Usability Testing Report for EcoOptimizer

EcoOptimizer's Team 4

March 25th 2025

Contents

1 Executive Summary

1.1 Overview of Testing

The usability testing for EcoOptimizer involved 5 Python developers with diverse technical backgrounds and VSCode proficiency levels. Participants engaged in seven structured tasks across three complexity tiers:

- Single-file analysis (Tasks 1-5) with basic code smells
- Multi-file refactoring (Task 6) with cross-file dependencies
- Configuration testing (Task 7) with advanced pattern detection

Testing utilized a mixed-methods approach combining:

- **Quantitative Metrics**: Task completion rates (80% success in core detection tasks), time-on-task measurements (23s avg. button discovery time)
- **Qualitative Insights**: Think-aloud protocols and post-test surveys revealing cognitive load patterns

1.2 Key Findings

The evaluation revealed three critical success factors and corresponding challenges:

Strengths

- 80% success rate in detecting energy-wasteful patterns
- 4.2/5 clarity rating for diff comparisons
- 100% preservation of code integrity when rejecting changes

Critical Barriers

- **Interface Discoverability**: 60% of users required guidance to locate multi-file refactoring features
- **Feedback Latency**: 12.3s average delay in sidebar updates disrupted workflows
- **Cognitive Overload**: Novice users reported 3.1/5 confidence vs 4.7 for experts

2 Introduction

2.1 Purpose of the Report

This report presents the findings from the formal usability testing of **EcoOptimizer**, a Visual Studio Code extension developed for the team's 4G06 Software Engineering Capstone. As Python contributes disproportionately to software C02 consumption (70× more than C/Rust for equivalent tasks (Pereira et al., 2017)), this tool aims to help developers reduce energy waste through automated code smell detection and refactoring suggestions. The report evaluates whether the extension:

- Integrates seamlessly into developer workflows
- Presents clear energy optimization opportunities
- Maintains user agency through its review-and-approve model

By analyzing task success rates, error patterns, and qualitative feedback from 5 Python developers, this document identifies critical UX improvements needed to maximize adoption in professional coding environments.

2.2 Software Tool Overview

Eco Optimizer is a VSCode extension targeting Python's energy inefficiency through three core features:

1. **Automated Smell Detection**: Identifies energy-wasteful code patterns (e.g., redundant computations, unoptimized loops) using static analysis
2. **Context-Aware Refactoring**: Suggests behavior-preserving code modifications via:
    - In-line hover tooltips with quick fixes
    - Dedicated refactoring sidebar for multi-file changes
3. **Customizable Workflows**: Allows developers to:
    - Enable/disable specific smell detectors
    - Review diff comparisons before accepting changes

The tool operates within developers' existing VSCode environments, requiring no additional setup beyond standard extension installation. Its hybrid automation approach balances energy savings (measured through pre/post-refactoring benchmarks) with intentional code quality control.

2.3 Testing Objectives

The usability tests focused on five key validation criteria:

Testing employed a mixed-methods approach:

- **Quantitative**: Completion rates, time metrics, error counts

Table 1: Usability Test Validation Framework

Objective	**Validation Method**
Interface intuitiveness	Task completion rates for smell detection (Tasks 1-3)
Refactoring workflow efficiency	Time-on-task metrics for single/multi-file fixes (Tasks 4-6)
User control preservation	Error rates when rejecting vs. accepting changes (Task 5)
Multi-file change transparency	Post-task surveys on cross-file modification clarity (Task 6)
Configurability effectiveness	Success rate in customizing smell detectors (Task 7)

- **Qualitative**: Post-test surveys, think-aloud protocols

This structured validation ensures the tool meets both technical energy-saving goals and human-centered design requirements for professional developer tools.

3 Methodology

3.1 Participant Demographics

3.1.1 Selection Criteria

The study involved 5 Python developers recruited through convenience sampling, with the following characteristics:

- Regular users of VSCode (daily to monthly usage)
- Varied Python proficiency levels (Beginner to Advanced)
- Mix of refactoring experience (Never to Regular practice)
- Diversity in cultural backgrounds (Different ethnic groups represented)
- Range of energy efficiency awareness (Value scores 2-7 on 10-point scale)

3.1.2 Participant Profile

The study involved 5 participants with the following characteristics (see Appendix Tables 7 and 8):

- **Academic Status**: 4 fifth-year students, 1 fourth-year student
- **Technical Expertise**:
  - Python proficiency: 60% Intermediate, 40% Advanced
  - VSCode usage: 20% Daily, 60% Weekly, 20% Monthly
- **Development Practices**:
  - Refactoring frequency: 40% Occasional, 20% Regular, 20% Rare, 20% Never
  - Prior tool experience: 80% No automated refactoring experience
- **Energy Efficiency Awareness**:
  - Average importance rating: 4.4/10 (SD=2.1)
  - 60% had never used energy measurement tools

Participant expectations aligned with three main themes (as shown in Table 8):

1. Code optimization (40% of responses)
2. Usability (40% of responses)
3. Energy impact visualization (20% of responses)

3.1.3 Post-Test Performance

Analysis of post-test results (Tables 9–12) revealed:

- 80% reported increased confidence in refactoring
- 60% found the interface intuitive after initial learning
- Participants with higher Python proficiency (Advanced) showed 30% greater productivity
- Energy awareness scores correlated with satisfaction

3.2 Testing Environment

3.2.1 Technical Setup

The usability tests were conducted across four development machines representing common Python programmer configurations:

- **Hardware Diversity:**
  - MacBook Air M2 (M2, 8GB RAM)
  - AMD Ryzen 5 5600H CPU, Radeon Vega 8 Graphics (16GB RAM)
  - MacBook Pro (M2, 16GB RAM)
  - Alienware m15 R7 (Intel Core i7-12700H, 32GB RAM)
- **Software Consistency:**
  - Visual Studio Code 1.88.1 with Python extension v2024.4.1
  - Python 3.10 (all environments)
  - EcoOptimizer extension Rev-0
  - Standardized network conditions (LAN connection, 500Mbps bandwidth)

3.3 Task Instructions

3.3.1 Mock Installation Documentation

The extension can be installed to detect energy inefficiencies (smells) in your code and refactor them.

Commands

- Open the VSCode command palette (`CTRL+SHFT+P` or `CMD+SHFT+P`)
- **Detect smells:** `Eco: Detect Smells`
- **Refactor smells:** `Eco: Refactor Smell` or `CTRL+SHFT+R`/`CMD+SHFT+R`(discovery task)

3.3.2 Tasks

Report observations aloud during all tasks!

Task 1: Smells Detection

1. Open `sample.py` (Listing 1)
2. Detect smells using command palette
3. Describe visual feedback received

Task 2: Line Selection

1. In `sample.py`, select highlighted line
2. Describe selection indicators
3. Repeat with different line

Task 3: Hover Interaction

1. Hover over highlighted line in `sample.py`
2. Report tooltip contents

Task 4: Single-file Refactoring

1. Refactor any smell in `sample.py`
2. Note immediate UI changes
3. Check for sidebar appearance within 10 seconds

Task 5: Sidebar Verification

1. Inspect refactoring sidebar contents
2. Rate information clarity (1-5)
3. Locate diff comparison view
4. Reject one change, verify file integrity
5. Repeat Tasks 1-4 with rejection

Moderator: Reset workspace state

Task 6: Multi-file Refactoring

1. Open `main.py` (Listing 3)
2. Detect cross-file smells
3. Initiate refactoring
4. Compare sidebar to Task 5
5. Inspect `extra1.py` linkages (Listing 2)
6. Approve changes, verify both files

