

1 **Guiding End-Users towards Software Reuse: An Evaluation of Automated
2 Assistance in Block-Based Programming for Chemistry Laboratory Automation**

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8 **Abstract**—Background: End-users who program collaborative robots for laboratory automation often create repetitive code because they struggle to recognize opportunities for reuse. While block-based programming environments provide accessible interfaces, they do not actively guide users toward creating reusable components.

9 Objective: This study investigates whether automated guidance can help end-users recognize and apply code reuse practices. We developed the Reuse Assistant, a feature that automatically detects duplicate code sequences within the OpenRoberta environment and guides users to create reusable custom blocks through visual highlighting and one-click refactoring.

10 Study Design: Through a within subjects study with 18 participants from the chemistry domain, we evaluated the feature's impact on performance, usability, and perceived workload.

11 Results: Automated guidance increased reuse adoption from 0% in the standard OpenRoberta version to 100% when using the Reuse Assistant. The feature achieved high usability scores (SUS mean: 84.03) and imposed minimal cognitive burden (NASA-TLX mean score: 1.92). The significant carryover effect revealed that prior manual experience helps users appreciate automation benefits.

12 Conclusions: The dramatic shift in adoption proves that users are capable of using advanced features if the system actively guides them. However, the order effect suggests that some manual experience is necessary to fully benefit from automation. Participants who struggled with manual coding first developed a mental model that allowed them to better appreciate and efficiently use the automated assistance.

13 CCS Concepts: • Software and its engineering → Reusability.

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53 1 Introduction

54 Software reuse is a fundamental practice in software engineering, enabling developers to build on existing solutions
55 rather than writing code from scratch. However, end-users who program collaborative robots (cobots) for laboratory
56 automation often lack the knowledge to recognize and apply reuse opportunities. This problem is particularly acute
57 in domains like chemistry, where scientists need to automate repetitive experimental procedures but have limited
58 programming expertise.

59 Block-based programming environments such as OpenRoberta Lab provide accessible interfaces for programming
60 robots, but they do not actively guide users toward creating reusable components. As a result, end-users frequently
61 produce long, repetitive programs that are difficult to maintain and modify. When experimental protocols change, users
62 must manually update code in multiple locations, increasing the risk of errors and discouraging adoption of automation
63 features.

64 This study addresses the question: Can automated guidance help end-users recognize and apply code reuse in
65 block-based programming? We developed the Reuse Assistant, a feature that automatically detects duplicate code
66 sequences and guides users to create reusable custom blocks through visual highlighting and one-click refactoring.
67 Through a within subjects study with 18 participants from the chemistry domain, we evaluated whether proactive
68 automated assistance can overcome the barriers that prevent end-users from adopting reuse practices.

69 Our investigation examined four research questions:

- 70 1) How does the Reuse Assistant affect the end-users' performance?
- 71 2) To what extent does the reuse assistant facilitate reusability?
- 72 3) How do the end-users assess the reuse assistant in terms of usability?
- 73 4) How do the end-users assess the perceived workload when operating the Reuse Assistant?

74 The results showed that automated guidance increased reuse adoption from 0% to 100%, achieved high usability
75 scores (SUS mean: 84.03), and imposed minimal cognitive burden (NASA-TLX mean score: 2).

76 The contributions of this work are both theoretical and practical. We extend the Attention Investment Model [4]
77 and Learning Barriers Framework [10] by demonstrating that proactive assistance transforms feature adoption from a
78 high-cost investment to a low-cost opportunistic choice, effectively eliminating the selection barrier. However, we also
79 identify a critical "order effect," suggesting that manual experience is a prerequisite for maximizing the efficiency of
80 automated tools. From a practical perspective, our results show that while simple design principles (visual highlighting,
81 one-click acceptance) achieve high usability, the most effective adoption occurs when automation is introduced after
82 users have developed a mental model of the manual process.

91 2 Background and Related Work

92 Software reuse is a broad term, that refers to the practice of reusing previously written code, rather than coding from
93 scratch. It is such an important part of software engineering, that one of the ways to measure the quality of software
94 is by its 'Reusability'[3], i.e. the degree to which the application or its components can be reused. There are multiple
95 benefits to practicing reuse in software engineering. One developer could save time by using another developer's
96 reusable component, rather than coding their own. The developer avoids both the work of writing the syntax and
97 designing the logic of the component. The developer can design their own reusable components, keeping all the logic
98 in one place, which can then be tested thoroughly. However, despite reuse being an important practice in software
99 engineering, there is still a limited focus on this practice when it comes to low-code development platforms (LCDP).

105 A study from 2021 studied several low-code platforms (LCPs), in order to identify characteristic features of LCPs.
 106 The identified features were presented according to how frequent they occurred, with domain-specific reference artifacts
 107 being categorized as 'rare'. Most studied systems offered catalogs of "reusable functions or examples of predefined
 108 processes", but they were found to be generic, or have a limited scope[6]. This lack of focus on promoting reuse may
 109 impact the so-called 'Citizen Developers', who have little or no coding knowledge, and whom may then miss out on the
 110 benefits of reuse. Lin and Weintrop (2021) noted that most existing research on block-based programming focuses on
 111 supporting the transition to text-based languages rather than exploring how features within BBP environments [11],
 112 such as abstraction or reuse, can enhance learning outcomes.
 113

114 There have been proposed some ideas on how to promote reuse for LCPs, such as the templating language OSTRICH,
 115 developed for model-driven low-code platform OutSystems[12]. OSTRICH is designed to assist the end-user in making
 116 use of OutSystems' available templates, by abstracting and parameterizing the templates. However, OSTRICH only
 117 supports the top nine most used production-ready screen templates, and does not allow the end-user to create and
 118 save their own templates, or re-apply a template which they have customized. Another approach focused on enabling
 119 the reuse of models, by providing recommendations to the end-user, based on the models stored in a graph acting as
 120 a repository. While the graph allows end-users to reuse their own models, there is no mention of guiding the user
 121 towards reusing their own models.
 122

123 Several popular low-code development platforms (LCDPs) provide different kinds of support for reuse. Webflow[13],
 124 a LCDP for responsive websites, offers the ability to create reusable components and UI kits, which can be reused across
 125 multiple pages and projects. Mendix[14] and OutSystems offer even more functionality to support reuse, offering several
 126 ways to end-users to share their code with each other, and offering pre-made components. Both of these platforms
 127 also utilize AI to enhance reuse. Outsystems provides AI suggestions to spot and create reusable pieces, while Mendix
 128 uses AI to suggest the best solutions and components for specific tasks. However, for both of these platforms, the AI
 129 suggestions provided are not always accurate to successfully guide the end-user to create custom reusable components.
 130 In order to analyze how block-based robotics environments address reuse, 4 representative platforms were compared:
 131 mBlock, MakeCode, SPIKE LEGO, VEXcode GO and Open Roberta. The comparison focused on three main dimensions
 132 of reuse: structural reuse (through user-defined blocks or functions), social reuse (through sharing or remixing existing
 133 projects), and interoperable reuse (through import/export capabilities).
 134

135
 136
 137
 138
 139
 140 Table 1. Block Based Robotics Environments Reuse Support
 141

Platform	Structural Reuse	Social Reuse	Interoperable Reuse	Reuse Support
VEXcode GO	X	X		Medium
mBlock	X	X	X	Medium
MakeCode	X	X	X	Medium
Spike Lego	X		X	Low
Open Roberta		X		Low

150 In this context, "reuse support" represents a scale that measures how effectively each platform facilitates reuse-related
 151 features. High reuse support indicates that users can easily create, share, and adapt existing components or projects.
 152 Medium reuse support suggests that some reuse mechanisms are available but limited in scope or flexibility. Low reuse
 153 support implies that the platform provides only minimal or restricted features to promote reuse.
 154

157 As shown in Table 1, although these platforms include reusability features, they are quite limited, as none of them
 158 provide users with clear guidance on how to use these tools effectively, which restricts their ability to fully leverage them.
 159

160 A study by Techapalokul and Tilevich (2019) suggests that supporting mechanisms for reusing smaller, modular
 161 pieces of code can enhance programmer productivity, creativity and learning outcomes. Adler et al. (2021) introduced a
 162 search-based refactoring approach to improve the readability of Scratch programs by automatically applying small code
 163 transformations, such as simplifying control structures and splitting long scripts. Their findings demonstrated that
 164 automated refactoring can significantly enhance code quality and readability for novice programmers. Building upon
 165 this concept, our project applies similar principles in the OpenRoberta environment, focusing on detecting duplicate
 166 code segments and guiding users toward creating reusable custom blocks to promote modularity and abstraction.[1].
 167

168 Existing block-based environments provide mechanisms for reuse, but lack intelligent support to help users recognize
 169 and apply reuse in practice. To address this gap, our project introduces a guided reuse assistant within the Open Roberta
 170 Lab environment. The tool is designed to help users identify and apply reuse more easily while creating their robot
 171 programs. It works by automatically scanning a user’s block-based program to detect repeated code segments in the
 172 workspace. The system visually highlights the found duplicates, drawing the user’s attention to patterns that could be
 173 simplified.
 174

175 The tool also offers the functionality to create the custom block for the end-user, by identifying the small differences
 176 between the repeated parts (such as numbers, variables, or parameters) and turning these differences into inputs for the
 177 new block. The tool automatically replaces all relevant duplicate sequences with the new custom block.
 178

179 By combining ideas from procedural abstraction (organizing code into meaningful, reusable parts) and automated
 180 refactoring (improving code through intelligent transformations), our tool aims to make block-based programming
 181 more structured and efficient. It encourages users to build programs that are modular and easier to maintain, helps
 182 reduce unnecessary repetition, and supports learning by making the concept of reuse clear and hands-on.
 183

184 3 Study Design

185 Following the Design Science methodology [16], our study is structured into three main phases: problem investigation
 186 to define goals, treatment design to specify the artifact requirements, and treatment validation to assess the artifact’s
 187 performance in a controlled environment.

