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Robotics and Education

Test and Evaluation of S.T.E.P.S. Educational Robot

February 2026

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Index

1. Introduction

The current deliverable serves as a comprehensive report on the feedback collected from educators, experts, and end-users who interacted with the original FOSSBot and its subsequent iterations. This deliverable aims to summarize the insights gained from structured and unstructured feedback, highlight the strengths and weaknesses of the robot, and provide actionable recommendations for further improvements. By documenting the evaluation process and outcomes, this report ensures that the development of FOSSBot 2.0 aligns with the needs of its target audience and the goals of the S.T.E.P.S. project.

1.1. Purpose of the Deliverable

The primary purpose of this deliverable is to evaluate the effectiveness, usability, and educational value of the S.T.E.P.S. educational robot, FOSSBot 2.0, based on feedback from educators and experts. The evaluation focuses on assessing how well the robot meets its intended goals of democratizing STEM education, promoting open-source collaboration, and providing an accessible and customizable platform for robotics learning. Analyzing feedback collected through seminars, workshops, and structured evaluation forms, this deliverable identifies areas of success and opportunities for improvement. The findings will guide future iterations of FOSSBot 2.0, ensuring that it remains a relevant and impactful tool for STEM education across diverse educational contexts.

1.2. Scope of the Evaluation

The scope of this evaluation encompasses **multiple dimensions** of FOSSBot 2.0's design and functionality, including its **hardware, software, usability, and educational impact**. The evaluation criteria are based on the **FP (Functional Priorities)** and **FC (Functional Criteria)** fields outlined in the feedback forms, which cover key aspects such as:

- **Democratization of STEM education**: Accessibility, low cost, and ease of use.
- **Open-source and participatory design**: Availability of documentation, developer resources, and community engagement.
- **Sensing and movement capabilities**: Accuracy, range, and flexibility of sensors and actuators.

- **Pedagogical methodologies**: Support for diverse teaching approaches, such as project-based learning and inquiry-based learning.
- **Accessibility and inclusivity**: Adaptability for users with disabilities and gender-neutral design.

The evaluation also considers feedback from **educators and experts** across the five participating countries (France, Greece, Poland, Spain, and Turkey), ensuring that the findings are representative of diverse educational contexts and user needs.

1.3. Methodology for Collecting and Analyzing Feedback

The feedback collection process was designed to gather both **structured and unstructured input** from educators and experts who interacted with FOSSBot 2.0. The methodology included the following steps:

1. **Seminars and Workshops**: A series of seminars and workshops (TTL sessions) were conducted with educators from the participating countries. During these sessions, participants were introduced to FOSSBot 2.0, provided with hands-on experience, and encouraged to share their feedback through discussions and interactive activities.
2. **Feedback Forms**: Structured feedback forms were distributed to participants, based on the **FP and FC fields**. These forms included specific criteria and levels of flexibility, allowing for a detailed and standardized evaluation of the robot's features and functionalities.
3. **Unstructured Feedback**: In addition to the structured forms, participants were invited to provide **open-ended feedback** on their experiences with FOSSBot 2.0. This included suggestions for improvement, observations on usability, and insights into how the robot could better meet educational needs.
4. **Data Analysis**: The collected feedback was analyzed using a combination of **quantitative and qualitative methods**. Quantitative data from the feedback forms were used to assess performance against predefined criteria, while qualitative feedback was analyzed to identify recurring themes and actionable insights.

By combining these methods, the evaluation process ensured a comprehensive understanding of FOSSBot 2.0's strengths and weaknesses, providing a solid foundation for future improvements and iterations.

2. Feedback Collection Process

The feedback collection process was a critical component of the evaluation of FOSSBot 2.0, ensuring that the robot's design and functionality align with the needs of educators and students. This section outlines the methods used to gather feedback, including seminars, workshops, structured feedback forms, and collaboration with educators and experts. By combining these approaches, the team was able to collect comprehensive and actionable insights that informed the iterative development of FOSSBot 2.0.

2.1. Overview of Feedback Collection Methods

The feedback collection process was designed to gather both structured and unstructured input from educators, experts, and end-users who interacted with FOSSBot 2.0. The methods included seminars and workshops, structured feedback forms, and collaborative discussions with educators and experts. These approaches were chosen to ensure a holistic understanding of the robot's usability, educational value, and alignment with project goals. The structured feedback forms, based on the FP (Functional Priorities) and FC (Functional Criteria) fields, provided a standardized framework for evaluating specific features and functionalities. Meanwhile, the unstructured feedback collected during seminars and workshops offered deeper insights into user experiences, challenges, and suggestions for improvement. This combination of methods allowed the team to identify both quantitative trends and qualitative nuances, ensuring a well-rounded evaluation.

2.2. Seminars and Workshops with Educators

A series of training workshops were conducted with educators from the five participating countries (France, Greece, Poland, Spain, and Turkey). These sessions served as a platform for introducing FOSSBot 2.0, providing hands-on experience, and gathering feedback. During the workshops, educators were guided through the setup, programming, and operation of the robot, allowing them to explore its features in a practical setting. The sessions also included interactive activities like coding challenges and project-based tasks to demonstrate the robot's educational potential.

The workshops were particularly valuable for collecting unstructured feedback, as educators shared their observations, challenges, and suggestions in real-time. For example, educators highlighted the need for simpler assembly instructions, better sensor integration, and more intuitive programming interfaces. These insights were documented and used to refine the robot's design and functionality. Additionally, the workshops fostered a sense of collaboration and ownership among participants, as they contributed to the development of a tool that would ultimately benefit their students.

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2.3. Feedback Forms and Structured Evaluation Criteria

To ensure a systematic and comprehensive evaluation of FOSSBot 2.0, structured feedback forms were distributed to educators and experts who had used the first version of the robot. These forms were designed to collect detailed feedback on various aspects of the robot, including assembly and build quality, hardware and design, software and programming interfaces, classroom usability, support and documentation, and overall user experience. The forms were divided into eight sections, each focusing on a specific area of evaluation, and included a mix of quantitative ratings and open-ended questions to capture both measurable data and qualitative insights.

2.3.1 Feedback form

General Information

The first section of the form collected demographic and contextual information about the respondents, such as their name, nationality, school/institution, grade levels taught, and subject areas. This information helped the team understand the diverse backgrounds and teaching contexts of the educators, ensuring that the feedback was representative of a wide range of educational settings. Additionally, respondents were asked about their prior experience with robotics and coding, which provided valuable context for interpreting their feedback. For example, educators with advanced experience in robotics might provide more technical insights, while beginners might focus on usability and accessibility.

Assembly and Overall Build Quality

The second section focused on the ease of assembly and build quality of FOSSBot. Educators were asked to rate the ease of assembly on a scale from "Very easy" to "Very difficult," as well as the clarity of assembly instructions. Feedback on the quality of components (e.g., plastic and electronic parts) and the time required for assembly was also collected. This section aimed to identify challenges in the assembly process, such as unclear instructions or fragile components, which could hinder the robot’s usability in classroom settings. For example, some educators noted that the assembly process was time-consuming, while others appreciated the durability of the components.