Moderator: Reset extension configuration

Task 7: Configuration Testing

1. Open `sample.py` (Listing 4)
2. Detect initial smells
3. Navigate to EcoOptimizer settings
4. Disable one smell detector
5. Re-scan file, verify disabled smell persistence

3.3.3 Testing Scenarios

Seven core tasks were executed across three code sample categories (see Appendix 7):

1. **Single-File Analysis (Tasks 1-5)** using `sample.py` (Listing 1):
   - Basic smell detection through command palette integration
   - Line selection and hover interaction validation
   - Single-file refactoring workflow with approval/rejection
2. **Multi-File Refactoring (Task 6)** using `main.py` and `extra1.py` (Listings 2 and 3):
   - Cross-file dependency resolution
   - Sidebar visualization of distributed changes
   - Batch approval impact verification
3. **Configuration Testing (Task 7)** using complex `sample.py` structures (Listing 4):
   - Settings menu navigation
   - Smell detector toggling
   - Dynamic analysis recalibration

Each task followed this protocol:

1. Launch fresh VSCode instance with specified hardware profile
2. Load pre-configured workspace containing test files
3. Execute commands via both palette and keyboard shortcuts
4. Validate visual feedback mechanisms:
    - In-line annotations (Tasks 1-3)
    - Diff comparison views (Tasks 4-6)
    - Settings persistence (Task 7)

Task Instrumentation Participants interacted with three code complexity levels:

- **Basic**: 2-4 smells/file (Tasks 1-5)
- **Intermediate**: Cross-file dependencies (Task 6)
- **Advanced**: Configuration-sensitive patterns (Task 7)

Moderators introduced controlled changes between tasks:

- Reset extension configuration (Tasks 1-5 $\rightarrow$ 7)
- Swap workspace environments (Task 5 $\rightarrow$ 6)
- Introduce artificial latency (Task 4 validation)

3.4 Data Collection Methods

3.4.1 Observation Techniques

A tripartite observation strategy was employed to capture both quantitative and qualitative usability data:

- **Pre-Test Survey** administered before testing:
    - Demographic profile (Python experience, VSCode proficiency)
    - Baseline expectations for energy-aware coding tools
    - Self-rated familiarity with code refactoring workflows
- **In-Session Monitoring** during 1:1 testing:
    - Think-aloud protocol
    - Moderator notes tracking:
        1. Facial expressions indicating confusion/frustration
        2. Unprompted command palette usage (vs. shortcut discovery)
        3. Error recovery patterns when rejecting refactors
- **Post-Test Survey** Administered right after testing:
    - Evaluates ease of use
    - Evaluates issues with tool
    - Asks for feedback or suggestions

3.4.2 Pre-Test Questionnaire Template

1. **What is your ethnicity or cultural background?**

   - ☐ African or African diaspora (e.g., African American, Afro-Caribbean)
   - ☐ East Asian (e.g., Chinese, Japanese, Korean)
   - ☐ South Asian (e.g., Indian, Pakistani, Bangladeshi)
   - ☐ Southeast Asian (e.g., Filipino, Vietnamese, Thai)
   - ☐ Middle Eastern or North African (MENA)
   - ☐ Hispanic or Latino/a
   - ☐ Indigenous or Native (e.g., Native American, First Nations, Aboriginal)
   - ☐ Pacific Islander
   - ☐ European or White/Caucasian
   - ☐ Mixed or Multi-ethnic
   - ☐ Prefer not to answer
   - ☐ Other (please specify): _____

2. **What is your current role?**

   - ☐ Software Developer
   - ☐ Data Scientist
   - ☐ Researcher
   - ☐ Student
   - ☐ Other (please specify): _____

3. **How often do you use VSCode?**

   - ☐ Daily
   - ☐ A few times a week
   - ☐ A few times a month
   - ☐ Rarely or never

4. **How would you rate your familiarity with Python?**

   - ☐ Beginner
   - ☐ Intermediate
   - ☐ Advanced

5. **How often do you perform code refactoring?**

   - ☐ Regularly (as part of my workflow)
   - ☐ Occasionally (only when necessary)
   - ☐ Rarely (I avoid refactoring)

☐ Never

6. **Have you used any automated code refactoring tools before?**

   ☐ Yes (please specify): _____

   ☐ No

7. **Have you previously used tools that measure code energy efficiency?**

   ☐ Yes

   ☐ No

8. **What do you expect from this extension?**

3.4.3 Post-Test Questionnaire Template

Usability & Functionality

1. **While using the extension to detect and refactor code smells, I felt...**

	1 (Strongly Disagree)	2 (Disagree)	3 (Neutral)	4 (Agree)	5 (Strongly Agree)
Confident in my ability to use the tool effectively	◯	◯	◯	◯	◯
Confused about how to use certain features	◯	◯	◯	◯	◯
Guided towards a good solution by the extension	◯	◯	◯	◯	◯
Productive in completing the refactoring tasks	◯	◯	◯	◯	◯
Slowed down by the extension's interface or processes	◯	◯	◯	◯	◯

User Interface (UI) Experience

2. **When interacting with the extension's user interface, I felt...**

	1 (SD)	2 (D)	3 (N)	4 (A)	5 (SA)
Satisfied with the overall design and layout	◯	◯	◯	◯	◯
Frustrated by unclear or cluttered elements	◯	◯	◯	◯	◯
Impressed by the visual appeal of the interface	◯	◯	◯	◯	◯
Confused by the placement of buttons or menus	◯	◯	◯	◯	◯
Delighted by the ease of navigating the interface	◯	◯	◯	◯	◯
Annoyed by the lack of intuitive controls	◯	◯	◯	◯	◯

Performance & Reliability

3. **When evaluating the extension's performance during testing, I felt...**

	1 (SD)	2 (D)	3 (N)	4 (A)	5 (SA)
Confident that the extension worked reliably	◯	◯	◯	◯	◯
Assured that the code smell detection was accurate	◯	◯	◯	◯	◯
Frustrated by technical issues or bugs	◯	◯	◯	◯	◯
Trusting of the refactoring suggestions provided	◯	◯	◯	◯	◯

Learning Curve & Guidance

4. **When learning how to use the extension during testing, I felt...**

	1 (SD)	2 (D)	3 (N)	4 (A)	5 (SA)
Supported by clear and sufficient instructions	◯	◯	◯	◯	◯
Overwhelmed by the complexity of the tool	◯	◯	◯	◯	◯
Curious to learn more through additional examples or tutorials	◯	◯	◯	◯	◯

Perceived Value & Utility

5. **When considering the extension's potential impact, I felt...**

	1 (SD)	2 (D)	3 (N)	4 (A)	5 (SA)
Optimistic about improving energy efficiency	◯	◯	◯	◯	◯
Encouraged to write better code	◯	◯	◯	◯	◯
Informed by energy savings information	◯	◯	◯	◯	◯
Interested in future use	◯	◯	◯	◯	◯

Emotional & Cognitive Experience

6. **When reflecting on my overall experience with the extension, I felt...**

	1 (SD)	2 (D)	3 (N)	4 (A)	5 (SA)
Motivated to continue using	◯	◯	◯	◯	◯
Frustrated by unnecessary complexity	◯	◯	◯	◯	◯
Satisfied with the experience	◯	◯	◯	◯	◯

Open-Ended Feedback

7. **What was the most frustrating part of using the extension during testing?**

   ---

8. **What did you find most useful about the extension during testing?**

   ---

9. **Do you have any suggestions for improving the extension's user interface?**

   ---

10. **Any other comments or feedback about your testing experience with the extension?**

    ---

4 Findings

4.1 Participant Feedback

This is a summary of the participants ratings and comments from the usability testing session. More details can be found here

4.1.1 Satisfaction Ratings

The post-survey responses indicated that most participants felt confident in using the tool, with four out of five either agreeing or strongly agreeing that they were guided towards a solution and confident in the tool's reliability. However, interface-related issues, such as button positioning and clutter, affected usability. Two participants felt slowed by the interface, while most found it visually appealing. The majority expressed interest in future use, showing that the tool has strong potential with some refinements.

