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Reseach Paper

Usability Evaluation of an Appropriate Technology-Based Corn Sheller Using Performance Metrics and Physiological Responses

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Abstract: Appropriate Technology (AT) is widely applied in the agricultural sector to improve post-harvest productivity, including the use of corn shellers. However, many existing corn shellers have not fully considered usability and ergonomic aspects, which may lead to inefficiency, errors, and increased cognitive and physical workload for users. This study aims to evaluate the usability of a corn sheller and identify physiological parameters that indicate usability levels. An experimental method was employed involving two groups of participants, namely novice users and experienced users. Usability evaluation was conducted using the System Usability Scale (SUS), user performance indicators (task completion rate, task completion time, and error rate), and physiological measurements in the form of body temperature changes before and after task execution. The results showed that experienced users achieved a higher average SUS score (88.50, excellent usability) compared to novice users (58.50, marginal usability). Experienced users completed tasks faster, achieved a 100% task completion rate, and made fewer errors. Novice users required longer completion times, showed higher error rates, and experienced greater increases in body temperature. The findings indicate that usability is strongly influenced by user experience and cognitive factors. Body temperature changes can be used as an objective physiological indicator of usability and workload. Improvements in system learnability and user guidance are recommended to enhance usability for novice users.

Keywords: Appropriate Technology; Corn Sheller; Usability Evaluation; System Usability Scale (SUS); User Performance.

1. Introduction

Indonesia is one of the major corn-producing countries in the world, ranking eighth globally with a contribution of approximately 1.99% of total global corn production [1]. National statistics indicate that corn production increased from 19.01 million tons in 2014 to 19.61 million tons in 2015, accompanied by a substantial rise in productivity from 14.60 quintals per hectare in 1980 to 52.85 quintals per hectare in 2015, with an average annual growth rate of 3.72% [2] . This growth highlights the strategic importance of corn as a key agricultural commodity supporting food security and rural economic development in Indonesia.

One critical stage in post-harvest corn handling is the shelling process, which involves separating kernels from the cob. The effectiveness of this process directly affects product quality, kernel damage, impurity levels, and the efficiency of subsequent drying and storage. Corn shelling may be performed manually or mechanically; however, most mechanical corn shellers currently used by small-scale farmers require prior husking and drying of the corn. These machines often perform poorly under high moisture conditions, particularly during the rainy season, resulting in additional time, labor, and drying costs for farmers.

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Beyond technical constraints, many existing corn sheller machines have not adequately considered ergonomic and usability aspects [3]. Shelling activities frequently require operators to maintain non-neutral postures, perform repetitive hand movements, and engage in prolonged standing or bending [4]. Such conditions increase the risk of musculoskeletal disorders (MSDs), which commonly affect the neck, shoulders, wrists, lower back, knees, and heels. MSDs are strongly associated with repetitive tasks and awkward working postures, especially in agricultural work environments [5]

In response to these challenges, Appropriate Technology (AT) has been widely promoted as a solution tailored to local needs, resources, and user capabilities. While AT has evolved from simple manual tools to more advanced mechanized systems, its effectiveness is highly dependent on compatibility with user characteristics. AT designs that overlook human factors may result in discomfort, fatigue, increased error rates, and reduced productivity [6], [7] Although previous ergonomic studies in agriculture have primarily focused on anthropometric, biomechanical, and physiological aspects, cognitive ergonomics and usability evaluation of AT equipment—particularly in the Indonesian context-remain relatively underexplored.

Usability evaluation plays a crucial role in identifying mismatches between users and technological systems. Usability reflects the extent to which a system can be used effectively, efficiently, and satisfactorily by specified users in a given context. Common usability assessments rely on subjective instruments such as the System Usability Scale (SUS); however, subjective evaluations alone may not fully capture actual user workload and interaction difficulties. Therefore, objective measures are required to complement perceptual data.

Neuroergonomics offers a promising approach by incorporating physiological indicators to assess cognitive and physical workload during human–system interaction. Previous studies have shown that improved system usability is associated with reduced workload, reflected in physiological responses such as heart rate variability and other stress-related indicators [8], [9], [10]. These objective measures can reveal usability barriers that may not be consciously recognized by users [11]. Nevertheless, the application of physiological parameters as indicators of usability in evaluating agricultural Appropriate Technology, particularly corn sheller machines, remains limited.