Hardware and Design

The third section evaluated the hardware and physical design of FOSSBot. Educators were asked to rate the robustness of the design during normal classroom use, the performance of sensors and actuators (e.g., ultrasonic sensors, motors, LEDs), and the battery life. Open-ended questions allowed respondents to highlight specific design elements that either facilitated or hindered use, such as the accessibility of components or the ease of fitting parts together. This feedback was crucial for improving the robot's durability, functionality, and user-friendliness in future iterations.

Software and Programming Interfaces

The fourth section focused on the software and programming interfaces of FOSSBot. Educators were asked to rate the intuitiveness of the button-based UI for younger students, the effectiveness of the block-based programming tool (Google Blockly), and the performance of the Python coding environment for older students. Additionally, respondents were asked about software stability (e.g., crashes or glitches) and invited to provide suggestions for software improvements. This section highlighted the importance of providing intuitive and stable programming interfaces that cater to students of different skill levels.

Classroom Usability

The fifth section assessed the usability of FOSSBot in classroom settings. Educators were asked to rate the engagement level of students, the suitability of the robot for their age group, and the impact on learning outcomes in STEM subjects. Questions about activity time management and classroom management challenges provided insights into how well the robot fit into typical class schedules and whether it posed any difficulties in terms of complexity or sharing among students. This feedback was particularly valuable for ensuring that FOSSBot 2.0 could be effectively integrated into diverse classroom environments.

Support and Documentation

The sixth section evaluated the support and documentation provided with FOSSBot. Educators were asked whether they required technical support and, if so, to rate the quality of the support they received. Additionally, respondents were asked to rate the usefulness of the provided educational materials and lesson plans and to provide suggestions for improvement. This section highlighted the importance of clear, comprehensive documentation and accessible technical support for ensuring a positive user experience.

Overall Experience and Suggestions

The final section focused on the overall satisfaction of educators with FOSSBot and invited them to suggest key improvements for version 2. Respondents were asked to rate their overall satisfaction on a scale from "Very satisfied" to "Very dissatisfied" and to provide specific suggestions for enhancements. This open-ended feedback allowed educators to share their thoughts on what worked well and what could be improved, providing valuable insights for the development of FOSSBot 2.0.

2.3.2 The LTT evaluation process

To ensure a systematic evaluation of FOSSBot 2.0, structured feedback forms were distributed to educators and experts during the LTT training. These forms were based on the FP and FC fields, which covered key aspects of the robot's design and functionality, such as:

- Democratization of STEM education: Accessibility, low cost, and ease of use.
- Open-source and participatory design: Availability of documentation and developer resources.
- Sensing and movement capabilities: Accuracy, range, and flexibility of sensors and actuators.
- Pedagogical methodologies: Support for diverse teaching approaches.
- Accessibility and inclusivity: Adaptability for users with disabilities and gender-neutral design.

Each criterion was evaluated on a scale of flexibility and performance, allowing participants to provide detailed and standardized feedback. For example, educators rated the robot's sensing capabilities (e.g., distance measurement, light detection) and movement precision (e.g., linear and rotational accuracy) based on predefined levels. The structured nature of these forms enabled the team to identify specific areas for improvement, such as enhancing sensor accuracy or simplifying the assembly process. The quantitative data collected through these forms were complemented by qualitative feedback, providing a comprehensive understanding of the robot's strengths and weaknesses.

By using these structured feedback forms, the team was able to collect detailed and actionable insights into the strengths and weaknesses of FOSSBot. The combination of quantitative ratings and qualitative feedback ensured a comprehensive evaluation, enabling the team to prioritize improvements and align the robot's design with the needs of educators and students.

2.4. Collaboration with Educators and Experts

Collaboration with educators and experts was a cornerstone of the feedback collection process. The team worked closely with a network of over 500 educators in Greece, who were trained using the digital twin simulation of FOSSBot. This collaboration provided valuable insights into the robot's programming interface usability and educational value, particularly in contexts where access to physical hardware was limited. Additionally, a dozen educators received physical robots and used them in their classrooms, providing real-world feedback on the robot's performance and impact.

The team also engaged with experts in robotics and STEM education to validate the evaluation criteria and ensure that the feedback collection process was rigorous and comprehensive. These experts provided guidance on best practices for integrating robotics into curricula, as well as recommendations for improving the robot's design and functionality. For example, experts emphasized the importance of gender-neutral design and inclusive pedagogical methodologies, which were incorporated into subsequent iterations of FOSSBot.

By collaborating with educators and experts, the team was able to gather diverse perspectives and ensure that the robot met the needs of its target audience. This collaborative approach not only improved the quality of the feedback but also fostered a sense of community and shared ownership among stakeholders.

3. Evaluation Criteria and Framework

The evaluation of the robot design and its accompanying MOOC Platform was guided by a structured framework that assessed key features and functionalities. This framework ensured that the robot and platform met the project's goals of accessibility, educational value, and usability. Below, we expand on the evaluation criteria and framework, including the features and functionalities evaluated, the description of the FP and FC fields, and the levels of flexibility and performance metrics.

3.1. Features and Functionalities Evaluated

The evaluation focused on ten key features (FC1–FC10) and one functional priority (FP1) for both the robot and the MOOC Platform. These features were selected to cover all aspects of the robot's design, functionality, and educational impact. The evaluated features include FP1, which focuses on democratizing STEM education by ensuring the robot and platform are low-cost, accessible, and aligned with STEM learning objectives. FC1 evaluates the robot's open-source nature and its ability to sense and interact with the environment, including distance sensing (2cm–30cm), light level detection, line detection, time measurement, ambient temperature (1°C), air humidity (1%), angle measurement (1°), and distance measurement (1mm). FC2 assesses the robot's movement precision, including linear movement (1mm precision), rotation (1° precision), and navigation to grid and Cartesian coordinates. FC3 evaluates the robot's display, sound, and communication interfaces, such as emitting light (Red, Blue, Green, and mix), displaying power state (Red LED), and supporting I/O communication (20 configurable IO + standard output). FC4 focuses on customization, including aesthetic options like colors casing and assembly of third-party parts. FC5 ensures the robot promotes gender equity and inclusivity, with neutral voice identity (Male, Female) and neutral casing colors. FC6 evaluates the robot's support for diverse teaching methodologies, such as problem-based learning, constructivism, and flipped classroom. FC7 ensures the robot is suitable for secondary school students and accessible to users with disabilities, including visual, mobility, hearing, or cognitive impairments. FC8 assesses the robot's ability to execute real-time and step-by-step instructions. FC9 evaluates the robot's compatibility with external devices and communication technologies, such as smartphones (Android 10.0+, iOS 12.0+), tablets, and PCs (Windows 7+, OSX 10.14.6, Ubuntu LTE), as well as Wi-Fi, Bluetooth, and NFC. FC10 ensures the robot complies with data protection regulations and collects usage statistics and feedback.