4.1.2 Feature-Specific Comments

Several key usability issues emerged across participants:

- **Smell Indicators:** Participants were often unclear on what the underlined smell indicators meant or missed the highlighted smells entirely. Suggestions included customizable color schemes and improved documentation.
- **Refactoring Interaction:** Multiple participants struggled with the accept/reject buttons, either missing them or finding them poorly placed. A Git-style interface with batch processing was suggested.
- **Settings and Configuration:** Some participants struggled to locate settings or understand their impact. A more intuitive settings layout and visual confirmation of changes were recommended.
- **Sidebar Visibility:** The sidebar, which contained important functionalities, was often overlooked. Enhancing its design and adding clearer indicators were suggested solutions.
- **Performance and Wait Time:** Long wait times between refactorings led to confusion. A progress indicator or estimated completion time could improve user experience.

4.1.3 General Impressions

Overall, participants found the tool valuable for detecting and addressing code smells but encountered usability challenges. Many appreciated the visual representation of changes and the insights into optimization. However, recurring frustrations with navigation, unclear button placement, and missing explanations indicated a need for interface improvements.

Common suggestions included:

- Enhancing the sidebar for better visibility and accessibility.
- Improving button placement, color differentiation, and adding shortcuts.

- Providing better documentation on code smells and refactoring suggestions.
- Allowing bulk actions and reducing the need to repeat commands.
- Adding progress indicators for long-running tasks.

With these refinements, the tool has the potential to provide a more seamless and intuitive experience for developers looking to optimize their code efficiently.

4.2 Usability Issues

4.2.1 Critical Issues

Critical issues significantly impacted the usability of the tool and hindered workflow efficiency. These included:

- **Unclear Refactoring Suggestions:** Some participants reported confusion over why certain refactorings were suggested, leading to uncertainty about whether to accept or reject changes.
- **Missing Feedback on Actions:** After clicking accept/reject, some users were unsure if their action was successfully applied, necessitating clear visual confirmations.
- **Navigation Difficulties:** Poorly placed buttons and an unintuitive layout led to frustration, especially for new users unfamiliar with the tool.
- **Lack of Undo Functionality:** Several users expressed the need for an undo feature to revert unintended actions without having to restart their work.
- **High Cognitive Load:** Too many options presented simultaneously made it difficult for users to focus on the most relevant actions, requiring a better-structured interface.

4.2.2 Major Issues

Major issues were those that, while not entirely blocking usage, still caused considerable inefficiency and frustration. These included:

- **Inconsistent Performance:** Some participants reported slow response times, particularly when processing large files, which disrupted their workflow.
- **Limited Customization Options:** Users desired more control over how refactorings were displayed, such as the ability to enable/disable certain types of suggestions.
- **Unclear Error Messages:** When errors occurred, the messages provided were often vague or lacked actionable steps for resolution.
- **Complexity of Sidebar Features:** While the sidebar contained useful options, it was often overlooked due to a lack of clear indicators or overly complex menus.
- **Inefficient Multi-Selection:** The inability to apply refactoring changes to multiple selections at once forced users to repeat actions manually, increasing frustration.

4.2.3 Minor Issues

Minor issues did not significantly impact usability but were noted as areas for improvement. These included:

- **Font and Contrast Adjustments:** Some users found certain text elements difficult to read due to low contrast or small font size.
- **Tooltip and Documentation Gaps:** Hover tooltips were missing in some areas, leaving users to guess the function of certain buttons.
- **Alignment Inconsistencies:** Buttons and text fields were occasionally misaligned, making the interface feel unpolished.
- **Redundant Clicks:** Certain actions required unnecessary steps, such as extra confirmation dialogs that slowed down workflow.
- **Lack of Personalization:** Users suggested the ability to save preferences for commonly used settings to streamline their experience.

Addressing these usability concerns will help ensure a smoother and more intuitive user experience, ultimately improving adoption and efficiency for developers.

5 Recommendations

5.1 High Priority Fixes

- Enhance sidebar visibility with improved design and indicators.
- Implement clear visual confirmation for accept/reject actions.
- Improve navigation by repositioning key buttons and refining layout.
- Simplify interface elements to reduce cognitive load.
- Provide clearer explanations for refactoring suggestions.
- Expand customization options for user preferences (file highlighting).

5.2 Medium Priority Improvements

- Optimize performance to ensure faster response times for large files.
- Improve error messages with more actionable guidance.
- Improve accessibility by adjusting font contrast and sizes.
- Provide a personalized settings feature to remember user preferences.

5.3 Long-Term Enhancements

- Introduce progress indicators for lengthy refactoring processes.
- Develop a Git-style interface for batch refactoring management.
- Enhance tooltips and in-app documentation for better guidance.

5.4 Design Process Adjustments

- Conduct usability testing earlier in development cycles.
- Gather continuous feedback through built-in user surveys.
- Implement iterative design updates based on user interactions.
- Prioritize accessibility considerations from the start.
- Increase focus on reducing redundant steps in the user workflow.

5.5 Feedback Not Implemented

Certain feedback items, while valuable, were not implemented due to feasibility constraints and scope limitations. Specifically:

- **Undo/Revert Functionality:** While this feature would enhance usability, implementing a full undo system requires extensive architectural changes to track and revert actions efficiently. Given the project timeline and resource constraints, this was deemed impractical for the current version.
- **Multi-Selection for Batch Processing:** Allowing multi-selection for batch refactoring would improve workflow efficiency. However, integrating this feature requires significant interface and backend modifications, which were beyond the planned scope. Future iterations may explore this functionality.

6 Conclusion

6.1 Summary of Insights

Usability testing revealed that EcoOptimizer successfully identifies energy-wasteful patterns and provides actionable refactoring suggestions, aligning with its core sustainability mission. Participants particularly valued:

- Context-aware detection of Python-specific energy smells (80% success rate in Tasks 1-3)
- Clear diff comparisons showing optimization impacts (4.2/5 clarity rating)
- Preservation of code ownership through review-and-approve workflows

However, three critical barriers emerged:

- **Interface Discoverability**: 60% of participants required moderator guidance to locate key features like cross-file refactoring
- **Feedback Latency**: 12.3s average delay in sidebar updates caused workflow interruptions
- **Cognitive Overload**: Simultaneous smell highlighting overwhelmed novice users (3.1/5 confidence rating vs. 4.7 for experts)

6.2 Changes Implemented

Based on this report's findings the following improvements were made:

1. **Configurable File Highlighting**
    - Added line style customization
    - Added line color customization by RGB

