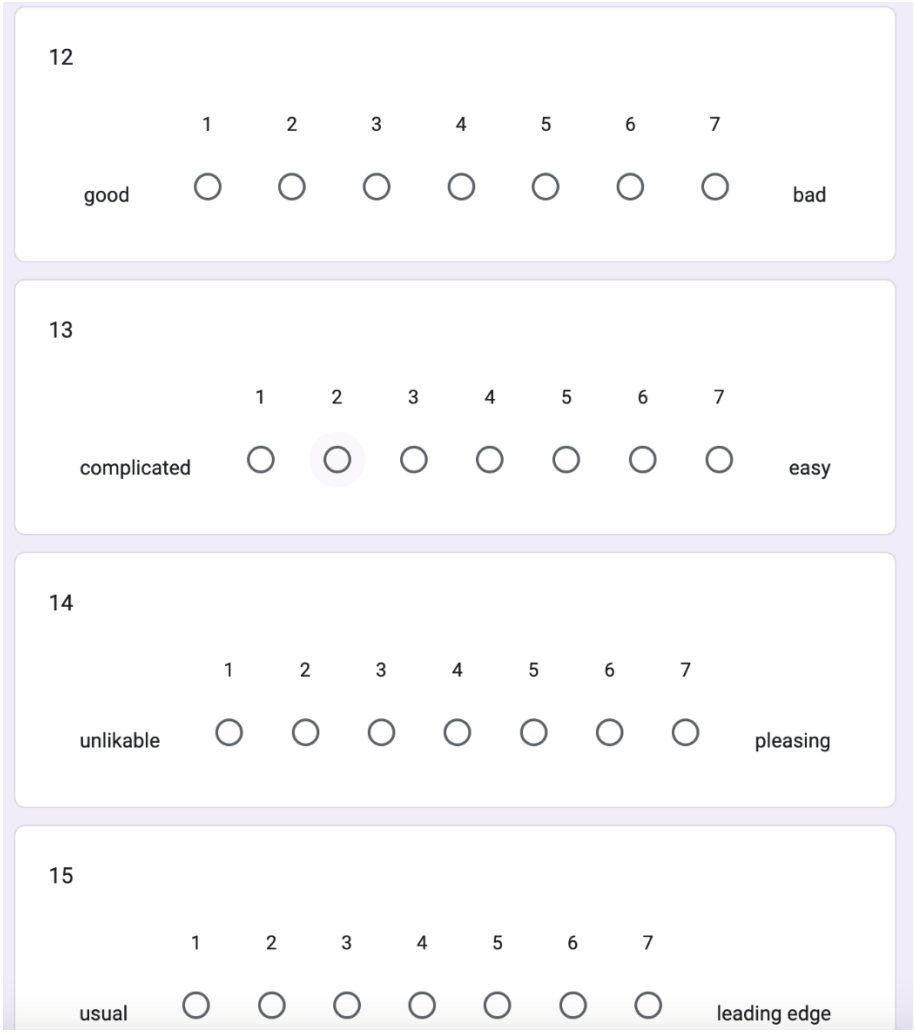
1 2 3 4 5 6 7
unpredictable
predictable
9
1 2 3 4 5 6 7
fast
slow
10
1 2 3 4 5 6 7
inventive
conventional
11
1 2 3 4 5 6 7
obstructive
supportive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1 2 3 4 5 6 7
good
bad
13
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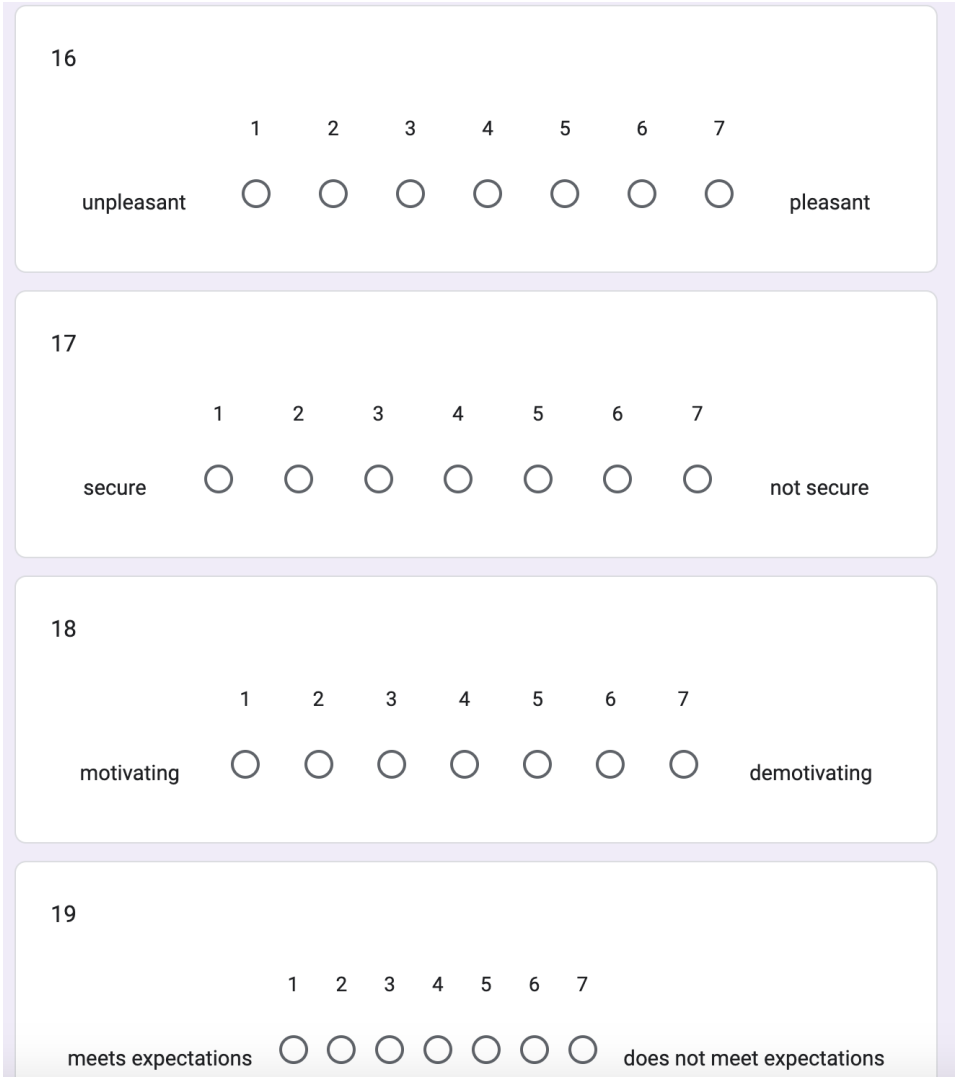
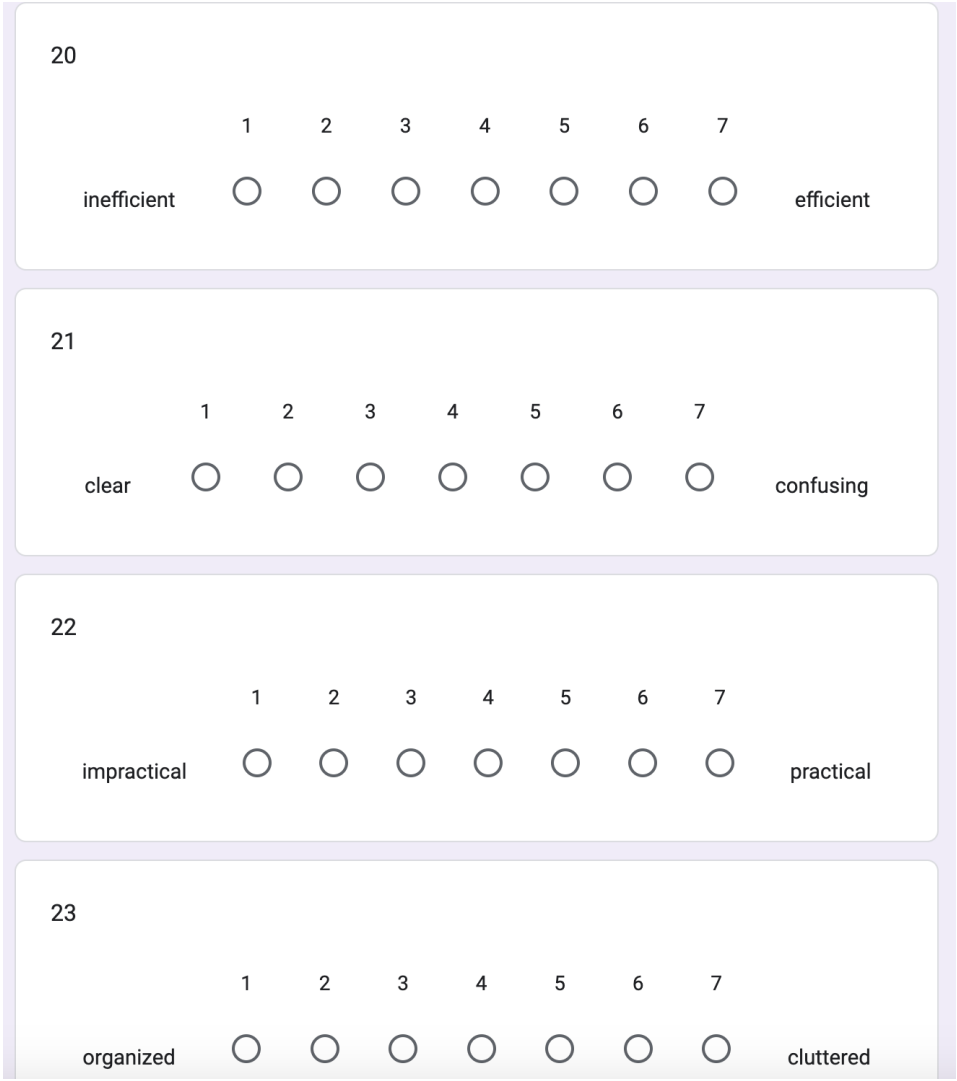
complicated
easy
14
1 2 3 4 5 6 7
unlikable
pleasing
15
1 2 3 4 5 6 7
usual
leading edge


16
1 2 3 4 5 6 7
unpleasant
pleasant
17
1 2 3 4 5 6 7
secure
not secure
18
1 2 3 4 5 6 7
motivating
demotivating
19
1 2 3 4 5 6 7
meets expectations
does not meet expectations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inefficient
efficient
21
1 2 3 4 5 6 7
clear
confusing
22
1 2 3 4 5 6 7
impractical
practical
23
1 2 3 4 5 6 7
organized
cluttered

24

	1	2	3	4	5	6	7	
attractive	○	○	○	○	○	○	○	unattractive

25

	1	2	3	4	5	6	7	
friendly	○	○	○	○	○	○	○	unfriendly

26

	1	2	3	4	5	6	7	
conservative	○	○	○	○	○	○	○	innovative

Direct feedback (if any) should be added here

Your answer