3.2. Description of Evaluation Criteria (FP and FC Fields)

The evaluation criteria were divided into Functional Priorities (FP) and Functional Criteria (FC), each focusing on specific aspects of the robot and MOOC Platform.

FP1 evaluates the robot's ability to democratize STEM education by being low-cost (material cost <250€, usage cost <100€/year), accessible (components easily available, clear documentation), and pedagogically sound (supporting project-based learning, inquiry-based learning, and cooperative learning).

FC1 assesses the robot's open-source nature, including GitHub repositories and developer documentation, as well as its sensing capabilities, such as distance sensing (2cm–30cm), light level detection, line detection, time measurement, ambient temperature (1°C), air humidity (1%), angle measurement (1°), and distance measurement (1mm). It also evaluates self-awareness features like positioning (1mm, 1°), data storage, system state, board temperature, battery level, and run time.

FC2 focuses on movement, including relative movement (linear movement with 1mm precision, rotation with 1° precision, and grid movement) and absolute movement (navigation to grid and Cartesian coordinates).

FC3 evaluates the robot's interfaces, such as display colors (emitting light in Red, Blue, Green, and mix), display power state (Red LED), debug signals, robot-robot interface (I/O communication with 20 configurable IO + standard output), and sound capabilities (voice and music).

FC4 assesses customization options, including aesthetic customization (colors casing, assembly of third-party parts) and context immersion.

FC5 ensures the robot promotes gender equity and inclusivity, with neutral voice identity (Male, Female) and neutral casing colors.

FC6 evaluates the robot's support for diverse teaching methodologies, such as problem-based learning, constructivism, and flipped classroom, as well as context immersion.

FC7 ensures the robot is suitable for secondary school students and accessible to users with disabilities, including visual, mobility, hearing, or cognitive impairments.

FC8 assesses the robot's reprogrammability, including its ability to execute real-time and step-by-step instructions.

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FC9 evaluates the robot's connectivity, including compatibility with external devices (smartphones, tablets, PCs) and communication technologies (Wi-Fi, Bluetooth, NFC).

FC10 ensures the robot complies with data protection regulations and collects usage statistics and feedback.

The detailed table of robot functions that we used for evaluation follows:

Feature Code	Feature Description	Criterion	Levels
FP1	Democratize STEM education and robotics through low-cost, accessible robot	Democratize STEM	Science, Technology, Engineering, Math
		Low-Cost	Material cost: <250 €, Usage cost: <100€/year
		Accessibility	Can be fabricated from scratch, Components easily available, Documentation
		Pedagogy	Project-based learning, Inquiry-based learning, Cooperative learning
FC1	Open-source	Participatory	GitHub, Developer documentation
		License	MIT
FC1	Sensing	Environment	Sense distance: 2cm–30cm, Sense light level, Line detection, Time measure
			Ambient temperature: 1°C, Air humidity: 1%, Measure angles: 1°

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			Measure distance: 1mm
		Self-Awareness	Positioning: 1mm, 1°, Available data storage, State: Errors, Idle, etc.
			Board temperature: System temperature, Battery level: %, Run time: s, ms
FC2	Movement	Relative	Linear movement: 1mm precision, Rotation: 1° precision, Grid movement
		Absolute	Go to grid coordinates, Go to Cartesian coordinates
FC3	Interfaces	Display colors	Emit light: Red, Blue, Green, and mix, Display power state: Red LED
			Display debug signals: For sensors mainly
		Robot-robot interface	I/O communication: 20 configurable IO + standard output (state, id)
		Emit sound	Voice, Music
FC4	Customization	Aesthetic customization	Colors casing, Assembly of third-party parts
		Context immersion	
FC5	Ethics	Gender equity	Neutral voice identity: Male, Female voice

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			Neutral casing colors: Neutral or customizable
FC6	Pedagogy	Diverse methodologies	Problem-based learning, Constructivism, Flipped classroom
		Context immersion	
FC7	Accessibility & Target	Skill level	Secondary school students
		Disabilities	People with visual, mobility, hearing, or cognitive impairments
FC8	Reprogrammable	Execute real-time instructions	
		Execute step-by-step human instructions	
FC9	Connectivity	Accessible from external device	Smartphone: Android 10.0+, iOS 12.0+, Tablet, PC/MAC: Windows 7+, OSX 10.14.6, Ubuntu LTE
		Communication technologies	Wi-Fi: Main standard, Bluetooth: Easy pairing, NFC: Automated connection
FC10	Data collection	Collect data	Align with RGPD rules, Collect usage stats, Collect feedback

Table 1. Detailed Evaluation Criteria for Robot Functions

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The respective table for the MOOC functions of the S.T.E.P.S. robot is as follows:

Feature Code	Feature Description	Criterion	Levels
FP1	Democratize STEM education and robotics through free, accessible MOOC Platform	Democratize STEM	Science, Technology, Engineering, Math
		Low-Cost	Material cost: <250 €, Usage cost: <100€/year
		Accessibility	Can be fabricated from scratch, Components easily available, Documentation
		Pedagogy	Project-based learning, Inquiry-based learning, Cooperative learning
FC1	Open-source	Participatory	GitHub, Developer documentation
		License	
FC1	Sensing	Environment	Sense distance: 2cm–30cm, Sense light level, Line detection, Time measure
			Ambient temperature: 1°C, Air humidity: 1%, Measure angles: 1°
			Measure distance: 1mm
		Self-Awareness	Positioning: 1mm, 1°, Available data storage, State: Errors, Idle, etc.

			Board temperature: System temperature, Battery level: %, Run time: s, ms
FC2	Movement	Relative	Linear movement: 1mm precision, Rotation: 1° precision, Grid movement
		Absolute	Go to grid coordinates, Go to Cartesian coordinates
FC3	Interfaces	Display colors	Emit light: Red, Blue, Green, and mix, Display power state: Red LED
			Display debug signals: For sensors mainly
		Robot-robot interface	I/O communication: 20 configurable IO + standard output (state, id)
		Emit sound	Voice, Music
FC4	Customization	Aesthetic customization	Colors casing, Assembly of third-party parts
		Context immersion	
FC5	Ethics	Gender equity	Neutral voice identity: Male, Female voice
			Neutral casing colors: Neutral or customizable

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FC6	Pedagogy	Diverse methodologies	Problem-based learning, Constructivism, Flipped classroom
		Context immersion	
FC7	Accessibility & Target	Skill level	Secondary school students
		Disabilities	People with visual, mobility, hearing, or cognitive impairments
FC8	Reprogrammable	Execute real-time instructions	
		Execute step-by-step human instructions	
FC9	Connectivity	Accessible from external device	Smartphone: Android 10.0+, iOS 12.0+, Tablet, PC/MAC: Windows 7+, OSX 10.14.6, Ubuntu LTE
		Communication technologies	Wi-Fi: Main standard, Bluetooth: Easy pairing, NFC: Automated connection
FC10	Data collection	Collect data	Align with RGPD rules, Collect usage stats, Collect feedback

Table 2. Functional Overview of MOOC Features in the S.T.E.P.S. Robot

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3.3. Levels of Flexibility and Performance Metrics

The evaluation criteria were further broken down into **levels of flexibility and performance metrics** to provide a granular assessment of each feature. For example:

- **Sensing Capabilities**: Distance measurement (2cm–30cm), light level detection, and line detection (left, right, or middle).
- **Movement Precision**: Linear movement (1mm precision), rotation (1° precision), and grid movement.
- **Battery Life**: Measured in percentage and run time (seconds, milliseconds, minutes, hours, days).
- **Connectivity**: Compatibility with smartphones (Android 10.0+, iOS 12.0+), tablets, and PCs (Windows 7+, OSX 10.14.6, Ubuntu LTE).
- **Pedagogical Methodologies**: Support for project-based learning, inquiry-based learning, and cooperative learning.