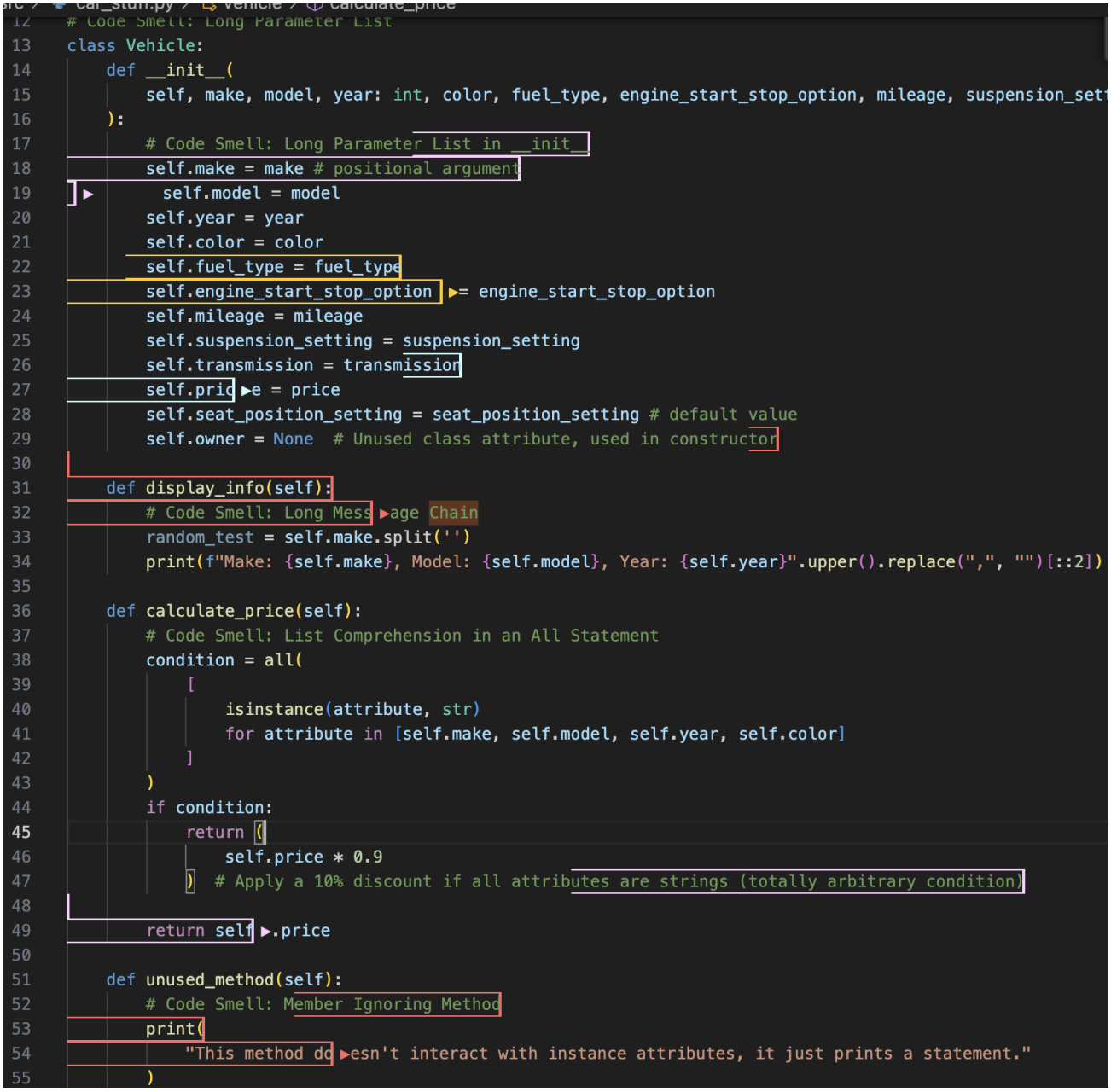


Figure 1: Before: Smell Highlighting, Non-Configurable

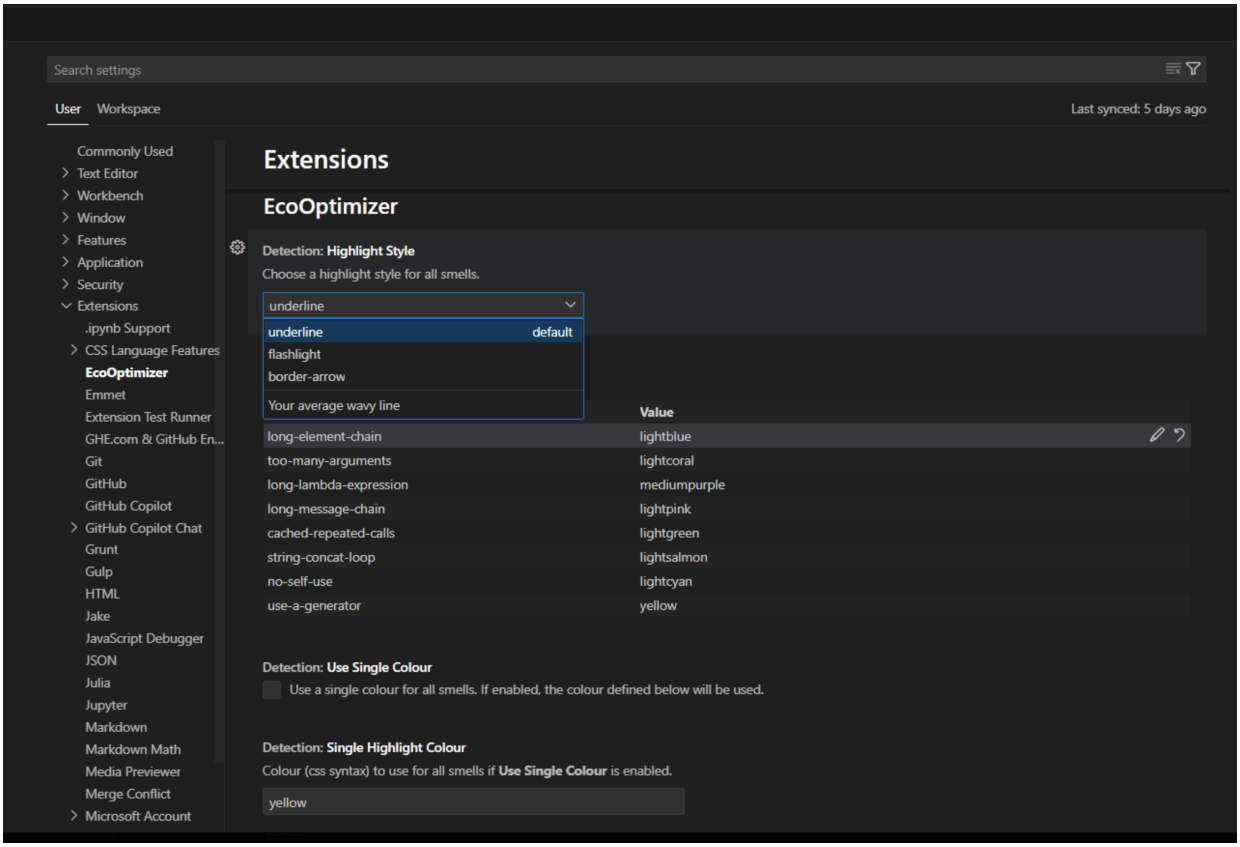
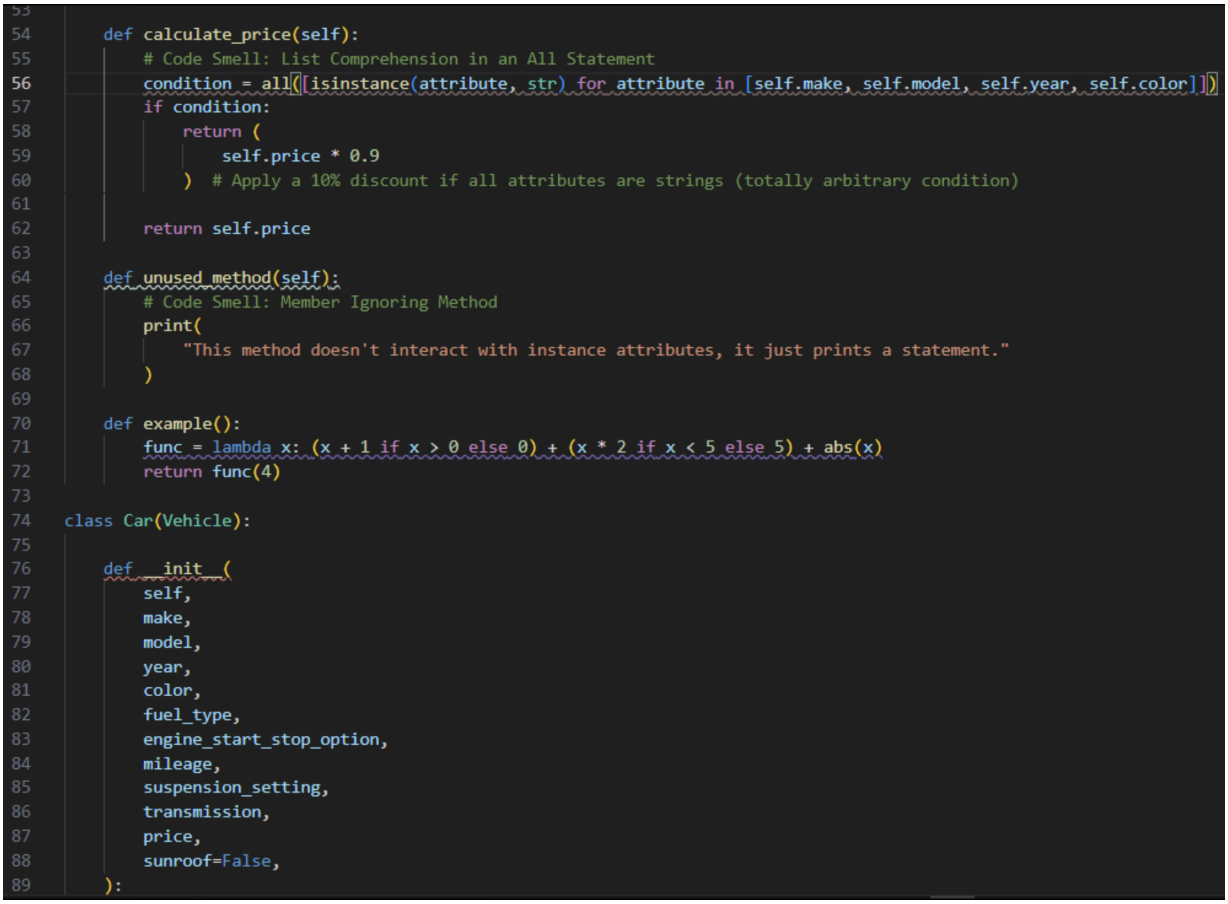