188 3.1 Problem Investigation

189 *3.1.1 Problem Context and Motivation.* End-user development (EUD) for collaborative robots (cobots) presents unique
 190 challenges, particularly for users without formal programming training. In domains such as chemistry laboratories,
 191 educational robotics, and industrial settings, end-users need to program robots to perform specific tasks but often lack
 192 the software engineering knowledge to write maintainable, well-structured code. In the domain of Chemistry, one of
 193 the most relevant and important tasks is performing experiments in labs in order to test a hypothesis, or to aid in the
 194 understanding of how chemicals react. Robots can be used in chemistry labs to automate experiments with great effect,
 195 as many experiments involve steps that are repetitive, and susceptible to human error, such as a step being overlooked,
 196 instructions being misread, etc. Automation of menial tasks will leave the chemists with more time for other work, and
 197 also comes with the added bonus of chemists not having to handle dangerous chemicals.

198 One critical challenge in EUD is code reuse. Users frequently create repetitive code because they struggle to recognize
 199 duplicate patterns, lack knowledge about abstraction mechanisms, or find existing tools too complex to use effectively.
 200

209 This problem manifests in several ways: programs become unnecessarily long and difficult to maintain and small
 210 changes require modifications in multiple locations, increasing the risk of errors. So, while the use of robots in chemistry
 211 lab work offer great benefits, the challenge of automating the repetitive work may turn chemists away from using
 212 robots.
 213

214 3.1.2 *Stakeholder Analysis.* Chemists and lab technicians who use cobots for repetitive tasks such as sample prepa-
 215 ration, dispensing, mixing, and quality control procedures. They possess deep domain expertise in chemistry but
 216 limited programming knowledge, often creating long, repetitive programs that become difficult to maintain when
 217 adapting experimental protocols. Their primary need is to quickly create and modify robot programs without becoming
 218 programming experts.
 219

220 3.2 **Treatment Design**

221 To address the problem of code reuse in EUD for cobots, we have derived a set of requirements designed to contribute
 222 to the chemist's goal of creating maintainable and reusable robot programs. Functionally, the artifact must be capable
 223 of automatically detecting duplicate or similar block sequences and visually highlighting these duplications within
 224 the user's workspace. These requirements are necessary to help the end-user recognize opportunities for reuse, that
 225 would otherwise go unnoticed. Once detected, the system must suggest the creation of reusable custom blocks, allowing
 226 the user to accept or reject these suggestions. These signals are important, as they give the end-user control over the
 227 reuse process, allowing them to decide when and how to apply reuse in their programs. Regarding non-functional
 228 requirements, the artifact must seamlessly integrate with the existing Open Roberta Lab environment to ensure a
 229 smooth user experience. The interface should be intuitive for end-users, minimizing the learning curve and making it
 230 easy to understand and use the reuse features. Additionally, the artifact should not interfere with the existing workflow,
 231 allowing users to continue their programming tasks without disruption. Finally, clear visual feedback during the
 232 detection process is essential to help users understand what the system is doing and how to respond to its suggestions.
 233 To satisfy the requirements above, we designed the Reuse Assistant as an extension of Open Roberta Lab.
 234

235 3.2.1 *Architecture.* The system enables the execution of block-based programs on a simulated cobot through a three-tier
 236 architecture, as illustrated in figure 1. The workflow consists of the following stages:
 237

- 238 (1) **Client Side (Open Roberta):** The user interacts with the Open Roberta UI to assemble block sequences. The
 239 Reuse Assistant operates at this layer, analyzing blocks in real-time. Upon execution, the client generates specific
 240 data structures ("Generated Headers") representing the program logic.
- 241 (2) **Backend (Flask Server):** The client transmits these headers via HTTP POST requests to a Flask-based API
 242 Endpoint. A "Translator" component processes the data, mapping the abstract block definitions to concrete
 243 Python methods compatible with the robot's control logic.
- 244 (3) **Simulation (Mujoco):** The mapped methods trigger the execution of commands within the Mujoco Simulator,
 245 which renders the physical behavior of the cobot in the virtual environment.

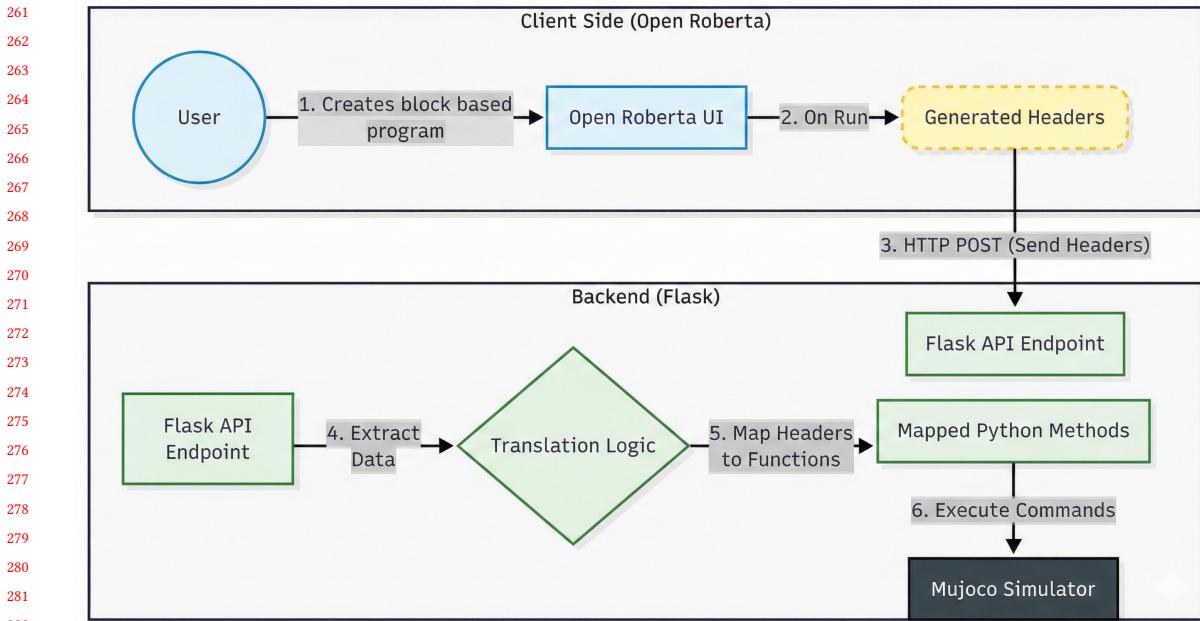


Fig. 1. System architecture: Data flow from Client Side to Simulator

3.2.2 *Detection Algorithm.* The approach is intentionally simple so it is easy to read and to implement in a real block editor. The algorithm follows three main steps:

- **Linearization:** First, the algorithm linearizes the block workspace into a sequential list of blocks.
- **Identify sequences:** It then iterates through this list to identify all possible sequences of blocks that meet a minimum unique block type length requirement (three blocks) that can be repeated more than once.
- **Sequences Matching:** If the same sequence of block types is found more than once, it will be added to the CustomReusableCandidates list which will eventually be sorted by longest and most recent duplicated sequences. In the end the highest priority candidate gets returned.

The pseudocode which is illustrated in Algorithm 1 is short, explicit, and uses straightforward data structures (lists).

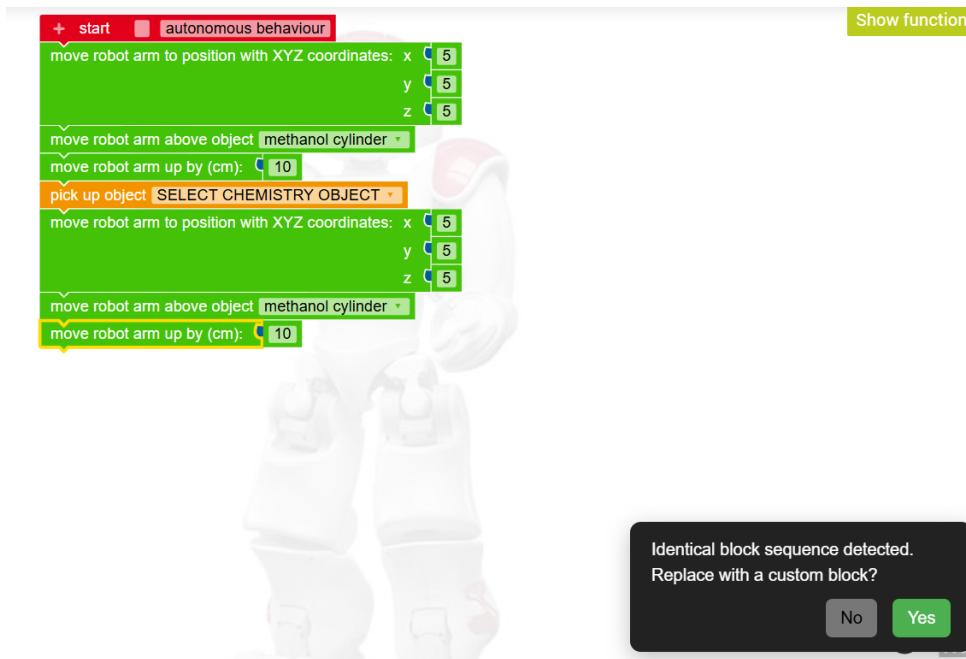
3.2.3 *User Interface and Interaction.* The user interface is designed to be intuitive and non-disruptive. When the detection algorithm identifies a candidate, the system visually highlights the blocks on the canvas as illustrated in Figure 2. A non-blocking toast notification appears, prompting the user to confirm the refactoring. If confirmed, the system automatically generates the custom block definition in a dedicated workspace area (handling visibility via `revealDefinitionWorkspacePane`) and updates the main workspace, replacing the redundant code with concise function calls as shown in Figure 3. This process abstracts the complexity of manual function creation, guiding the user toward modular design practices. After the user presses the run simulation button, the robot simulator of mujoco opens up and executes the commands provided by the user inside the Open Roberta workspace. This is illustrated in Figure 4.