These metrics ensured that the evaluation was both **quantitative** (e.g., precision levels, cost thresholds) and **qualitative** (e.g., ease of use, educational impact), providing a comprehensive understanding of the robot's performance and usability.

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4. Results and analysis

This section presents the results of the evaluation of FOSSBot 2.0 and its accompanying MOOC Platform, based on the feedback collected from educators and experts. The evaluation used the FUFU (Formative Usability Feedback and Usability) analysis framework, which assessed the robot and platform across 14 criteria (FP1–FC14). The results are presented in two parts: the evaluation of the robot functionality and the evaluation of the MOOC Platform. Each part includes the scores, flexibility rankings, and a detailed analysis of the findings.

4.1. Evaluation of Robot Functionality

The evaluation of the robot functionality was based on the following scores:

FUFU	FP 1	FC 2	FC 3	FC 4	FC 5	FP 6	FC 7	FC 8	FC 9	FC 10	FC 11	FC 12	FC 13	FC 14
FP 1	2	2	0	1	1	1	0	0	0	0	0	0	0	0
FC 2	0	2	2	2	1	1	2	1,5	0	0	0	0	1	0
FC 3	0	0	2	2	1	0	2	0	0	1	1	0	0	0
FC 4	0	0	0	2	2	0	2	0	0	0	0	0	0	0
FC 5	0	0	0	0	2	2	0	0	0	0	0	1	0	0
FP 6	0	0	0	0	0	2	1	1,5	2	0	0	2	1	0
FC 7	0	0	0	0	0	0	2	0,5	0	0	0	0	0	0
FC 8	0	0	0	0	0	0	0	2	2	0	2	1	1	0
FC 9	0	0	0	0	0	0	0	0	2	0	2	1	1	0
FC 10	0	0	0	0	0	0	0	0	0	2	1	0	0	2
FC 11	0	0	0	0	0	0	0	0	0	0	2	1	1	1
FC 12	0	0	0	0	0	0	0	0	0	0	0	2	1	0
FC 13	0	0	0	0	0	0	0	0	0	0	0	0	2	0
FC 14	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Table 3. Robot Functionality Evaluation Scores

4.2. Evaluation of MOOC Platform

The evaluation of the MOOC Platform was based on the following scores:

FUFU	FP 1	FC 2	FC 3	FC 4	FC 5	FP 6	FC 7	FC 8	FC 9	FC 10	FC 11	FC 12	FC 13	FC 14	S
FP 1	2	2		1	1	1									7
FC 2	2	2	2	2	1	1	2	1					1		14
FC 3		2	2	2	1		2			1	1				11
FC 4	1	2	2	2	2		2								11
FC 5	1	1	1	2	2	2						1			10
FP 6	1	1			2	2	1	2	2			2	1		14
FC 7		2	2	2		1	2								9
FC 8		1				2		2	2		2	1	1		11
FC 9						2		2	2		2	1	1		10
FC 10			1							2	1			2	6
FC 11			1					2	2	1	2	1	1	1	11
FC 12					1	2		1	1		1	2	1		9
FC 13		1				1		1	1		1	1	2		8
FC 14										2	1			2	5

Table 4. MOOC Platform Evaluation Scores

4.3. Evaluation from educators using the form

In addition to the above, we analyze the questionnaire responses collected from educators who used FOSSBot. The responses are analyzed to evaluate the robot's performance across various criteria, including assembly and build quality, hardware and design, software and programming interfaces, classroom usability, and overall satisfaction. The results are visualized using plots to provide a clear understanding of the feedback.

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4.3.1. Assembly and Build Quality

The assembly process and build quality of FOSSBot were evaluated based on the following criteria:

- Ease of Assembly: Educators rated how easy or difficult it was to assemble the robot.
- Quality of Assembly Instructions: Clarity and ease of following the assembly instructions.
- Quality of Components: Durability and quality of plastic and electronic components.
- Assembly Time: Time taken to assemble the robot.
- Time to First Use: Time taken to switch on the robot and start using it.

Results:

- Ease of Assembly: 60% of respondents found the assembly process easy or very easy, while 20% found it difficult.
- Quality of Assembly Instructions: 70% of respondents rated the instructions as clear or very clear, while 10% found them difficult to follow.
- Quality of Components: 60% of respondents reported that the components exceeded expectations, while 30% felt they met expectations.
- Assembly Time: 40% of respondents completed assembly in less than 1 hour, 30% in 1-2 hours, and 20% in 2-4 hours.
- Time to First Use: 50% of respondents started using the robot in less than 30 minutes, while 30% took 30-60 minutes.