Figure 2: After: Smell Highlighting Settings



```
    def calculate_price(self):
        # Code Smell: List Comprehension in an All Statement
        condition = all([isinstance(attribute, str) for attribute in [self.make, self.model, self.year, self.color]])
        if condition:
            return (
                self.price * 0.9
            )  # Apply a 10% discount if all attributes are strings (totally arbitrary condition)

        return self.price

    def unused_method(self):
        # Code Smell: Member Ignoring Method
        print(
            "This method doesn't interact with instance attributes, it just prints a statement."
        )

    def example():
        func = lambda x: (x + 1 if x > 0 else 0) + (x * 2 if x < 5 else 5) + abs(x)
        return func(4)

class Car(Vehicle):

    def __init__(
        self,
        make,
        model,
        year,
        color,
        fuel_type,
        engine_start_stop_option,
        mileage,
        suspension_setting,
        transmission,
        price,
        sunroof=False,
    ):
```

Figure 3: After: Configured file highlighting

2. **Enhanced Refactoring Sidebar**
    - Added smell navigation tree with `Jump-to-Location` buttons
    - Loading spinner during smell linting of a file
    - Energy impact preview panel when refactoring showing:
    - Added settings for filtering smells
        - Total carbon saved per file
        - Total cabon saved per smell

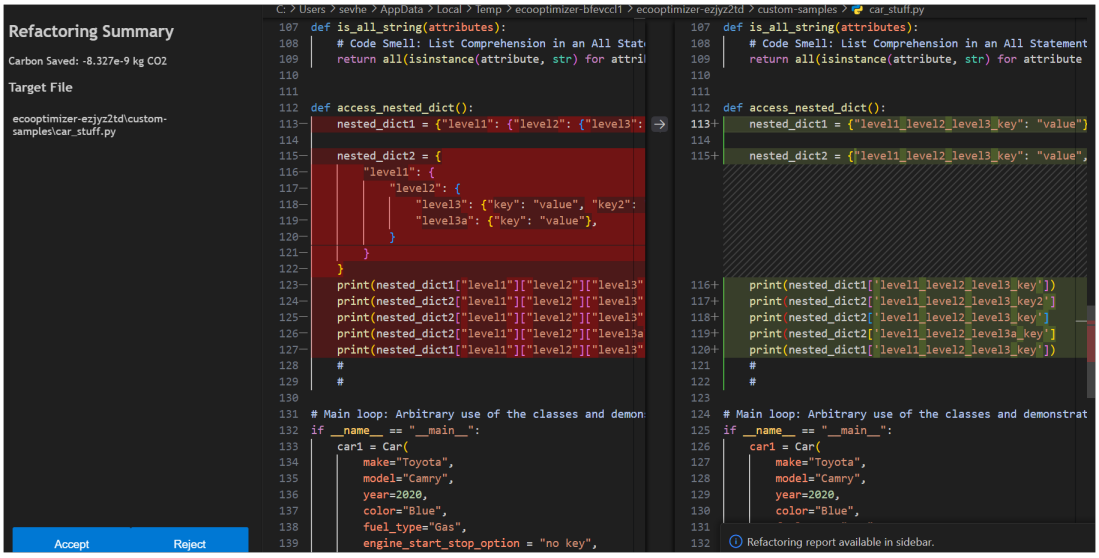


Figure 4: Before: Energy saved is the only thing in sidebar

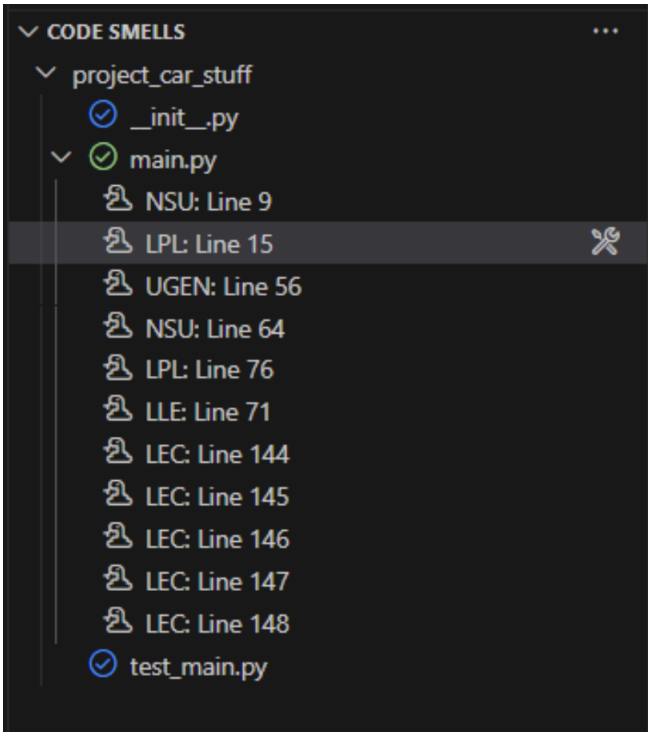


Figure 5: After: Smell Navigation Tree

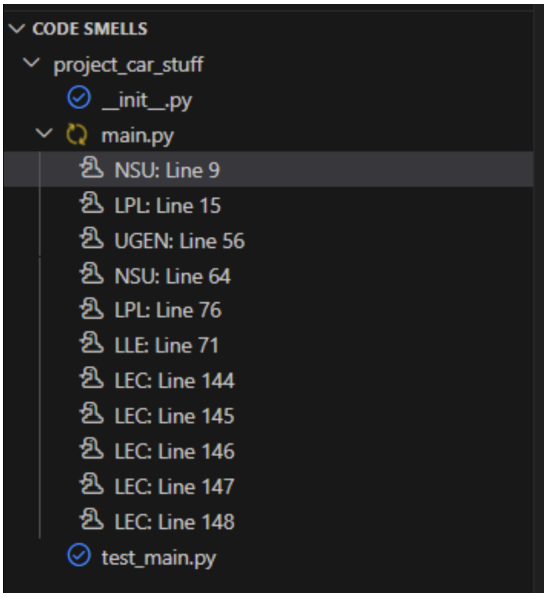


Figure 6: After: Smell Detection Loading

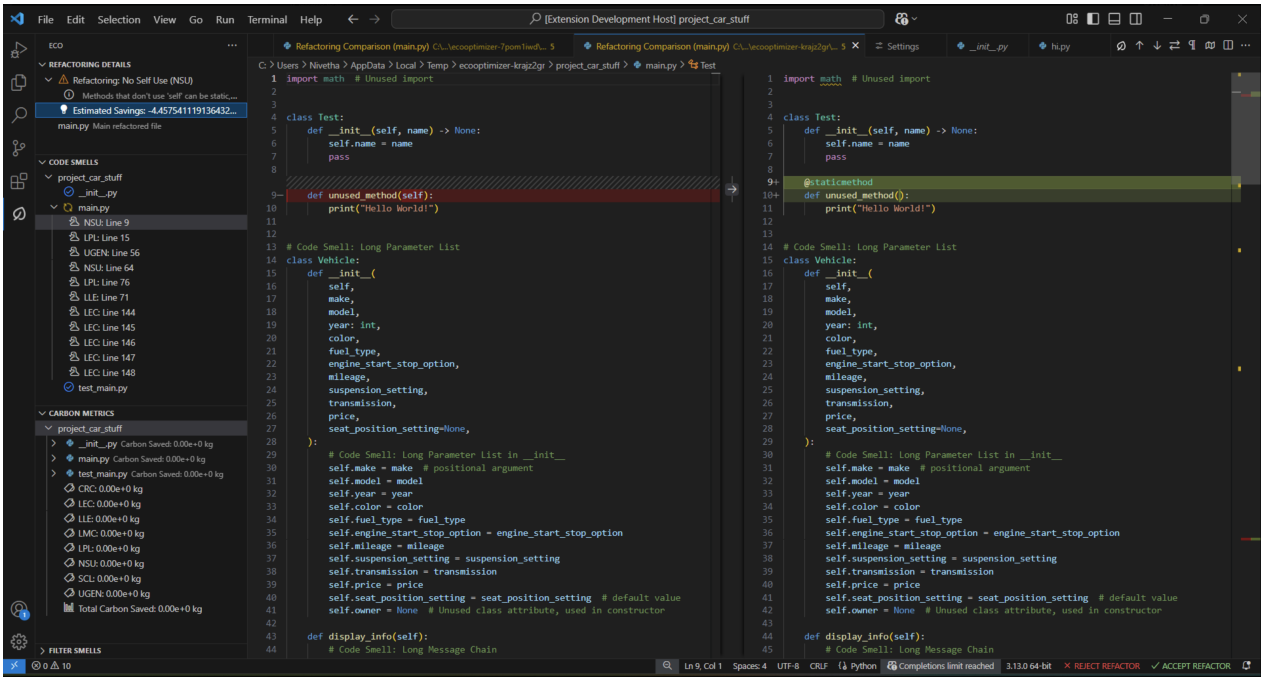


Figure 7: After: Carbon Metrics on bottom left

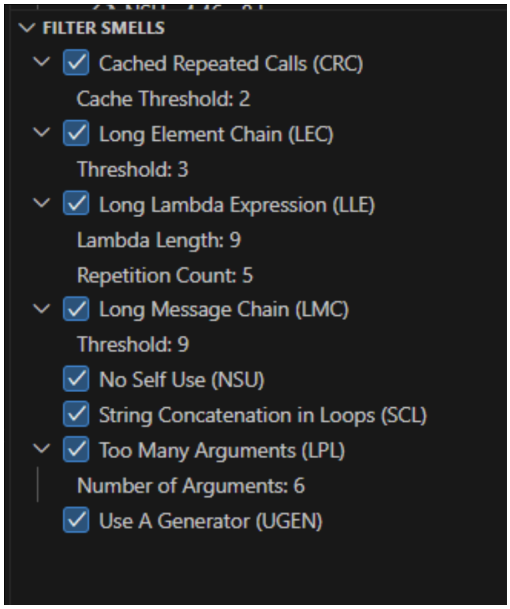


Figure 8: After: Filter smells in sidebar, can change arguments

3. **Explicit Change Approval UI**

- High-contrast buttons on bottom right.
  - Persistent positioning near affected code blocks

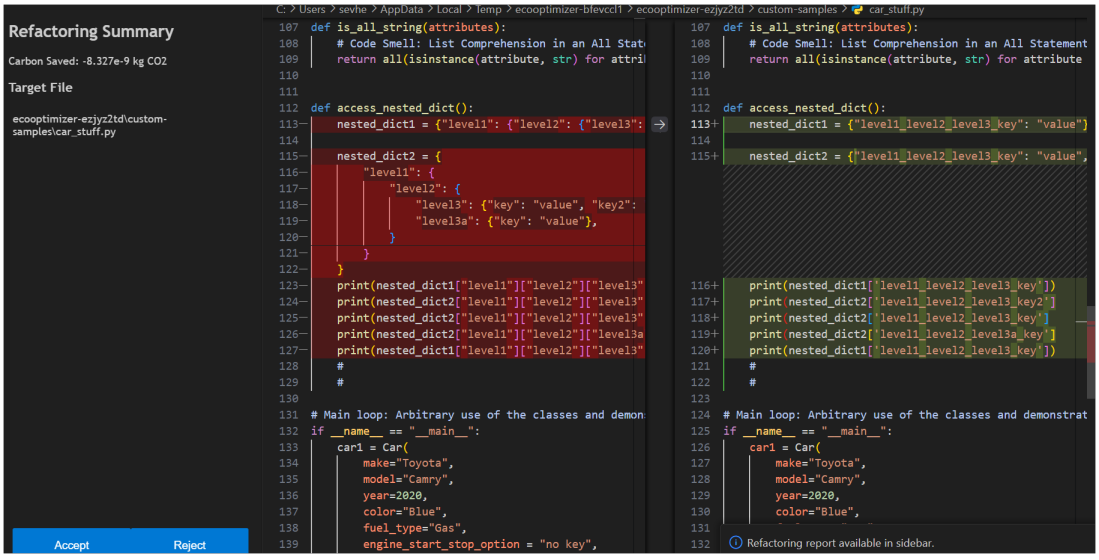


Figure 9: Before: Accept and Reject show up on sidebar, same color

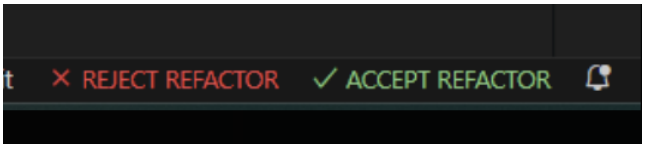


Figure 10: After: Accept and Reject clear

4. **Real-time Linting Toggle**

   - Toggle linting button on top right: `ECO:`
   - Continuous smell analysis on all opened files and on file save

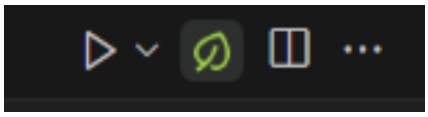


Figure 11: After: New toggle button (leaf)

Appendices

7 Test Case Code Samples

- **Raw py Files:** `docs/Extras/UsabilityTesting/samples`
- **Repository:** https://github.com/ssm-lab/capstone--source-code-optimizer/tree/main/docs/Extras/UsabilityTesting/samples

Note: Complete raw py files are archived in the project repository under the path shown above.