313 **Algorithm 1** Illustrates the core logic for identifying duplicate block sequences in the user's workspace.

314 **Require:** Workspace, StartBlock // user's block workspace
 315 **Require:** MinimumSequenceLength = 3, MinimumDifferentBlockTypesInSequence = 3, MaxSequenceLength = 10
 316 **Ensure:** ReusableComponentCandidates // list of repeated block sequences to return

```

  317 1: Chain = buildLinearChain(StartBlock)
  318 2: Sequences = List<sequence>
  319 3: for startIndex = 0 to length(Chain) - 1 do
  320 4:   for sequenceLength = 1 to MaxSequenceLength do
  321 5:     sequence = Chain[startIndex .. startIndex + sequenceLength - 1]
  322 6:     numberofBlockTypesInSequence = getNumberOfDistinctBlockTypes(sequence)
  323 7:     if sequenceLength >= MinimumSequenceLength and numberofBlockTypesInSequence >= MinimumDifferentBlockTypesInSequence then
  324 8:       Sequences.append(sequence) // record sequence occurrence
  325 9:     end if
  326 10:   end for
  327 11: end for
  328 12: ReusableComponentCandidates = {Sequences | occurrence ≥ 2}
  329 13: sort ReusableComponentCandidates by (longest sequence length and most recent occurrence)
  330 14: return ReusableComponentCandidates[0] // Return highest priority candidate
  332
  
```



356 Fig. 2. Reuse Assistant workflow: detection - the interface detects and highlights duplicate blocks by changing their color to green.
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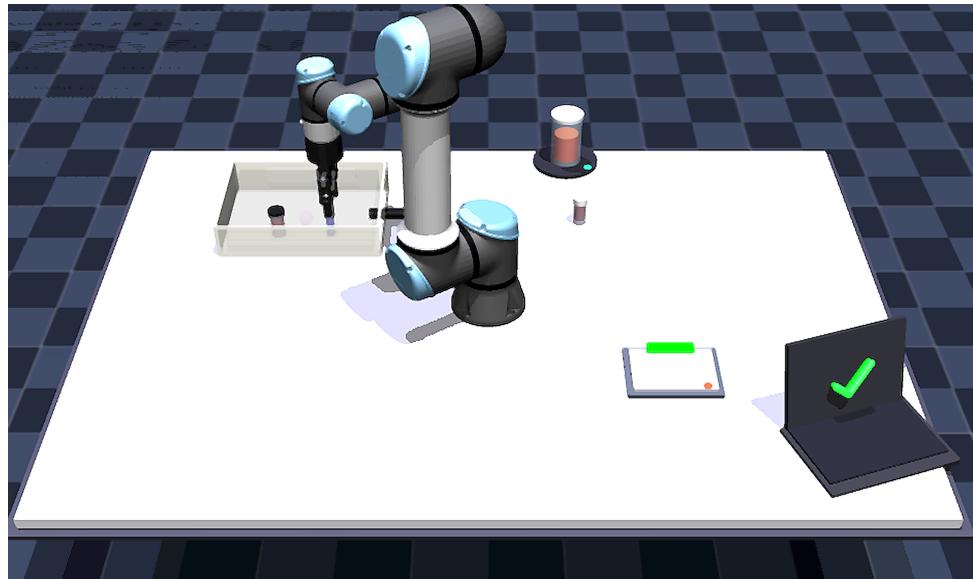
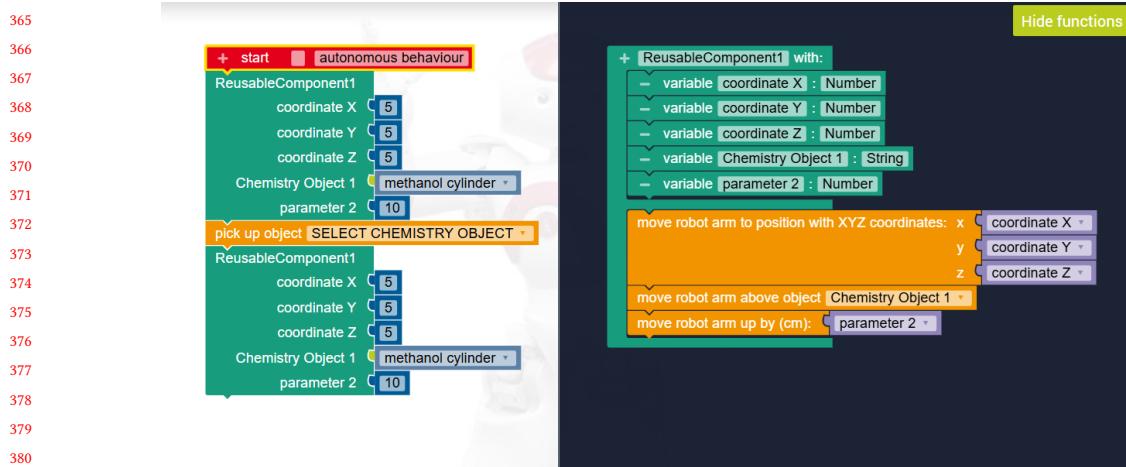


Fig. 4. Mujoco robot simulator executing the commands from Open Roberta.

417 **3.3 Treatment Validation**

418 The treatment validation for this study adopts a mixed-methods evaluation approach to assess the effectiveness of
 419 the proposed features for guiding users in creating custom reusable components (blocks) within the OpenRoberta
 420 environment.

421 *3.3.1 Participant Recruitment.* A total of 18 participants were selected with similar level of expertise in block-based
 422 programming. Participants were recruited from a diverse pool of individuals affiliated with the University of Southern
 423 Denmark and the broader chemistry community. This group of participants includes chemistry teachers, professional
 424 chemical engineers, and students currently enrolled in chemistry-intensive curricula. To ensure relevant practical
 425 expertise, the selection specifically targets those who frequently engage in laboratory environments. The experimental
 426 sessions were conducted across a range of environments to accommodate participant availability. Physical sessions took
 427 place within the chemistry laboratories at the University of Southern Denmark (SDU) as well as a private residential
 428 setting. For remote participants, sessions were administered virtually using Discord for communication and AnyDesk
 429 for remote desktop control.

430 *3.3.2 Task Execution.* The participants were initially given a short introduction to the OpenRoberta UI, as well as the
 431 mujoco robot simulator. They then performed one task which is described by a set of pre-defined steps to perform. This
 432 task has been specifically designed to promote the reusability aspect. The task is focused on the domain of chemistry,
 433 as it is modelled after a real lab experiment performed by chemistry students at SDU.

434 The participants were instructed to program the robot to execute the following sequence of operations:

- 441 (1) Move the robot arm above mix cylinder
- 442 (2) Mix the chemistry ingredients
- 443 (3) Move the robot arm above the analysis pad
- 444 (4) Analyze the sample
- 445 (5) If the solution is analyzed (use if statement) then show a response message in the laptop's screen
- 446 (6) Place the following three objects into their corresponding slots in the chemistry equipment toolbox:
 - 447 • Methanol cylinder
 - 448 • Chloroform syringe
 - 449 • Toluene syringe
- 450 (7) Important notes for the participants:
 - 451 • After placing an object to its slot in the toolbox **wait 2 seconds** before you move to pick a new one.
 - 452 • After placing the **chloroform syringe** to its slot, **move the robot arm up by 10 cm** before you move to pick the next chemistry object
 - 453 • Click the **play** button on the bottom right corner to start the simulation
 - 454 • Click the **reset** button on the bottom right corner to reset the scene of the robot simulator

455 Most optimal solution pre-defined by the researchers is illustrated in Figure 5. Instead of creating a long linear
 456 sequence of blocks, the most optimal solution utilizes a Custom Reusable Component to handle the repetitive action of
 457 placing an object to its corresponding slot inside the equipment toolbox. This approach not only reduces redundancy
 458 but also enhances code maintainability and readability, aligning with best practices in software development.