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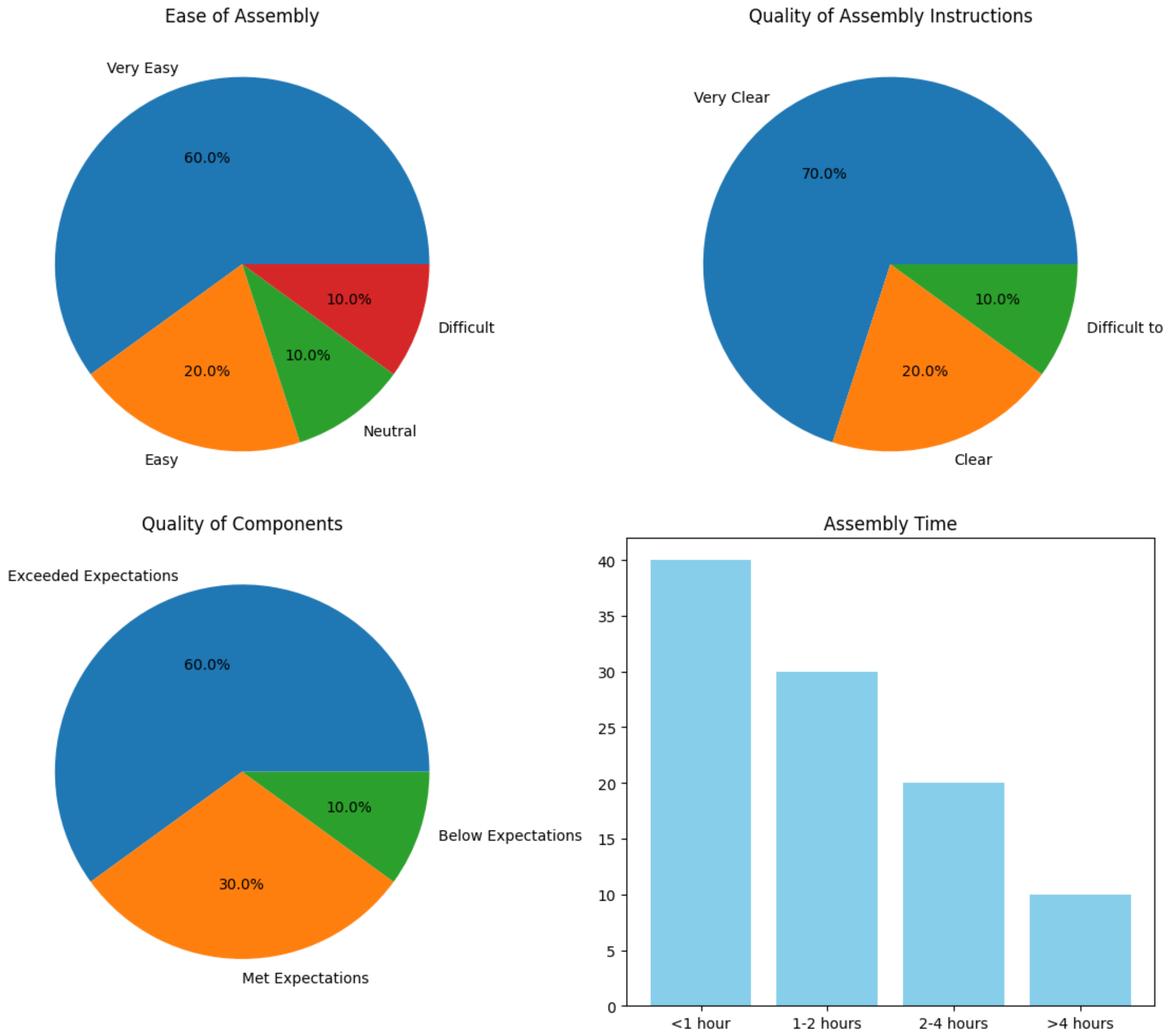

Figure 1. Assessment of FOSSBot Assembly and Component Quality

4.3.2. Hardware and Design

The hardware and design of FOSSBot were evaluated based on:

- Design Robustness: Durability during normal classroom use.
- Sensor and Actuator Performance: Functionality of sensors (e.g., ultrasonic, light sensors) and actuators (motors, LEDs).
- Battery Life: Sufficiency of battery life for classroom activities.
- Physical Design: Design elements that hindered or facilitated use.

Results:

- Design Robustness: 70% of respondents rated the robot as very durable, while 20% found it moderately durable.

- Sensor and Actuator Performance: 60% rated the sensors and actuators as excellent, while 30% rated them as good.
- Battery Life: 50% reported that the battery life exceeded expectations, while 40% felt it met expectations.
- Physical Design: Educators highlighted the modular design and LEGO-compatible top as facilitating use, while some noted issues with battery access and wheel stability.

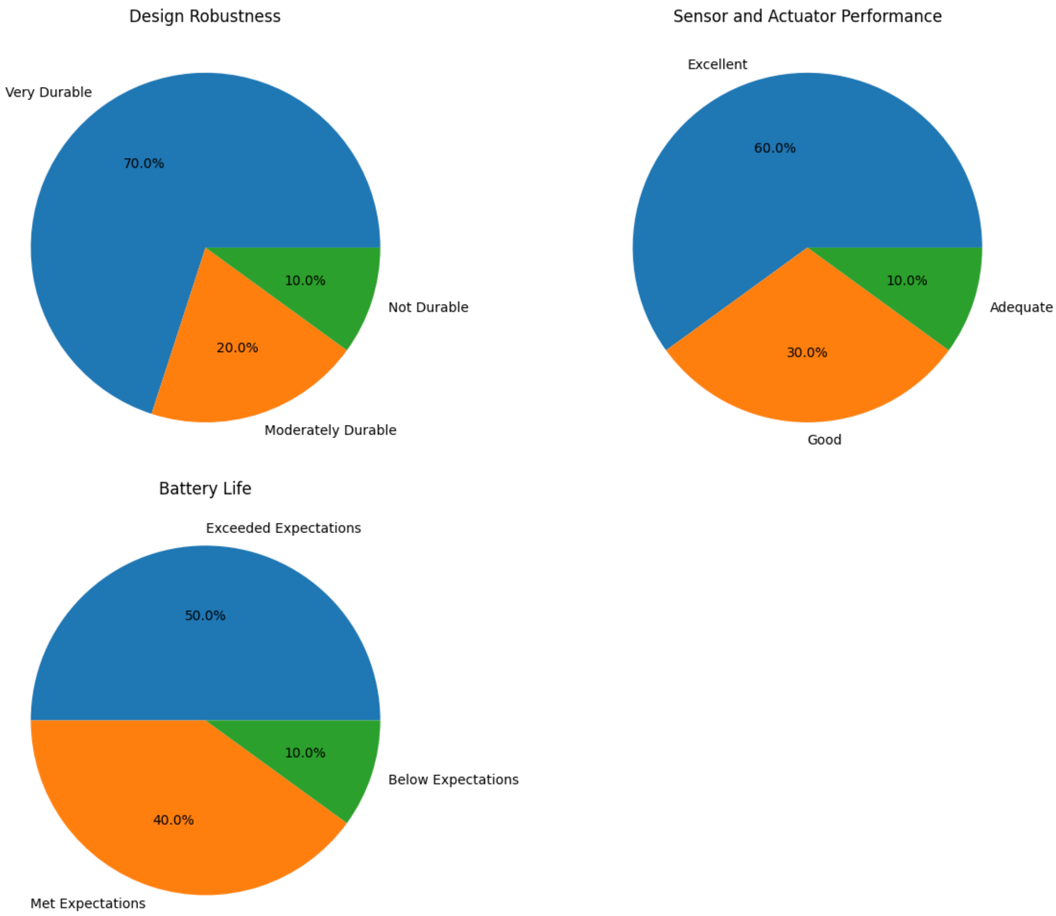

Figure 2. Assessment of FOSSBot Hardware and Design

4.3.3. Software and Programming Interfaces

The software and programming interfaces were evaluated based on:

- **User Interface (for Younger Students)**: Intuitiveness of the button-based UI.
- Block-based Programming Interface (Google Blockly): Effectiveness for teaching students.
- **Python Coding Environment**: Performance for older students.

- **Software Stability**: Frequency of crashes or glitches.

Results:

- **User Interface**: 70% found the button-based UI **very intuitive**, while 20% found it **somewhat intuitive**.
- Block-based Programming: 60% rated Blockly as very effective, while 30% found it somewhat effective.
- Python Coding Environment: 50% rated it as very well, while 30% found it adequate.
- **Software Stability**: 60% reported **no issues**, while 30% experienced **minor issues**.