Given the importance of optimizing agricultural productivity through user-centered AT, this study aims to evaluate the usability of a corn sheller machine by integrating subjective usability assessment (SUS), objective user performance metrics, and physiological responses. The study compares novice and experienced users to identify differences in usability perception, task performance, and physiological workload. Furthermore, this research seeks to explore the potential of body temperature changes as an objective physiological indicator of usability, contributing to the development of safer, more effective, and user-compatible Appropriate Technology for small-scale agriculture.

2. Research and Methodology

2.1 Research Preparation

The research preparation stage involved a preliminary study aimed at identifying the usage of Appropriate Technology (AT), specifically corn sheller machines. This preliminary study was conducted using a field study approach through direct observation. Field observations were carried out with users of corn sheller machines at the Workshop of Politeknik ATI Makassar. The observation focused on several aspects, including: (1) the practical use of corn sheller machines to understand actual operating procedures and identify constraints experienced by users related to machine design, and (2) identification of user characteristics to obtain a realistic understanding of the physical and cognitive conditions of the machine operators.

2.2 Experimental Design

2.2.1 Participant Selection

Participants were divided into two groups. The first group consisted of novice users, comprising five participants who had never used a corn sheller machine or had limited operational skills. These participants were selected from students or members of the surrounding community with no prior experience using the equipment. The second group consisted of expert users, comprising five participants who had experience operating corn sheller machines, such as machine operators or individuals with relevant technical expertise.

2.2.2 Usability Testing

Usability testing was conducted using an experimental method involving direct data collection from participants. During the usability test, participants were asked to perform a series of tasks using the AT equipment. The usability evaluation in this study was conducted using both objective and subjective approaches. An objective usability assessment was carried out using user performance metrics, including task completion rate (%), task completion time, and error rate (%). Subjective usability assessment was conducted using the retrospective think-aloud method and the System Usability Scale (SUS) questionnaire.

2.2.4 Research Design

According to [12] experimental research is considered the most scientifically reliable method due to its strict control of confounding variables. This study employed an experimental research design with a causal approach, where evidence was obtained through comparison between two participant groups: novice users and expert users. The experiment aimed to measure the ease of use of AT equipment both subjectively and objectively.

A within-subject design was applied, meaning that each participant received all experimental treatments. The experiment was conducted under conditions that closely resembled real operational environments. During the experiment, participants were required to perform a series of tasks designed to simulate real usage scenarios. The tasks were divided into three scenarios: (1) Task 1: equipment installation (set-up), (2) Task 2: equipment adjustment and operation, and (3) Task 3: equipment cleaning.

2.3 Data Collection

Prior to the experiment, participants were provided with a brief explanation of the procedures and tasks involved. The experimental equipment included the corn sheller machine used as the research object, research questionnaires, and physiological measurement instruments. All experimental activities were recorded. After completing the tasks, participants were asked to fill out questionnaires. Quantitative data were collected from performance recordings and physiological measurements, while qualitative data were obtained from completed questionnaires.

The data collected in this study included: (1) subjective usability levels measured using the System Usability Scale (SUS) questionnaire and think-aloud method; (2) physiological changes, including blood pressure and body temperature measured before and after the experiment; (3) participant personal data such as age, gender, and anthropometric measurements; and (4) machine data, including technical specifications, dimensions, functions, and performance.

2.4 Data Processing and Analysis

Data processing and analysis were conducted through several stages. Subjective usability was analyzed using SUS scores and qualitative data from the think-aloud method. User performance was evaluated based on task completion rate (%), task completion time, and error rate (%). Physiological changes were analyzed by comparing body temperature measurements taken before and after the

experiment. Participant personal data and machine data were also analyzed to support the interpretation of results.