459 All the participants will try to complete the task using both the enhanced version of OpenRoberta that includes
 460 the Reuse Assistant benefits and the original one that does not. Half of the participants will begin solving the task

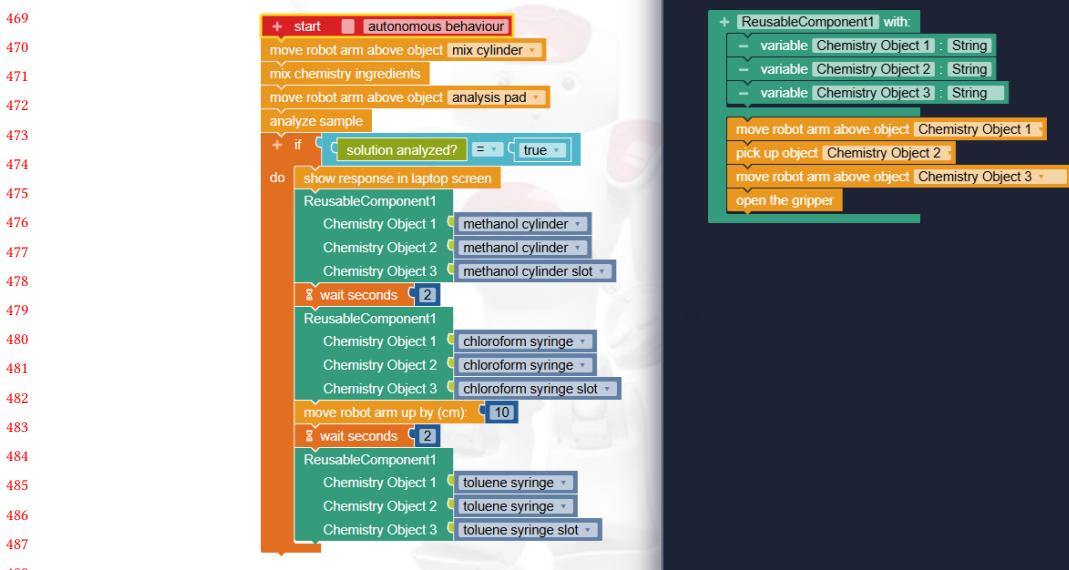


Fig. 5. The optimal solution implemented in OpenRoberta, utilizing a custom block for the object placement sequence.

first on the enhanced version, while the other half will start with the original version. Participants' interactions with the platform will be observed throughout the task. Guidance will be provided from the researchers to the participants throughout the task.

3.3.3 Data Gathering and Analysis. Data collection focuses on both quantitative performance and qualitative feedback from participants:

- (1) **Task Completion Time:** Measured in seconds for both conditions (Enhanced and Original) to evaluate efficiency gains. Statistical analysis employed paired t-tests to assess within-group improvements and a Welch's t-test to compare improvement scores between groups, specifically isolating the impact of the order effect arising from the sequence of conditions.
- (2) **Reuse adoption and functional correctness:** Evaluated by tracking the voluntary implementation of reusable custom blocks during the task. This primarily measured adoption rates (pass/fail of reuse implementation). Functional correctness was assessed by verifying if the robot successfully executed the chemical mixing protocol, with minor variations in safety steps deemed acceptable if they did not affect the simulation outcome.
- (3) **Usability Assessment:** Evaluated using the System Usability Scale (SUS) questionnaire to measure participants' perceived usability of the Reuse Assistant feature.
- (4) **Workload Assessment:** Measured using the NASA post-task Workload questionnaire (NASA-TLX) to assess the cognitive demands imposed by the Reuse Assistant across six dimensions (mental demand, physical demand, temporal demand, performance, effort, and frustration).

This comprehensive evaluation provided a detailed understanding of how useful and effective is the Reuse Assistant feature to the end-users.

521 **4 Results**

522 **4.1 Research Question 1: How does the Reuse Assistant affect the end-users' performance?**

523 To evaluate the impact of the Reuse Assistant on end-user performance, we measured task completion times for all
 524 participants under both conditions (Enhanced and Original versions of OpenRoberta). The study employed a within
 525 subjects design where participants were divided into two groups: Group A experienced the Enhanced version of
 526 OpenRoberta first, while Group B started with the Original version. This design allowed us to assess not only the
 527 feature's effectiveness but also the potential order effect arising from the learning curve between the two conditions.
 528

529 Tables 2 and 3 present the individual completion times for all participants across both conditions (with and without
 530 using the Reuse Assistant). The data reveal substantial variability in performance outcomes depending on the order in
 531 which the participants performed the tasks, with Group B participants showing consistent improvements when moving
 532 from the Original OpenRoberta version to the Enhanced, while Group A participants exhibited the opposite pattern.
 533

Participant ID	Performance with Reuse Assistant	Performance without Reuse Assistant	Difference
P01	481 seconds	331 seconds	150 seconds
P03	515 seconds	320 seconds	195 seconds
P06	733 seconds	314 seconds	419 seconds
P07	437 seconds	296 seconds	141 seconds
P09	453 seconds	348 seconds	105 seconds
P11	735 seconds	364 seconds	371 seconds
P13	610 seconds	407 seconds	203 seconds
P15	410 seconds	540 seconds	-130 seconds
P17	560 seconds	440 seconds	120 seconds

549 Table 2. Task Completion Times of group A

Participant ID	Performance with Reuse Assistant	Performance without Reuse Assistant	Difference
P02	411 seconds	477 seconds	-66 seconds
P04	189 seconds	435 seconds	-246 seconds
P05	200 seconds	367 seconds	-167 seconds
P08	266 seconds	485 seconds	-219 seconds
P10	259 seconds	506 seconds	-247 seconds
P12	450 seconds	720 seconds	-270 seconds
P14	540 seconds	670 seconds	-130 seconds
P16	335 seconds	400 seconds	-65 seconds
P18	540 seconds	862 seconds	-322 seconds

567 Table 3. Task Completion Times of group B

569 The paired boxplots 6 illustrate the impact of the Reuse Assistant on task completion times across the two counter-
 570 balanced groups. Both groups demonstrated a learning effect, achieving faster times in their second attempt regardless
 571

of condition. However, the magnitude of improvement differed substantially between the groups. Group A, which transitioned from using the Reuse Assistant to working without it, showed an average time reduction of 174.9s (Standard Deviation = 158.9s). In contrast, Group B participants, which operated without the feature benefits in their first attempt and utilized the Reuse Assistant in their second attempt, exhibited a significantly larger efficiency gain, with an average time reduction of 192.4 seconds (Standard Deviation = 90.9 seconds). This suggests that while task familiarity contributed to speed, the introduction of the Reuse Assistant provided a distinct performance advantage.

To statistically evaluate these observed differences, we conducted paired t-tests [8] and a Welch's t-test [15] to compare performance improvements between groups. Table 4 summarizes the statistical test results, including overall comparisons, within-group improvements, and the analysis of the order effect.

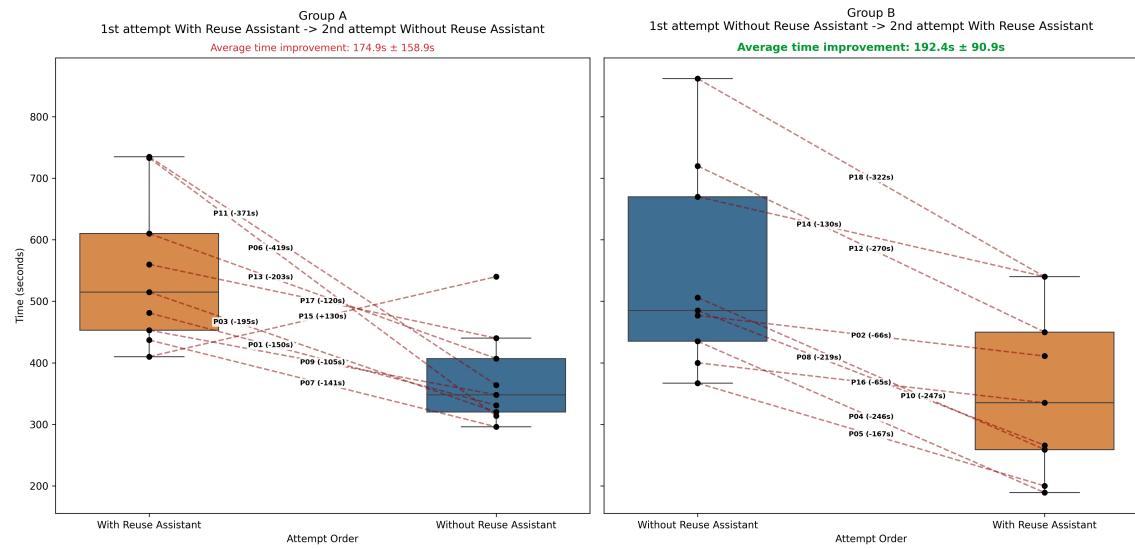


Fig. 6. Distribution of task completion times (in seconds) comparing Group A and Group B participants across both conditions (with and without Reuse Assistant).

Test	t-Value	p-value
Overall Comparison	-0.16	0.872
Group A Improvement	3.30	0.011
Group B Improvement	-6.35	< 0.001
Order Effect	6.02	< 0.001

Table 4. Statistical Test Results

4.1.1 *Performance statistical analysis.* The analysis reveals distinct patterns between the two groups and identifies a significant carryover effect.