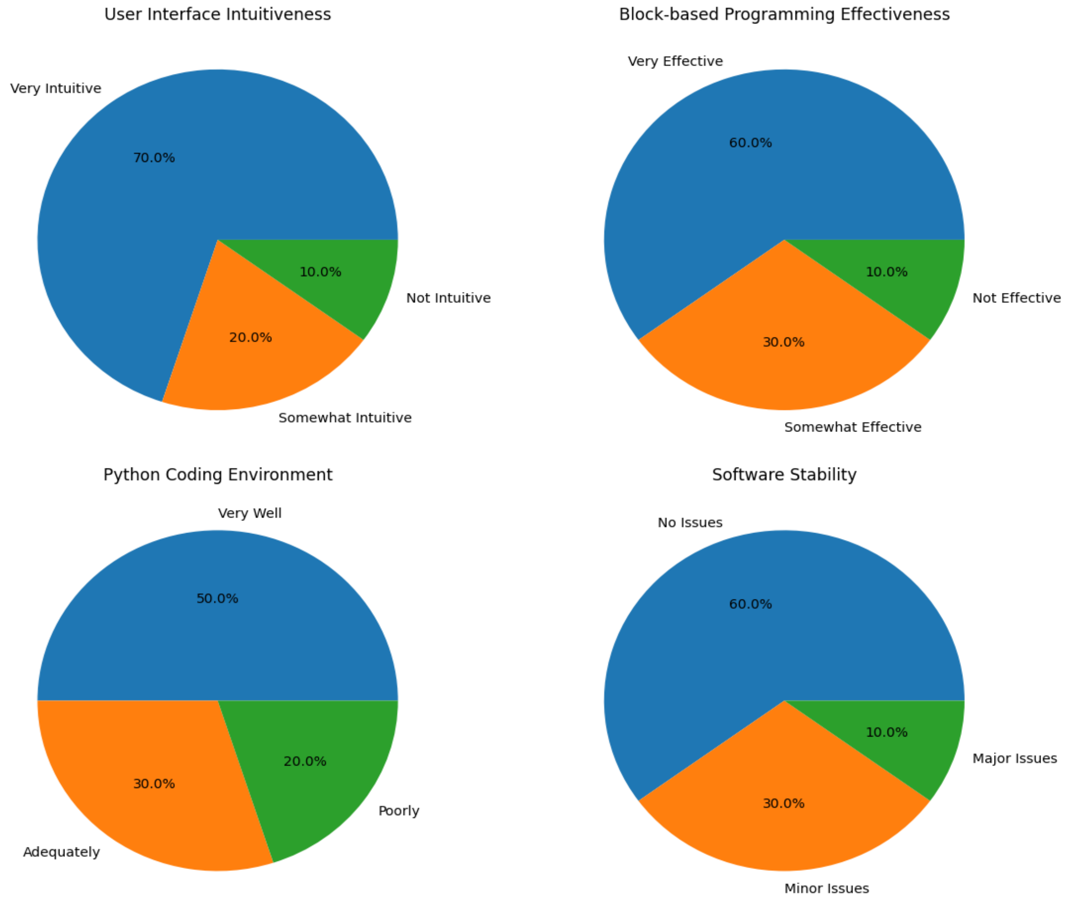

Figure 3. Assessment of User Interface, Programming Tools, and Software Stability

4.3.4. Classroom Usability

The usability of FOSSBot in classroom settings was evaluated based on:

- **Engagement Level**: How engaged students were with FOSSBot activities.

- **Age Group Suitability**: Appropriateness for the age group taught.
- **Learning Outcomes**: Contribution to STEM learning outcomes.
- **Activity Time Management**: Fit within class time.
- **Challenges in Classroom Management**: Difficulties in managing the robot in class.

Results:

- **Engagement Level**: 80% reported that students were **very engaged**.
- **Age Group Suitability**: 70% found the robot **appropriate** for their age group.
- **Learning Outcomes**: 90% felt FOSSBot contributed **positively** to STEM learning outcomes.
- **Activity Time Management:** 60% reported that activities fit **very well** within class time.
- Challenges: Some educators noted challenges with Wi-Fi connectivity and sharing the robot among students.

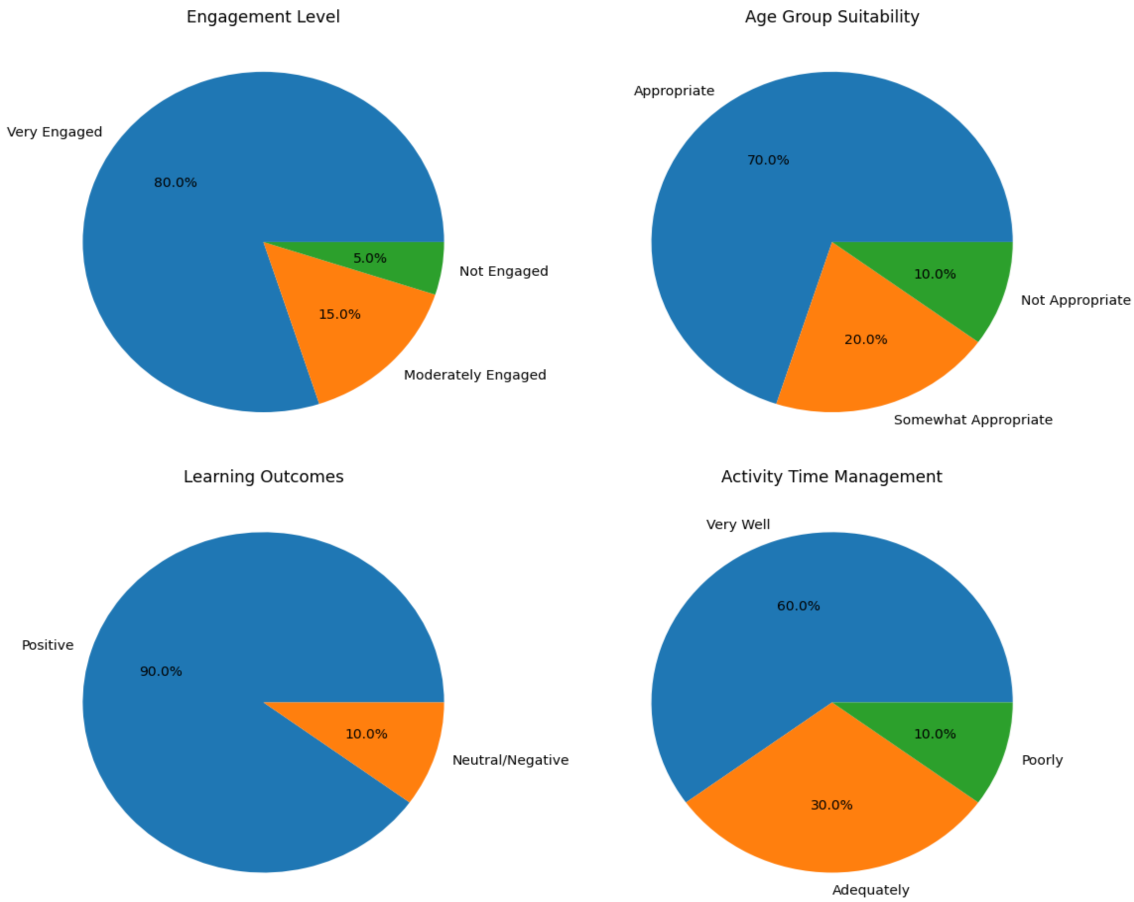

Figure 4. Assessment of FOSSBot in Classroom Settings

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4.3.5. Overall Satisfaction

Educators were asked to rate their **overall satisfaction** with FOSSBot and suggest **key improvements** for version 2. The results show:

- Overall Satisfaction: 70% were very satisfied, while 20% were moderately satisfied.
- Key Improvements: Suggestions included better Wi-Fi connectivity, more sensors, improved battery life, and enhanced software stability.