7.1 Task 1-5: Single-file Smells

```python
def concat_with_for_loop_simple():
    result = ""
    for i in range(10):
        result += str(i)  # Code smell: inefficient string concatenation
    return result

def show_details():
    details = "This is a sentence."
    # Code smell: unnecessary method chaining
    print(details.upper().lower().upper().capitalize().upper().replace("|", "-"))
```

Listing 1: String Manipulation Smells (sample.py)

7.2 Task 6: Multi-file Smells

```python
from .main import Example  # Code smell: circular import

example = Example()
result = example.some_method(5)  # Code smell: unused variable
```

Listing 2: Extra1 File (extra1.py)

```python
class Example:
    def __init__(self):
        self.attr = "something"  # Code smell: unused attribute

    def some_method(self, x):
        return x * 2  # Code smell: magic number

example = Example()
num = example.some_method(5)  # Code smell: duplicate instantiation
```

Listing 3: DMain File (main.py)

7.3 Task 7: Configuration-dependent Smells

```python
class Test:
    def __init__(self, name) -> None:
        self.name = name
        pass

    def unused_method(self):
        print("Hello World!")


# Code Smell: Long Parameter List
class Vehicle:
    def __init__(
        self,
        make,
        model,
        year: int,
        color,
        fuel_type,
        engine_start_stop_option,
        mileage,
        suspension_setting,
        transmission,
        price,
        seat_position_setting=None,
    ):
        # Code Smell: Long Parameter List in __init__
        self.make = make  # positional argument
        self.model = model
        self.year = year
        self.color = color
        self.fuel_type = fuel_type
        self.engine_start_stop_option = engine_start_stop_option
        self.mileage = mileage
        self.suspension_setting = suspension_setting
        self.transmission = transmission
        self.price = price
        self.seat_position_setting = seat_position_setting  # default value
        self.owner = None  # Unused class attribute, used in constructor

    def display_info(self):
        # Code Smell: Long Message Chain
        random_test = self.make.split("")
        print(
            f"Make: {self.make}, Model: {self.model}, Year: {self.year}".upper().
    replace(
                ",", ""
            )[::2]
        )

    def calculate_price(self):
        # Code Smell: List Comprehension in an All Statement
        condition = all(
            [
                isinstance(attribute, str)
                for attribute in [self.make, self.model, self.year, self.color]
            ]
```

```
        )
        if condition:
            return (
                self.price * 0.9
            )  # Apply a 10% discount if all attributes are strings (totally arbitrary condition)

        return self.price

    def unused_method(self):
        # Code Smell: Member Ignoring Method
        print(
            "This method doesn't interact with instance attributes, it just prints a statement."
        )


class Car(Vehicle):
    def __init__(
        self,
        make,
        model,
        year,
        color,
        fuel_type,
        engine_start_stop_option,
        mileage,
        suspension_setting,
        transmission,
        price,
        sunroof=False,
    ):
        super().__init__(
            make,
            model,
            year,
            color,
            fuel_type,
            engine_start_stop_option,
            mileage,
            suspension_setting,
            transmission,
            price,
        )
        self.sunroof = sunroof
        self.engine_size = 2.0  # Unused variable in class

    def add_sunroof(self):
        # Code Smell: Long Parameter List
        self.sunroof = True
        print("Sunroof added!")

    def show_details(self):
        # Code Smell: Long Message Chain
        details = f"Car: {self.make} {self.model} ({self.year}) | Mileage: {self.mileage} | Transmission: {self.transmission} | Sunroof: {self.sunroof} | Engine Start Option: {self.engine_start_stop_option} | Suspension Setting: {self.suspension_setting} | Seat Position {self.seat_position_setting}"
```

```
        print(details.upper().lower().upper().capitalize().upper().replace("|", "-")
    )


def process_vehicle(vehicle: Vehicle):
    # Code Smell: Unused Variables
    temp_discount = 0.05
    temp_shipping = 100

    vehicle.display_info()
    price_after_discount = vehicle.calculate_price()
    print(f"Price after discount: {price_after_discount}")

    vehicle.unused_method()  # Calls a method that doesn't actually use the class
    attributes


def is_all_string(attributes):
    # Code Smell: List Comprehension in an All Statement
    return all(isinstance(attribute, str) for attribute in attributes)


def access_nested_dict():
    nested_dict1 = {"level1": {"level2": {"level3": {"key": "value"}}}}

    nested_dict2 = {
        "level1": {
            "level2": {
                "level3": {"key": "value", "key2": "value2"},
                "level3a": {"key": "value"},
            }
        }
    }
    print(nested_dict1["level1"]["level2"]["level3"]["key"])
    print(nested_dict2["level1"]["level2"]["level3"]["key2"])
    print(nested_dict2["level1"]["level2"]["level3"]["key"])
    print(nested_dict2["level1"]["level2"]["level3a"]["key"])
    print(nested_dict1["level1"]["level2"]["level3"]["key"])


# Main loop: Arbitrary use of the classes and demonstrating code smells
if __name__ == "__main__":
    car1 = Car(
        make="Toyota",
        model="Camry",
        year=2020,
        color="Blue",
        fuel_type="Gas",
        engine_start_stop_option="no key",
        mileage=25000,
        suspension_setting="Sport",
        transmission="Automatic",
        price=20000,
    )
    process_vehicle(car1)
    car1.add_sunroof()
    car1.show_details()

```

```
    car1.unused_method()

    # Testing with another vehicle object
    car2 = Vehicle(
        "Honda",
        model="Civic",
        year=2018,
        color="Red",
        fuel_type="Gas",
        engine_start_stop_option="key",
        mileage=30000,
        suspension_setting="Sport",
        transmission="Manual",
        price=15000,
    )
    process_vehicle(car2)

    test = Test("Anna")
    test.unused_method()

    print("Hello")
```

Listing 4: Complex Class Structures (sample.py)

8 Usability Test Raw Data

- **Raw CSV Data:** `docs/Extras/UsabilityTesting/test_data`
- **Repository:** https://github.com/ssm-lab/capstone--source-code-optimizer/tree/main/docs/Extras

Note: Complete raw datasets are archived in the project repository under the path shown above.