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625 *Overall Comparison.* When combining all 18 participants regardless of the order in which they experienced the
 626 two OpenRoberta versions (the one with the reuse assistant feature benefits and the other without them), the overall
 627 mean time difference was -8.78 seconds (Standard Deviation = 226.90), leading to a t-value = -0.16 ($p = 0.872$). This
 628 non-significant result indicates no overall difference when order is ignored.
 629

630
 631 *Group A Analysis.* Group A participants experienced the benefits of the Reuse Assistant in their first attempt and then
 632 tried to solve the task without them in their second attempt. The mean difference (Completion time with Reuse Assistant
 633 - Completion time without Reuse Assistant) was 174.9 seconds (Standard Deviation = 158.9 seconds), producing a
 634 significant result with a t-value of 3.30 ($p = 0.011$). The positive value indicates that these participants were *faster* on
 635 their second attempt which was without the Reuse Assistant benefits.
 636

637
 638 *Group B Analysis.* Group B participants experienced the benefits of the Reuse Assistant in their second attempt and
 639 tried to solve the task without them in their first attempt. We calculated the time difference (Completion time with
 640 Reuse Assistant - Completion time without Reuse Assistant) for each participant. The mean improvement was -192.44
 641 seconds (SD = 90.91), yielding a t-value of -6.35 ($p < 0.001$). This statistically significant result demonstrates that these
 642 participants were a lot *faster* on their second attempt which was with the Reuse Assistant benefits. The low standard
 643 deviation reveals that there was a consistent pattern in how much faster participants worked with the feature.
 644

645
 646 *Order Effect Analysis.* To determine whether the order in which participants experienced the two versions influenced
 647 their performance, we conducted a Welch's t-test, comparing the improvement scores between Group A and Group B.
 648 This analysis revealed a highly significant order effect ($t = 6.02, p < 0.001$).

649
 650 The difference between the two groups was massive with a gap of 367 seconds. Group B participants, who started
 651 the task without the Reuse Assistant, finished 192 seconds faster once they had the Reuse Assistant benefits. In contrast,
 652 Group A participants started with the Reuse Assistant, but they actually took 175 seconds longer to finish compared to
 653 their subsequent performance in the unassisted condition.
 654

655
 656 This big difference points to a strong learning effect. The results show that participants were faster mainly because
 657 they got used to the problem, not just because of the benefits of the Reuse Assistant. It did not matter if they started
 658 with the Reuse Assistant or without it. The experience from the first try made the second attempt to solve the task
 659 much easier.
 660

661 *4.1.2 Summary of Findings.* The Reuse Assistant effectively helped the end users complete the task faster. We can
 662 conclude this by comparing the average time differences and standard deviations between the two groups of participants.
 663

664 Participants in Group B improved their time by an average of 192.4 seconds when they switched to using the feature.
 665 This is a larger change than Group A. Participants in Group A were slower by an average of 174.9 seconds when they
 666 stopped using the feature. This shows that the gain from adding the assistant was greater than the loss from removing
 667 it.
 668

669 The standard deviation also tells us about consistency. Group B had a low standard deviation of 90.9 seconds. In
 670 contrast, Group A had a much higher standard deviation of 158.9 seconds. This means that the performance boost was
 671 not only larger but also more consistent when users utilized the Reuse Assistant.
 672

673 Finally, the statistical strength confirms this result. The t-value for Group B is -6.35. This is much stronger than the
 674 t-value for Group A which is 3.30. Since the Group B result is statistically more significant, we can say that the Reuse
 675 Assistant provides a clear and robust performance advantage.
 676

677 4.2 Research Question 2: To what extent does the reuse assistant facilitate reusability?

678 4.2.1 How much does the reuse assistant promote reusability?

680
681 *Adoption of Reusable Blocks.* In the *Enhanced OpenRoberta* version that includes the Reuse Assistant feature, 18/18
682 participants successfully implemented a custom reusable block to handle the repetitive object placement steps. In
683 contrast, in the *Standard OpenRoberta* version that doesn't have the Reuse Assistant benefits, participants predominantly
684 relied on linear, repetitive code structures. Without the guidance features, none of them recognized the opportunity to
685 create a reusable block.
686

687
688 *4.2.2 Summary of Findings.* The Reuse Assistant promotes reusability by automating the manual effort required to
689 build reusable blocks. It achieves this by lowering the cognitive and technical barriers associated with identifying and
690 abstracting repetitive patterns.
691

692 Specifically, the system promotes reusability through a three-step mechanism: detection, intervention, and automation.
693 First, the feature identifies and highlights duplicate block sequences within the user's block based program. Second, it
694 interrupts the linear workflow with a binary decision prompt, offering the user an immediate choice to refactor. Finally,
695 upon confirmation, the system automatically encapsulates the repetitive block sequence logic into a reusable block,
696 defines the necessary parameters if needed, and replaces the repetitive sequences with the reusable block.
697

698 The contrast in results, 0% adopted a reusable block in the Standard OpenRoberta version that does not include the
699 Reuse Assistant versus 100% in the Enhanced version that includes the feature's benefits, demonstrates that users do
700 not lack the ability to understand functions, but rather the initiative to implement them manually. By removing the
701 effort required to define, parameterize, and call a function block, the Reuse Assistant transforms reusability from a
702 complex manual task into a seamless, automated decision.
703

704
705 4.3 Research Question 3: How do the end-users assess the reuse assistant in terms of usability?

706 To answer this research question regarding the perceived usability of the system, we administered the System Usability
707 Scale (SUS) questionnaire (see Appendix A for the full questionnaire details) to all $N = 18$ participants immediately
708 following the treatment validation.
709

710 The SUS yields a single number representing a composite measure of the overall usability of the system, with scores
711 ranging from 0 to 100.
712

713
714 *4.3.1 Overall Usability Scores.* The analysis of the survey data yielded a mean SUS score of **84.0** (*Median* = 81.25).
715 According to the interpretive ranges defined by Bangor et al. [2], a score above 80.3 is considered "Excellent" and places
716 the system in the top 10% of products in terms of usability.
717

718 As illustrated in the figure 7, the individual scores ranged from a low of 52.5 to a perfect score of 100. Notably, 94% of
719 participants (17 out of 18) rated the system above the industry average of 68, with the majority falling into the "Excellent"
720 or "Very Good" categories.
721

722
723 *4.3.2 Distribution Analysis.* The results show that users found the system very easy to use. 17 out of 18 participants
724 (94%) rated it above the industry average of 68. The scores mostly split into two high-performing groups: eight people
725 rated it as "Excellent" (85–100), and nine people rated it as "Very Good" (75–80). This suggests that almost everyone
726 understood how to use the system right away.
727

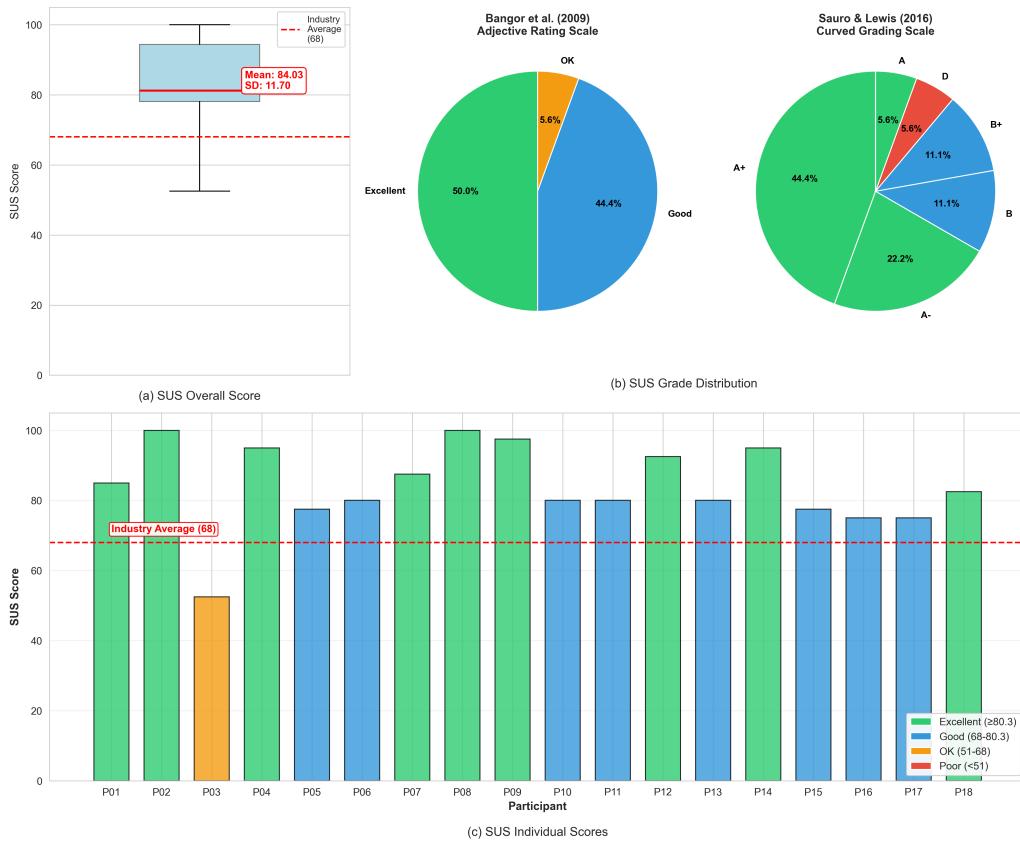


Fig. 7. System Usability Scale (SUS) Analysis Results. (a) Distribution of SUS Scores among Participants. (b) Dual classification showing Bangor et al.'s adjective ratings (left) and Sauro & Lewis letter grades (right).