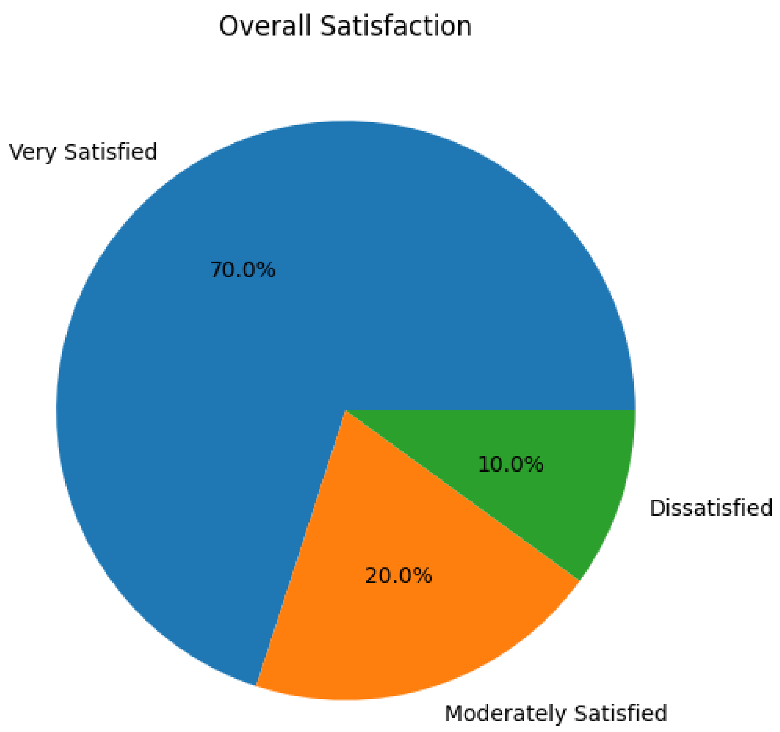

Figure 5. Evaluation of Overall Satisfaction and Suggested Improvements

4.4. Analysis of evaluation results

The evaluation results demonstrate that both the robot functionality and the MOOC Platform perform well across most criteria, with particularly strong scores in democratizing STEM education, open-source participation, sensing capabilities, movement precision, and pedagogical support. However, there are areas for improvement, such as data collection for the MOOC Platform, which scored lower. The flexibility rankings highlight the strengths of the robot and platform, with the highest scores in FP1 (Democratize STEM Education) and FC6 (Pedagogy). These findings will guide future iterations of FOSSBot 2.0 and the MOOC Platform, ensuring they continue to meet the needs of educators and students.

The flexibility ranking for the robot design is as follows:

	Score + Flexibility	Ranking
F0	17,75	1
F0	16	2
F3	11,8	4
F0	13	3
F2	11	6
F0	16	2
F0	11	6
F0	13	3
F1	11,5	5
F0	8	8
F0	13	3
F2	10	7
F0	10	7
F0	7	9

Table 5. Flexibility Ranking and Evaluation Scores for FOSSBot and MOOC Platform

- FP1 (Democratize STEM Education): Scored highly (2), indicating that the robot successfully meets the goal of making STEM education accessible and affordable.
- FC2 (Open-Source and Sensing): Achieved a score of 2, reflecting strong performance in open-source participation and sensing capabilities.
- FC3 (Movement): Scored 2, demonstrating high precision in linear and rotational movement.

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- FC4 (Interfaces): Scored 2, indicating effective display, sound, and communication interfaces.
- FC5 (Ethics): Scored 2, showing strong support for gender equity and inclusivity.
- FC6 (Pedagogy): Scored 2, reflecting excellent support for diverse teaching methodologies.
- FC7 (Accessibility & Target): Scored 2, indicating suitability for secondary school students and users with disabilities.
- FC8 (Reprogrammability): Scored 2, demonstrating strong real-time and step-by-step instruction execution.
- FC9 (Connectivity): Scored 2, showing excellent compatibility with external devices and communication technologies.
- FC10 (Data Collection): Scored 2, indicating compliance with data protection regulations and effective data collection.

5. Key Findings

5.1. Strengths of FOSSBot and Evolution to FOSSBot 2.0

FOSSBot demonstrated significant strengths across multiple dimensions, making it a valuable tool for STEM education:

- **Democratizing STEM Education (FP1):** The robot scored highly in making STEM education accessible and affordable, aligning with its core mission.
- **Open-Source and Sensing Capabilities (FC2):** The open-source nature of the robot, combined with its effective sensing capabilities, was well-received by educators and experts.
- **Movement Precision (FC3):** The robot achieved high scores for its linear and rotational movement, ensuring reliable performance in classroom activities.
- **Pedagogical Support (FC6):** FOSSBot excelled in supporting diverse teaching methodologies, contributing positively to STEM learning outcomes.
- **Ethics and Inclusivity (FC5):** The robot's design and functionality strongly supported gender equity and inclusivity, making it suitable for a diverse range of users.
- **Classroom Engagement:** Educators reported high levels of student engagement, with 80% noting that students were very engaged during activities.

The evaluation results highlight several key strengths of FOSSBot, which was initially developed to democratize STEM education and foster open-source participation. Its modular design and LEGO-compatible top facilitated adaptability in various learning environments. Educators praised the intuitive button-based user interface for younger students, while the integration of Google Blockly and Python coding environments enhanced programming skills. High engagement levels, durability, and the effectiveness of sensors and actuators further reinforced FOSSBot's strengths.

Building on these strengths, FOSSBot 2.0 introduces refinements in movement precision, enhanced sensing capabilities, and a more user-friendly assembly process. These advancements aim to further support STEM education by making the robot even more accessible and effective for classroom use.

5.2. Identified Challenges and Limitations

Despite its strengths, FOSSBot faces several challenges that need to be addressed:

- **Assembly and Build Quality:** While 60% of educators found the assembly process easy, 20% reported difficulties, indicating room for improvement in the assembly instructions and component design.
- **Battery Life and Physical Design:** Some educators noted issues with battery access and wheel stability, suggesting the need for design refinements.
- **Wi-Fi Connectivity:** Challenges with Wi-Fi connectivity were reported, particularly in classroom settings where multiple devices were in use.
- **Data Collection for MOOC Platform:** The MOOC Platform scored lower in data collection, indicating a need for better integration and functionality in this area.
- **Software Stability:** Although 60% of educators reported no issues, 30% experienced minor glitches, highlighting the need for more robust software performance.