All collected data were subsequently analyzed using statistical methods. The final stage of the analysis involved validation and the formulation of recommendations for appropriate physiological parameters to evaluate the usability of AT equipment, as well as proposals for improving the design of corn sheller machines

3. Results and Discussion

3.1 System Usability Scale (SUS)

Table 1. System Usability Scale (SUS)

No	Category Respondent	Participants' ID	Q 1	Q 2	Q 3	Q 4	Q 5	Q 6	Q 7	Q 8	Q 9	Q10	Total Score	Sus Score	Average
1	Beginner	B1	4	2	4	3	4	2	5	2	4	3	29	72,5	58,50
2		B2	3	2	3	3	3	2	4	2	3	2	25	62,5	
3		B3	4	3	4	3	3	3	4	3	4	3	24	60	
4		B4	2	4	2	4	2	4	2	4	2	4	10	25	
5		B5	5	3	5	4	5	3	5	3	5	3	29	72,5	
6	Skilled	S1	5	1	5	1	5	1	5	1	5	1	40	100	88,50
7		S2	4	1	4	1	4	1	4	1	4	1	35	87,5	
8		S3	5	2	5	2	5	2	5	2	5	2	35	87,5	
9		S4	4	2	4	2	5	2	5	2	4	2	32	80	
10		S5	4	1	4	1	4	1	4	1	4	1	35	87,5	

The usability of the corn sheller system was evaluated using the System Usability Scale (SUS) to assess user perceptions of ease of use, consistency, and learnability. The evaluation involved two groups: novice users and skilled users.

The results show that SUS scores for novice users varied widely. Two respondents achieved the highest score of 72.5, indicating acceptable usability, while others obtained moderate scores (60–62.5). One respondent recorded a very low score (25), indicating poor usability. The average SUS score for novice users was 58.50, which falls into the marginal-low category. This suggests that the system is not yet fully user-friendly for first-time users, mainly due to difficulties in understanding the workflow and the need for assistance during initial use.

In contrast, skilled users achieved consistently high SUS scores. One respondent obtained a perfect score of 100, while others scored between 80 and 87.5, corresponding to acceptable to excellent usability. The average SUS score for skilled users was 88.50, indicating that the system is easy to use, consistent, and well understood by experienced users.

Overall, the comparison indicates that user experience significantly influences usability perception, and improvements are required to enhance learnability for novice users.

3.1 User Performance

Table 2. Task Completion Rate

No	Category Respondent	Participants' ID	Number of Tasks Completed	Completion Rate (%)
1	Beginner	B1	3 of 3	100
2		B2	2 of 3	66,67
3		B3	2 of 3	66,67
4		B4	1 of 3	33,33
5		B5	3 of 3	100

No	Category Respondent	Participants' ID	Number of Tasks Completed	Completion Rate (%)
6		S1	3 of 3	100
7		S2	3 of 3	100
8	Skilled	S3	3 of 3	100
9		S4	3 of 3	100
10		S5	3 of 3	100

User performance was evaluated based on task completion rate, task completion time, and error rate. All skilled users successfully completed all assigned tasks, achieving a 100% task completion rate, while novice users showed varying success rates ranging from 33.33% to 100%. This indicates that novice users experienced difficulties, particularly during early system interaction.

Table 3. Task Completion Time

No	Category Respondent	Participants' ID	Task 1 (second) installing the tool (set-up)	Task 2 (seconds) organize/operate the tool	Task 3 (seconds) cleaning the tool	Total (seconds)
1		B1	150	380	180	710
2		B2	140	360	170	670
3	Beginner	B3	160	400	190	750
4		B4	170	420	200	790
5		B5	145	390	175	710
6		S1	60	240	95	395
7		S2	65	250	100	415
8	Skilled	S3	58	230	90	378
9		S4	70	260	105	435
10		S5	62	245	98	405

Table 4. Task Completion Error

No	Category Respondent	Participants' ID	Number of Errors	Error Rate (%)
1		B1	3	33,33
2		B2	6	66,67
3	Beginner	B3	8	88,89
4		B4	10	111,11
5		B5	4	44,44
6		S1	1	11,11
7		S2	2	22,22
8	Skilled	S3	0	0,00
9		S4	1	11,11
10		S5	1	11,11

In terms of efficiency, novice users required an average of 726 seconds to complete all tasks, whereas skilled users completed the same tasks in approximately 406 seconds. Additionally, novice users exhibited higher error rates, including repeated errors within a single task, while skilled users

made very few or no errors. These findings demonstrate that the system supports effective and efficient performance for experienced users but still presents challenges for novice users.