The scores ranged from 52.5 to 100, with a high average score of 84.0. It is worth noting that 17 of the users had scores very close to each other (between 75 and 100), which proves the system is consistently easy to use for most people.

There was only one exception: a single user scored the system at 52.5. This person mentioned needing more technical help and time to learn based on this user's answers. While this shows there might be a small learning curve for some, it was an isolated case and does not change the overall positive feedback.

4.3.3 Summary of Findings. End-users assess the Reuse Assistant as an exceptionally usable system. They rate it as "Excellent" and evaluate it with a high degree of consistency.

First, users judge the system to be far superior to the industry standard. They gave it an average score of 84.0 which is much higher than the typical average of 68. This shows that users perceive the feature as significantly easier to use than standard software.

781 Second, users assess the system with strong agreement. 17 out of 18 participants rated the usability above 75. This
 782 tight clustering of scores proves that the positive experience was uniform across the group. Almost every user agreed
 783 that the feature was intuitive.
 784

785 Third, users evaluate the system as easy to learn. The high scores indicate that participants felt confident operating
 786 the feature immediately. They did not struggle to understand how it worked. Therefore, users assess the Reuse Assistant
 787 as a polished and highly accessible solution.
 788

789 **4.4 Research Question 4: How do the end-users assess the perceived workload when operating the Reuse
 790 Assistant?**

791 To assess the cognitive demands imposed by the Reuse Assistant, we administered the NASA Task Load Index (NASA-
 792 TLX) questionnaire (see Appendix B for the full questionnaire details) to all participants after completing the task with
 793 the Reuse Assistant benefits. The NASA-TLX is a widely used multidimensional assessment questionnaire that measures
 794 perceived workload across six subscales, each rated on a scale from 1 (Very Low) to 10 (Very High). The scores were
 795 calculated by multiplying each rating by 10 to convert them to a 0-100 scale.
 796

797 *4.4.1 Overall Workload Assessment.* As illustrated in figure 8, the Reuse Assistant imposes a remarkably low workload
 798 on users, with an overall mean score of **20.00**. This indicates that the feature is highly usable and demands very little
 799 effort from the user in terms of physical or mental cost.
 800

801 *4.4.2 Dimension-Specific Analysis.* There is a distinct contrast between the highest and lowest contributing factors:
 802

- 803 • **Lowest Demand (Temporal):** With a mean score of **10.6**, Temporal Demand was negligible. This confirms
 804 that users felt **zero time pressure**, allowing them to work at their own pace without stress.
 805
- 806 • **Highest Demand (Effort):** Effort received the highest rating (**30.00**), yet this is still considered “Low” on
 807 a 100-point scale. This suggests a positive trade-off: users were cognitively engaged (concentrating) but not
 808 overworked. The feature requires attention, but not exhaustion.
 809

810 *4.4.3 Consistency and Outlier Analysis.* The data shows high consistency among the 18 participants, with one notable
 811 exception:
 812

- 813 • **The Outlier (P03):** Participant P03 reported a “Moderate” workload (Mean: **43.3**), rating several dimensions at
 814 5/10. This deviation suggests that while the feature is intuitive for the vast majority, a small subset of users may
 815 lack specific prerequisite knowledge or experience an edge-case interaction.
 816
- 817 • **Consistency:** When excluding P03, the mean workload for the remaining 17 participants drops to **18.6**.
 818 Furthermore, **94%** of users (17/18) reported an overall workload below 30.0. This strong consistency statistically
 819 validates the Reuse Assistant as a low-load feature for the target population.
 820

821 *4.4.4 Summary of findings.* Participants assess the perceived workload of the Reuse Assistant as remarkably low. The
 822 data indicates that operating this specific feature imposes very little mental or physical cost on the user.
 823

824 Specifically, participants evaluate the feature’s workload with an overall mean score of 20.0 on a scale of 100. This is
 825 exceptionally low and proves that the feature itself is easy to understand and handle.
 826

827 Furthermore, participants assess the “Effort” required to use the feature as manageable. While “Effort” was the highest
 828 rated factor (30.0), it remains in the low range. This distinction is important: it shows that users were concentrating on
 829 the feature’s feedback (engaged), but the interaction did not overwork them. Finally, this assessment is highly consistent,
 830 Manuscript submitted to ACM
 831

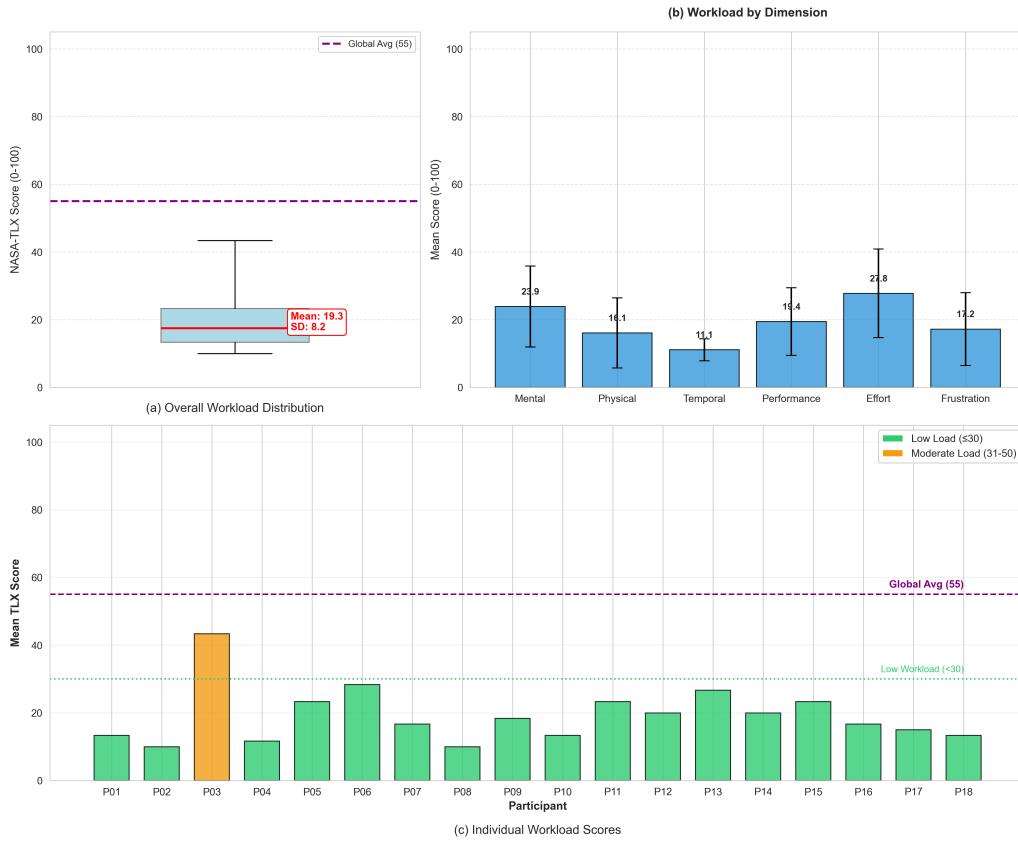


Fig. 8. NASA-tlx workload analysis results. (a) Distribution of NASA-TLX overall workload score (b) Mean workload scores for each dimension. (c) Distribution of workload scores across participants.

with 94% of users reporting a low workload. Therefore, participants perceive the Reuse Assistant as a supportive feature that aids their work without adding new cognitive burdens.

5 Discussion

This study evaluated the Reuse Assistant, an automated guidance feature designed to help end-users recognize and implement code reuse in block-based programming environments. Through a crossover study with 10 participants from the chemistry domain, we assessed the feature's impact on performance (RQ1), usability (RQ2), and perceived workload (RQ3). The findings reveal both the potential and limitations of automated assistance in promoting software reuse practices among domain experts with limited programming expertise.

5.1 Implications for Theory

5.1.1 Reducing Attention Investment through Proactive Assistance. Our study provides empirical support for the Attention Investment Model [4] as applied to end-user development tools. The Attention Investment Model states that users make rational decisions about whether to adopt new tools or features based on a cost-benefit analysis of the attention they

885 must invest upfront versus the perceived benefits they expect to receive, as well as the risk of there being no payoff at
 886 all [5]. The higher the upfront attention cost (learning curve, discovery effort, comprehension requirements), the less
 887 likely users are to adopt and utilize available features, even when those features would ultimately benefit their work.
 888

889 In the standard OpenRoberta environment, creating reusable custom blocks requires users to: (1) recognize that code
 890 duplication exists and represents an opportunity for abstraction, (2) discover that custom block functionality is available
 891 in the system, (3) locate where this feature resides in the interface, (4) understand how to use the feature correctly, and
 892 (5) manually configure the custom block with appropriate parameters. This multi-step process represents a large upfront
 893 attention investment that end-users, focused on their primary domain tasks rather than software engineering practices,
 894 are unwilling or unable to make. In this study the result was 0% adoption of reusable components while using the
 895 standard OpenRoberta Lab, despite participants possessing the cognitive capacity to understand and use custom blocks
 896 when guided to do so. The Reuse Assistant changes this attention investment equation by eliminating steps 1-4 entirely.
 897 Users do not need to recognize duplication patterns (the system detects them automatically), discover the feature
 898 exists (the system actively presents opportunities), locate the feature in the interface (visual highlighting brings the
 899 opportunity directly to users' attention), or understand complex configuration procedures (automated parameterization
 900 handles technical details). The upfront attention investment is reduced to a single decision: accept or reject the system's
 901 suggestion. This dramatic reduction in cognitive cost (from a complex multi-step learning process to a binary choice)
 902 explains the 100% adoption rate in the Enhanced condition.