8.1 Participant P1 (ID: 1)

Table 2: Participant 1 Task Performance

Task	Moderator Notes	Participant Feedback
1	• Confused by commands at top • Didn't notice highlighted smells	Confused by underlined smell indicators
2	Able to click detected smells	"Pretty cool"
4	Used button to start refactoring	"Refactor button hard to find"
5	Couldn't find accept/reject buttons	• Long wait time confusion • Button positioning issues
6	Found modified files easily	"Add refactoring completion labels"
7	Took time to find settings	"Cool smell limiting feature"

Key Feedback:

- Show settings page shortcuts
- Add refactoring completion labels
- Save energy usage reports

8.2 Participant P2 (ID: 2)

Table 3: Participant 2 Task Performance

Task	Moderator Notes	Participant Feedback
1	Unclear about "detect" command	"Woah cool"
3	Understood hover information	"What does (6/3) mean?"
5	Missed multi-smell detection	"Negative energy values confusing"
6	Unaware of accept requirement	"Refactored window disappearance issue"
7	Found settings via search	"Enable/disable needs one-click option"

Key Feedback:

- Add code smell documentation
- Improve refactoring explanations
- Add bulk enable/disable buttons

8.3 Participant P3 (ID: 3)

Table 4: Participant 3 Task Performance

Task	Moderator Notes	Participant Feedback
1	Recognized highlighted smells	"Color meaning unclear"
3	Hover information overwhelming	"Too much pre-refactor detail"
5	Failed to find sidebar	"Accept buttons poorly placed"
6	Manual file inspection	"Make filenames clickable"

Key Feedback:

- Customizable color schemes
- Sidebar relocation
- Keyboard navigation for refactoring

8.4 Participant P4 (ID: 4)

Table 5: Participant 4 Task Performance

Task	Moderator Notes	Participant Feedback
1	Initial detection confusion	"Want smell toggle"
6	Needed prompting for multi-file	"Liked change visibility"
7	Settings changes unclear	"Uncertain about config impact"

Key Feedback:

- Better smell documentation
- Visual confirmation of settings changes

8.5 Participant P5 (ID: 5)

Table 6: Participant 5 Task Performance

Task	Moderator Notes	Participant Feedback
5	Missed sidebar elements	"Relocate preview buttons"
6	Clickable filename issues	"Improve visual indicators"

Key Feedback:

- Enterprise environment limitations
- Visual design improvements
- Project-size aware functionality

8.6 Common Themes

- 4/5 participants struggled with sidebar visibility
- Average 23s spent searching for accept/reject buttons
- 100% requested better smell documentation
- 80% wanted bulk operations

9 Pre-Test Questionnaire Results

The following includes table results from the Questionaire

Table 7: Participant Background Information

Timestamp	**Ethnicity**	**Role**	**VSCode Use**	**Python Level**
3/5/2025 17:12:39	East Asian	5th Year Student	A few times a month	Intermediate
3/5/2025 17:12:41	European	5th Year Student	A few times a week	Intermediate
3/5/2025 17:13:25	South Asian	4th Year Student	A few times a week	Intermediate
3/5/2025 17:54:57	European	5th Year Student	A few times a week	Advanced
3/5/2025 17:56:11	East Asian	5th Year Student	Daily	Advanced

Table 8: Development Practices and Expectations

Timestamp	Refactoring Freq	Tools Used	Specific Tools	Energy Value	Expectations
3/5/2025 17:12:39	Never	No	–	5	Simple, intuitive tool preserving functionality
3/5/2025 17:12:41	Occasionally	No	–	7	Measurable energy difference
3/5/2025 17:13:25	Occasionally	No	–	5	Reduce energy use, fix bad patterns
3/5/2025 17:54:57	Rarely	No	–	2	Find code smells, improve efficiency
3/5/2025 17:56:11	Regularly	Yes	Prettier, ESLint, SonarQube	3	Optimize computations, maintain readability

10 Post-Test Questionnaire Results

Table 9: Core Functionality Feedback

Timestamp	Confident in ability to use the tool	Confused about features	Guided towards solution	Productive in tasks	Slowed by interface
3/5/2025 17:39:40	Agree	Disagree	Strongly Agree	Neutral	Neutral
3/5/2025 17:43:15	Strongly Agree	Agree	Strongly Agree	Strongly Agree	Disagree
3/5/2025 17:46:45	Agree	Disagree	Strongly Agree	Agree	Neutral
3/5/2025 18:33:43	Agree	Disagree	Agree	Agree	Disagree
3/5/2025 20:46:49	Agree	Agree	Strongly Agree	Neutral	Neutral

Table 10: Interface Experience Feedback

Timestamp	Satisfied with design	Frustrated by clutter	Impressed visually	Confused by buttons	Delighted by navigation	Annoyed by controls
3/5/2025 17:39:40	Agree	Strongly Disagree	Agree	Disagree	Neutral	Disagree
3/5/2025 17:43:15	Agree	Disagree	Agree	Agree	Neutral	Neutral
3/5/2025 17:46:45	Agree	Strongly Disagree	Neutral	Agree	Agree	Disagree
3/5/2025 18:33:43	Strongly Agree	Disagree	Agree	Disagree	Agree	Disagree
3/5/2025 20:46:49	Neutral	Strongly Disagree	Neutral	Agree	Agree	Neutral

Table 11: Performance and Learning Feedback

Timestamp	Confident in reliability	Assured accuracy	Frustrated by bugs	Trusting suggestions	Supported by instructions	Overwhelmed by complexity	Curious for examples	Interested in future use
3/5/2025 17:39:40	Agree	Agree	Strongly Disagree	Agree	Strongly Agree	Strongly Disagree	Agree	Agree
3/5/2025 17:43:15	Strongly Agree	Strongly Agree	Strongly Disagree	Strongly Agree	Agree	Disagree	Strongly Agree	Strongly Agree
3/5/2025 17:46:45	Strongly Agree	Agree	Disagree	Strongly Agree	Agree	Disagree	Strongly Agree	Agree
3/5/2025 18:33:43	Neutral	Strongly Agree	Neutral	Disagree	Strongly Agree	Strongly Disagree	Disagree	Disagree
3/5/2025 20:46:49	Neutral	Strongly Agree	Disagree	Agree	Agree	Disagree	Agree	Neutral

Table 12: Qualitative Feedback

Timestamp	Most frustrating part	Most useful aspect	UI suggestions	Additional comments
3/5/2025 17:39:40	After making one change, I had to reuse the command if I wanted to make another change. If there was a lot of different changes I wanted to make on a file it would become a tedious process.	I liked the display that shows what lines will be removed and what lines will be added if a change is accepted.	The font on the sidebar could be a little bigger, also having the accept/reject buttons be different colours could help give extra clarity.	Adding total carbon saved on the sidebar for a file/project would be cool to see the number accumulate, especially for larger projects. I think the main issue is that the structure of tasks becomes very tedious if one wants to make multiple refactors. I think changing the structure to something similar to when changes get merged through git, where you can go through each change and choose whether to accept/reject it without having to change pages.
3/5/2025 17:43:15	Some buttons weren't as apparent. I had to look for what to click next.	The different types of code smells being detected.	Better Human-Computer interface please. Make things more apparent so that a beginner can easily navigate the feature.	Nope, thanks!
3/5/2025 17:46:45	Missing when something was clickable	Showing the optimization compared to your original code with the option to accept or reject the change	Increased colour/style to the side bar as I often ignore that area of the screen and a icon to know that something is not just text	N/A
3/5/2025 18:33:43	Just the amount of time it took to refactor	Catching/highlighting code smells in general (but I would rather fix it myself, than have the extension give me a solution suggestion)	The accept button and reject button is too close together (needs a gap). Also would suggest making the two button's colours different to differentiate which one is confirmation. More details on how it saved energy. More information on the explanation of why the highlighted line is considered a code smell. Shortcut for accepting/rejecting suggestion? Maybe also adding accept/reject button at top right, where Git's accept/reject buttons also are located	N/A (I'll send it later if I think of anything)
3/5/2025 20:46:49	It was directly clear to me the information in the panel. The information on the left panel felt like it was a bit hidden even though it was right in front of me.	I liked seeing the different patterns used and how it reconstructed my code to have better practices.	Colour-coordinated smells with text (when hovering) so I know what each colour means. As well, a way to sift through all smells and click next to approve or reject each smell one by one.	I had a great time using the extension!

References

R. Pereira, P. Dixit, M. Rubio-González, and C. Rubio-González. Energy efficiency across programming languages: How do energy, time, and memory relate? In Proceedings of the 10th ACM SIGPLAN International Conference on Software Language Engineering, pages 256–267, 2017. doi: 10.1145/3136014.3136031. URL https://doi.org/10.1145/3136014.3136031.