3.1 Physiological Response (Body Temperature)

Table 5. Task Completion Temperature

No	Category	Participants' ID	Before Temperature (°C)	Temperature After (°C)	ΔT (°C)
1		B1	36,2	36,9	0,7
2		B2	36,1	36,8	0,7
3	Beginner	B3	36	37	1
4		B4	36,3	37,2	0,9
5		B5	36,1	36,7	0,6
6		S1	36	36,2	0,2
7		S2	36,1	36,3	0,2
8	Skilled	S3	36,2	36,4	0,2
9		S4	36	36,1	0,1
10		S5	36,1	36,2	0,1

Physiological measurements showed that novice users experienced a higher average increase in body temperature (0.78°C) compared to skilled users (0.16°C). This indicates greater physiological and cognitive workload among novice users, which is consistent with their longer task completion times and higher error rates.

3.4 Participant Characteristics

Table 6. Participant Anthropometry

No	Category	Respondents' ID	Age (Years)	Gender	Height (CM)	Arm Length (cm)	Body Weight (KG)
1		B1	21	Women	160	65	62
2		B2	22	Men	170	68	67
3	Beginner	B3	22	Women	156	64	59
4		B4	22	Men	170	69	69
5		B5	22	Women	160	66	57
6		S1	30	Men	169	67	66
7		S2	33	Men	170	68	70
8	Skilled	S3	37	Women	161	66	67
9		S4	32	Men	171	70	72
10		S5	34	Women	168	65	65

Beginner users were aged 20–24 years, while skilled users ranged from 30–35 years, reflecting differences in experience and familiarity with similar systems. Anthropometric data showed no extreme differences between groups, indicating that performance differences were mainly influenced by experience and cognitive factors, rather than physical characteristics.

4. Conclusion

This study evaluated the usability and user performance of a corn sheller system by comparing novice and expert users using the System Usability Scale (SUS), task-based performance metrics, and physiological responses. The results indicate a clear distinction between the two user groups,

which is consistent with findings reported in previous usability and human–machine interaction studies.

The SUS results showed that expert users achieved a high average score of 88.50, categorized as *excellent usability*, while novice users obtained a lower average score of 58.50, classified as *marginal-low*. This finding is in line with the empirical study by Bangor et al. [13] , which demonstrated that SUS scores below the benchmark value of 68 are typically associated with learnability issues and difficulties experienced by first-time users. Previous research also suggests that experienced users tend to rate systems more positively due to familiarity with operational workflows and reduced cognitive effort during interaction [13][14]. Therefore, the lower SUS scores among novice users in this study indicate that the corn sheller system still requires improvements in learnability and initial guidance.

User performance analysis further supports these findings. Expert users demonstrated higher task completion rates, shorter task completion times, and lower error rates compared to novice users. Similar performance gaps between novice and experienced users have been reported in prior ergonomics and task-performance studies, which emphasize that operational experience significantly improves efficiency and accuracy, particularly in manual and semi-mechanical systems [15]. In contrast, novice users in this study required more time and made more errors, indicating higher cognitive demand and limited familiarity with task sequences, consistent with earlier findings in usability research.

Physiological measurements revealed that novice users experienced greater increases in body temperature during system interaction, indicating higher cognitive and physiological workload. This result aligns with previous workload assessment studies using physiological indicators, which report that increased physiological responses are associated with elevated mental workload during unfamiliar or cognitively demanding tasks [16]. Conversely, the minimal physiological changes observed among expert users suggest better adaptation and lower stress levels, as also reported in prior human factors research [4].

Anthropometric factors were found to have no significant influence on performance or physiological responses. This finding is consistent with earlier studies indicating that, when workstation and tool dimensions fall within acceptable ergonomic ranges, performance differences are primarily driven by cognitive factors and user experience rather than physical characteristics [17].

Overall, the findings of this study are consistent with previous DOI-indexed research, confirming that user experience plays a critical role in usability perception, task efficiency, and cognitive workload. While the corn sheller system demonstrates good usability and performance for experienced users, improvements in interface clarity, operational consistency, and initial user guidance are necessary to enhance usability for novice users and reduce cognitive and physiological workload, as recommended by prior usability and ergonomics studies [13][14][17].

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Conflict of Interest: The authors declare that there are no conflicts of interest.

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