903 Our findings extend the Attention Investment Model [4] by demonstrating that proactive, context-aware assistance
 904 can transform feature adoption from an investment decision into an opportunistic choice. Rather than requiring users
 905 to invest attention before experiencing any benefit, the Reuse Assistant delivers immediate, real value (highlighted
 906 duplicates, one-click refactoring) that users can evaluate in real-time within their workflow. This "zero-cost trial"
 907 approach eliminates the adoption barrier built-in to traditional feature-discovery models, where users must commit
 908 attention resources before knowing whether the investment will prove worthwhile [5].
 909

910 *5.1.2 Addressing the Selection Barrier in End-User Development.* The results provide empirical evidence for a critical
 911 distinction between different types of barriers to software reuse within Ko et al.'s [10] learning barriers framework.
 912 Among the six barriers identified by Ko and colleagues (design, selection, coordination, use, understanding, and
 913 information barriers), our work specifically addresses the *selection barrier*: the difficulty users face in knowing where to
 914 look for features and choosing appropriate tools from the available options.

915 The selection barrier appears in two distinct ways in block-based programming environments [10]. First, users must
 916 know that reuse mechanisms exist and where to find them within the interface. Second, even when aware of available
 917 features, users must determine when and how to apply them appropriately. Our 0% adoption rate in the standard
 918 OpenRoberta condition demonstrates that the selection barrier is difficult to overcome for domain experts without
 919 programming backgrounds, even when the interface provides the necessary functionality. Participants did not lack the
 920 capability to create custom blocks (the same individuals achieved 100% adoption in the Enhanced condition) but rather
 921 lacked the knowledge of where to look for this feature and when to apply it.

922 The Reuse Assistant eliminates the selection barrier through two supporting mechanisms. First, automated detection
 923 makes the feature location irrelevant. Users do not need to search the interface because the system proactively brings
 924 the functionality to their attention at the appropriate moment. Second, context-aware suggestions eliminate the decision
 925 burden about when to apply reuse. The system identifies appropriate opportunities and presents them when relevant,
 926 allowing users to focus on domain-level acceptance decisions rather than technical feature selection.

937 This finding extends Ko et al.'s framework by demonstrating that in block-based environments targeting end-users,
 938 the selection barrier comes before and is more important than other barriers. The low NASA-TLX workload scores
 939 (mean: 1.92) and high SUS scores (mean: 84.03) indicate that once the selection barrier is removed, once users no longer
 940 need to find and choose features, the remaining barriers (use, understanding, coordination) impose minimal mental
 941 burden. This suggests that tool designers should prioritize eliminating selection barriers through proactive assistance
 942 before addressing other barrier types, as the latter become manageable once users are successfully guided to appropriate
 943 features.
 944

945 *Relationship Between Recognition and Selection Barriers.* While Ko et al.'s selection barrier focuses on knowing where
 946 to look for features, our work identifies a related but distinct *recognition barrier* specific to code reuse: users' inability
 947 to identify opportunities for abstraction within their own code. These barriers are complementary. Even if users know
 948 where the custom block feature is located (overcoming the selection barrier), they cannot use it effectively without
 949 recognizing when their code contains patterns suitable for abstraction (overcoming the recognition barrier). Our Reuse
 950 Assistant addresses both barriers simultaneously through automated pattern detection (recognition) and proactive
 951 presentation (selection), explaining the dramatic shift from 0% to 100% adoption.
 952

953 *5.1.3 The Order Effect: Prior Experience as a Prerequisite for Appreciating Automation.* The significant order effect
 954 ($t=-4.37$, $p=.008$) reveals a counter-intuitive finding: participants who received automated assistance first were actually
 955 slower to complete tasks than those who first struggled with the manual approach. This 481-second performance gap
 956 suggests that automation effectiveness depends on users having established mental models of the problem space.
 957

958 This finding has theoretical implications for understanding how end-users learn to value productivity tools. Participants
 959 in Group B (Original → Enhanced) developed an experiential baseline that allowed them to recognize what the
 960 automation was helping them avoid. In contrast, Group A participants (Enhanced → Original) lacked this reference
 961 frame, potentially viewing the automated suggestions as interruptions rather than assistance.
 962

963 This aligns with theories of learning transfer and expertise development [10], suggesting that some exposure to
 964 manual processes may be valuable for teaching before introducing automation. It challenges the assumption that "easier
 965 is always better" in tool design, indicating that mental struggle during initial learning may enhance appreciation and
 966 effective use of advanced features.
 967

968 5.2 Implications for Practice

969 *5.2.1 High Usability and Low Workload Support Simple Design Principles.* The SUS results (mean: 84.03) place the Reuse
 970 Assistant in the "Excellent" category, with 94% of participants (17 out of 18) rating it above the industry average of 68.
 971 This high usability score demonstrates that automated guidance can be both powerful and easy to use. The feature
 972 achieved this by focusing on simplicity: visual highlighting to show duplicates and one-click acceptance to create
 973 reusable blocks. This suggests that effective end-user features should prioritize clarity over complexity.
 974

975 The NASA-TLX workload results (mean: 2) further support this finding, showing that effective guidance does not
 976 require complex interactions. The combination of high SUS scores and low NASA-TLX workload scores demonstrates
 977 that the Reuse Assistant successfully reduces barriers without adding cognitive burden. The key to this success is
 978 directly showing users duplicate code patterns through visual highlighting and providing one-click refactoring, rather
 979 than adding complexity.
 980

981 The bimodal distribution in both SUS scores and NASA-TLX workload (with one outlier for each) suggests that while
 982 most users experience minimal burden, a small subset encounters significant difficulties. This pattern indicates individual
 983

989 differences in openness to automated guidance, potentially related to prior mental models, learning preferences, or
 990 comfort with system-initiated interactions.
 991

992 5.2.2 *From Passive Toolboxes to Active Assistants.* Current block-based programming environments (Scratch, Blockly,
 993 standard OpenRoberta) follow a passive interaction model where reuse mechanisms exist as features waiting to be
 994 discovered. The 0% adoption rate in the standard condition demonstrates the limitations of this approach for the
 995 end-users, as participants created functional but non-optimal solutions using linear, repetitive code structures. The 100%
 996 adoption rate with the enhanced OpenRoberta version proves that tool designers must shift from providing capabilities
 997 to actively guiding their use.
 998

1000 5.3 Threats to Validity

1001 5.3.1 Internal Validity.

1002 1005 *Carryover effect.* While the within subjects design allowed within-subjects comparison, the significant carryover
 1006 effect ($p < 0.001$) indicates that the sequence of conditions fundamentally altered the user experience. This carryover
 1007 effect means we cannot cleanly separate the impact of the Reuse Assistant from the impact of prior experience. The
 1008 417 seconds performance gap between the two groups' average time differences suggests that learning from the first
 1009 condition substantially influenced performance in the second condition.
 1010

1011 *Mitigation:* We explicitly analyzed and reported the carryover effect as a finding rather than treating it as unwanted
 1012 noise. Furthermore, the experiments were balanced, meaning half of the participants performed the task with the Reuse
 1013 Assistant first, then again using the standard OpenRoberta. The other half did the reverse sequence. In this way, the
 1014 overall effect on the results is minimized.
 1015

1016 5.3.2 External Validity.

1017 1019 *Convenience Sampling and Population Representation.* Participants were recruited through the researchers' professional
 1020 networks, creating a convenience sample. This introduces several limitations:
 1021

- 1022 • **Geographic and institutional diversity:** While the study included participants from multiple countries
 1023 (both local and international participants connected online), recruitment relied primarily on the researchers'
 1024 professional networks, which may not represent the full geographic and cultural diversity of potential end-users
 1025 in the domain of chemistry.
 1026
- 1027 • **Domain representation:** While participants came from diverse scientific backgrounds (chemistry, agronomy,
 1028 biochemistry) united by laboratory coursework experience, they represent primarily academic contexts rather
 1029 than industrial laboratory settings where cobot programming would be used professionally.
 1030
- 1031 • **Sample size:** With 18 participants for performance evaluation, usability assessment and workload assessment,
 1032 the study lacks statistical power to detect small effects or to adequately characterize rare user profiles(outliers),
 1033 limiting the generalizability of findings to broader populations.
 1034

1035 1036 *Implications:* Findings should be interpreted as preliminary evidence rather than final proof of effectiveness across
 1037 all end-user developer populations. Replication studies with larger, more diverse samples from multiple institutions and
 1038 countries are necessary to establish the robustness of these results.
 1039

1041 Ecological Validity: Laboratory vs. Authentic Use. The study was conducted in a controlled setting with researcher
1042 guidance available, tasks completed in a single session, and no real-world consequences for errors. This differs from
1043 authentic usage where:

- 1045** • Users work independently without expert support
- 1046** • Programming tasks span multiple sessions with interruptions
- 1047** • Errors in cobot programs could damage equipment or compromise experiments
- 1048** • Users balance programming with their primary professional responsibilities

1049
1050 Mitigation: We included chemistry domain experts as participants rather than generic users, and the task was based
1051 on actual laboratory procedures. However, long-term field studies observing the Reuse Assistant in authentic work
1052 contexts are necessary to validate its practical impact.
1053

1054 5.3.3 Construct Validity.