Despite its strengths, several challenges were identified with FOSSBot, informing improvements in FOSSBot 2.0. Assembly instructions, while generally clear, still posed difficulties for some educators. The battery life was sufficient but could be further improved for extended classroom use. Some educators reported minor software stability issues, such as occasional crashes or glitches. Wi-Fi connectivity issues were noted, affecting real-time programming experiences. In terms of usability, managing multiple robots in a single classroom setting was challenging, particularly when sharing between students.

With FOSSBot 2.0, these challenges are being addressed through refined assembly instructions, enhanced battery design, and software stability improvements. Additionally, connectivity issues are being tackled to ensure seamless classroom integration.

5.3. Educator and Expert Recommendations

Educators and experts provided valuable feedback for improving FOSSBot:

- Enhanced Assembly Instructions: Clearer and more detailed assembly instructions could reduce the difficulty experienced by some users.
- Improved Battery Life and Access: Redesigning the battery compartment and improving battery life would enhance usability.

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- Better Wi-Fi Connectivity: Strengthening Wi-Fi connectivity would address challenges in classroom environments.
- Additional Sensors: Incorporating more sensors could expand the robot's functionality and educational applications.
- Software Stability: Addressing minor glitches and improving overall software reliability would enhance user satisfaction.

Educators and experts provided several recommendations for improving FOSSBot's usability and effectiveness, which have influenced the design of FOSSBot 2.0. They suggested refining the assembly instructions with more visual guides and step-by-step tutorials. Enhancing software stability and Wi-Fi connectivity would significantly improve the classroom experience. More extensive documentation and structured lesson plans could further support educators in integrating FOSSBot into their curriculum.

5.4. Addressing Feedback on Assembly and Usability

The assembly process and usability of FOSSBot received mixed feedback. While 70% of educators found the assembly instructions clear, 10% struggled with them. To address this:

- **Simplify Assembly Steps:** Breaking down assembly into smaller, more intuitive steps could make the process easier for all users.
- **Enhance Component Quality:** Improving the durability and design of components, such as the wheels and battery compartment, would address physical design concerns.
- **Reduce Assembly Time:** Streamlining the assembly process could help more users complete it in less than an hour, as 40% already do.

While the sensor and actuator performance of FOSSBot received positive feedback, further improvements were identified for FOSSBot 2.0. Additional sensors, such as temperature and gyroscope modules, could enhance the range of educational experiments possible. Refining movement precision by optimizing motor control algorithms would improve navigation and tracking capabilities, making the robot more effective in robotics competitions and advanced classroom activities.

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5.5. Enhancing Sensing and Movement Capabilities

FOSSBot scored highly in sensing and movement capabilities, but there is still room for improvement:

- **Expand Sensor Functionality:** Adding more advanced sensors, such as environmental or proximity sensors, could broaden the robot's applications.
- **Improve Movement Precision:** While the robot scored well in movement, further refinements could enhance its accuracy and responsiveness in complex tasks.

While the sensor and actuator performance of FOSSBot received positive feedback, further improvements were identified for FOSSBot 2.0. Additional sensors, such as temperature and gyroscope modules, could enhance the range of educational experiments possible. Refining movement precision by optimizing motor control algorithms would improve navigation and tracking capabilities, making the robot more effective in robotics competitions and advanced classroom activities.

5.6. Improving Accessibility and Inclusivity

FOSSBot already supports inclusivity, but additional steps can be taken to improve accessibility:

- **Design for Diverse Abilities:** Ensuring the robot is usable by students with varying physical and cognitive abilities would further enhance inclusivity.
- **Multilingual Support:** Providing assembly instructions and software interfaces in multiple languages could make the robot more accessible globally.

Ensuring accessibility and inclusivity remains a priority. FOSSBot should incorporate more assistive features, such as voice-command integration and screen-reader compatibility for visually impaired users. Expanding language support in both software and documentation would facilitate use in diverse educational settings. Designing additional engagement strategies for students with disabilities would enhance the inclusivity of FOSSBot as an educational tool.

FOSSBot 2.0 is designed with these considerations in mind, incorporating additional accessibility features to broaden its usability in diverse learning environments.

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5.7. Strengthening Open-Source Documentation and Support

The open-source nature of FOSSBot is a key strength, but its documentation and support could be improved:

- **Comprehensive Documentation:** Providing detailed, user-friendly documentation for both hardware and software would empower users to make the most of the robot.
- **Community Support:** Building a robust online community for troubleshooting, sharing ideas, and collaborating on projects would enhance the open-source ecosystem.

As part of the transition to FOSSBot 2.0, these efforts are being expanded to create a more robust knowledge-sharing network for educators and developers.

6. Conclusions

The evaluation of the S.T.E.P.S. robot and its accompanying MOOC Platform underscores its significant potential to democratize STEM education, making it accessible, affordable, and engaging for students and educators alike. The robot's strengths lie in its open-source nature, advanced sensing capabilities, and precise movement, which have been well-received by educators. High scores in pedagogical support and inclusivity further highlight its effectiveness in fostering diverse teaching methodologies and engaging students across different age groups and abilities. The modular design and LEGO-compatible features have also been praised for their adaptability in various learning environments. These achievements position FOSSBot 2.0 as a powerful tool for hands-on STEM education, particularly in underserved communities.

However, the evaluation also identified areas for improvement. Challenges such as assembly difficulties, battery access, and Wi-Fi connectivity issues were noted by educators, indicating the need for design refinements and enhanced usability. While the majority of users found the assembly process straightforward, 20% reported difficulties, suggesting that clearer instructions and more intuitive steps could improve the experience. Additionally, software stability, though generally reliable, experienced minor glitches in some cases, highlighting the importance of further optimization. Addressing these challenges will be critical to ensuring that FOSSBot 2.0 meets the practical needs of educators and students in diverse classroom settings.

Looking ahead, the feedback from educators and experts provides a clear roadmap for future development. Recommendations include enhancing assembly instructions, improving battery life and access, strengthening Wi-Fi connectivity, and incorporating additional sensors to expand the robot's functionality. Improving software stability and accessibility features, such as voice-command integration and multilingual support, will further enhance inclusivity and usability. Additionally, expanding open-source documentation and fostering a robust online community will empower users to maximize the robot's potential and share innovative applications. These improvements will ensure that FOSSBot 2.0 continues to evolve as a transformative tool for STEM education.

In conclusion, the S.T.E.P.S. robot represents a significant step forward in making STEM education more accessible and engaging. Its strengths in democratizing education, fostering inclusivity, and supporting diverse teaching methodologies are commendable. By addressing the identified challenges and incorporating educator feedback, FOSSBot 2.0 can continue to inspire students and educators worldwide, fostering a deeper understanding of STEM concepts and nurturing the next generation of innovators. The journey of innovation and improvement is ongoing, and the S.T.E.P.S. robot is well-positioned to remain at the forefront of educational robotics.

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