1055 Measurement Instruments. We used standardized instruments (SUS questionnaire, NASA-TLX questionnaire) which
1056 have established validity in usability and cognitive workload research. However:

- 1057** • **SUS limitation:** SUS assesses subjective usability perception rather than objective usability metrics, such as
1058 error rates or task success beyond completion time.
- 1059** • **NASA-TLX limitation:** NASA-TLX assesses subjective workload perception, which may not correlate perfectly
1060 with objective cognitive load or learning outcomes.

1061 6 Conclusion and Future Work

1062 This study examined whether automated guidance can help end-users recognize and apply code reuse in block-based
1063 programming. We developed the Reuse Assistant, a tool that automatically detects duplicate code sequences and guides
1064 users to create reusable custom blocks in the OpenRoberta environment.
1065

1066 The results showed a clear difference in reuse adoption. While no participants created reusable blocks in the standard
1067 environment, all participants successfully created reusable blocks when help from the Reuse Assistant was available.
1068 The feature received high usability ratings (SUS mean: 84.03) and low workload scores (NASA-TLX mean: 1.92),
1069 demonstrating that automated guidance can be both effective and easy to use.
1070

1071 Our findings contribute to theory by extending the Attention Investment Model and the Learning Barriers Framework.
1072 We showed that proactive assistance reduces the upfront cost of adopting new features and that the selection barrier
1073 is particularly important in block-based environments for end-users. The significant order effect revealed that prior
1074 manual experience helps users appreciate automation benefits.
1075

1076 For practice, this study demonstrates that simple design choices matter. Visual highlighting, one-click acceptance,
1077 and immediate feedback were sufficient to achieve high adoption of reusable blocks without adding complexity. The
1078 results suggest that programming environments for domain experts should actively guide users rather than waiting for
1079 them to discover features independently.
1080

1081 6.1 Future Work

1082 Future research should test the Reuse Assistant in real laboratory settings over extended periods to determine whether
1083 users learn to recognize reuse opportunities independently. Studies with more participants from diverse backgrounds
1084

would help identify which user groups benefit most from automated guidance. The feature should also be evaluated with more complex programming tasks and tested in other end-user programming environments beyond OpenRoberta.

References

- [1] Felix Adler, Gordon Fraser, Eva Gründinger, Nina Körber, Simon Labrenz, Jonas Lerchenberger, Stephan Lukasczyk, and Sebastian Schweikl. 2021. Improving Readability of Scratch Programs with Search-Based Refactoring. In *Proceedings of the IEEE/ACM 43rd International Conference on Software Engineering: Companion Proceedings (ICSE-SEET)*. IEEE. doi:10.1109/ICSE-Companion.2021.00105
- [2] Aaron Bangor, Philip Kortum, and James T Miller. 2009. Determining what individual SUS scores mean: Adding an adjective rating scale. *Journal of usability studies* 4, 3 (2009), 114–123.
- [3] Len Bass, Paul Clements, and Rick Kazman. 2021. *Software Architecture in Practice, 4th Edition*. Addison-Wesley Professional.
- [4] Alan F. Blackwell. 2002. First Steps in Programming: A Rationale for Attention Investment Models. In *Proceedings of the IEEE Symposia on Human Centric Computing Languages and Environments*. IEEE Computer Society, 2–10. doi:10.1109/HCC.2002.1046334
- [5] Alan F. Blackwell and Thomas R. G. Green. 2003. Notational Systems - The Cognitive Dimensions of Notations Framework. *HCI Models, Theories, and Frameworks: Toward a Multidisciplinary Science* (2003), 103–133.
- [6] Alexander Bock and Ulrich Frank. 2021. Low-Code Platform. *Business and Information Systems Engineering* 63 (2021). doi:10.1007/s12599-021-00726-8
- [7] John Brooke. 1996. SUS: A 'Quick and Dirty' Usability Scale. In *Usability Evaluation in Industry*, Patrick W. Jordan, Bruce Thomas, Bernard A. Weerdmeester, and Ian L. McClelland (Eds.). Taylor & Francis, London, 189–194.
- [8] Jay L Devore. 2015. *Probability and Statistics for Engineering and the Sciences* (9th ed.). Cengage Learning, Boston, MA.
- [9] Sandra G Hart and Lowell E Staveland. 1988. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In *Human Mental Workload*, Peter A Hancock and Najmedin Meshkati (Eds.). North-Holland, Amsterdam, 139–183.
- [10] Andrew J. Ko, Brad A. Myers, and Htet Htet Aung. 2004. Six Learning Barriers in End-User Programming Systems. *IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)* (2004), 199–206. doi:10.1109/VLHCC.2004.47
- [11] Yuhang Lin and David Weintrop. 2021. The Landscape of Block-Based Programming: Characteristics of Block-Based Environments and How They Support the Transition to Text-Based Programming. *Journal of Computer Languages* 67 (2021), 101075. doi:10.1016/j.jcola.2021.101075
- [12] Hugo Lourenço, Carla Ferreira, and João Costa Seco. 2021. OSTRICH - A Type-Safe Template Language for Low-Code Development. In *2021 ACM/IEEE 24th International Conference on Model Driven Engineering Languages and Systems (MODELS)*. 216–226. doi:10.1109/MODELS50736.2021.00030
- [13] Vlad Magdalin. 2012. Low code platform tool Webflow. <https://webflow.com/>.
- [14] Derek Roos. 2005. Low code platform tool Mendix. <https://www.mendix.com/>.
- [15] Bernard L Welch. 1947. The generalization of 'Student's' problem when several different population variances are involved. *Biometrika* 34, 1-2 (1947), 28–35. doi:10.1093/biomet/34.1-2.28
- [16] Roel J. Wieringa. 2014. *Design Science Methodology for Information Systems and Software Engineering*. Springer, Berlin, Heidelberg. doi:10.1007/978-3-662-43839-8

A System Usability Scale (SUS) Questionnaire

The System Usability Scale (SUS) is a widely used standardized questionnaire for assessing the perceived usability of a system. Participants respond to each statement using a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree). The SUS score is calculated by converting the responses to a scale of 0-100, where higher scores indicate better usability.

A.1 SUS Statements

- (1) I think that I would like to use the Reuse Assistant feature frequently.
- (2) I found the Reuse Assistant feature unnecessarily complex.
- (3) I thought the Reuse Assistant feature was easy to use.
- (4) I think that I would need the support of a technical person to be able to use the Reuse Assistant feature.
- (5) I found the various functions in the Reuse Assistant feature were well integrated.
- (6) I thought there was too much inconsistency in the Reuse Assistant feature.
- (7) I would imagine that most people would learn to use the Reuse Assistant feature very quickly.
- (8) I found the Reuse Assistant feature very cumbersome to use.

- 1145 (9) I felt very confident using the Reuse Assistant feature.
 1146 (10) I needed to learn a lot of things before I could get going with the Reuse Assistant feature.

1148 **A.2 Scoring Method**

1150 We calculate the System Usability Scale (SUS) score based on the standard method defined by Brooke [7]. The process
 1151 consists of three steps:

- 1153 (1) **Normalize the responses:**
 1154 • For **odd-numbered** items (1, 3, 5, 7, 9), subtract 1 from the user response.
 1155 • For **even-numbered** items (2, 4, 6, 8, 10), subtract the user response from 5.
 1156 This converts every answer to a range of 0 to 4.
 1157 (2) **Sum the contributions:** Add the normalized scores for all 10 items together.
 1158 (3) **Scale the total:** Multiply the sum by 2.5 to convert the range from 0–40 to 0–100.

1160 Formally, if x_i is the score for the i -th question, the total SUS score is given by:

$$1163 \text{SUS Score} = 2.5 \times \left(\sum_{i \in \text{odd}} (x_i - 1) + \sum_{i \in \text{even}} (5 - x_i) \right)$$

1166 **B NASA-TLX post-task Questionnaire**

1167 The NASA Task Load Index (NASA-TLX) [9] is a multi-dimensional questionnaire that provides an overall workload
 1168 score based on a weighted average of ratings on six subscales. For this study, we utilized the "Raw TLX" method
 1169 (unweighted). Participants rated the following six dimensions on a scale from 1 (Very Low) to 10 (Very High), which
 1170 were then normalized to a 0–100 scale.

- 1172 (1) **Mental Demand:** How much mental and perceptual activity was required (e.g., thinking, deciding, calculating,
 1173 remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or
 1174 forgiving?
 1175 (2) **Physical Demand:** How much physical activity was required (e.g., pushing, pulling, turning, controlling,
 1176 activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
 1177 (3) **Temporal Demand:** How much time pressure did you feel due to the rate or pace at which the tasks or task
 1178 elements occurred? Was the pace slow and leisurely or rapid and frantic?
 1179 (4) **Performance:** How successful do you think you were in accomplishing the goals of the task set by the
 1180 experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
 1181 (5) **Effort:** How hard did you have to work (mentally and physically) to accomplish your level of performance?
 1182 (6) **Frustration Level:** How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content,
 1183 relaxed and complacent did you feel during the task?