User Centered Design: Design and Development Methodology of Seed Planting Tools

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Abstract. Gejlek or Galah is a conventional wood-made seed planting tools aid common used by corn farmers. The limited functions and heavy weight of the existing seed planting caused low productivity and long duration in planting activity. The aim of the research is to design and to develop seed planting tools which able to accommodate user needs. User-Centered Design (UCD) methods used to design product focused on customer satisfaction. 15 respondents involved in this research to measure productivity, practicality, reliability and ergonomic. Validity test represent by F-value produce result test in between 0.35 to 0.625 where Fₑᵣₛ > Fₑₘₛ means reject H₀ or seed planting tools design able to fulfil user needs and different from previous design. User test show how work load against pulse measurement improve 26.44% and Nordic Body Map decrease by average 25% which mean there are significant improvement in terms of work load and ergonomics. It helps increase work productivity.

1. Background
Recently, Farmer used Tugal method or conventional method to plant the corn. Tools made from wood, called gejlek or galah. The limited functions and heavy weight of the existing seed planting caused low productivity and long duration in planting activity. Repetitive motion during planting activity is ne of the essential factors caused non-ergonomic posture, arise fatigue and complaint on certain body parts[1][2][3][4][5].The field research showed that the average pulse during work was 108.12 dpm (heavy workload category). The average for the % HR Reserve operator was 37.5% (need improvement). In addition, NORDIC measurements state that the most frequent of pain complaints were right shoulder 75%, right elbow 87.5%, right wrist 75%, upper back 87.5%, lower back / waist 100%, thigh 62.5% and knee 75 %. Corn seed planting tools design is very important in developing corn seed planting tools to simplify the planting process, increase productivity, and reduce planting time[5][14].

Involving users throughout the design process, design trials up through to final evaluation via a variety of research and design techniques so as to create highly usable and accessible products for them[15][23]. User-Centered Design (UCD) is an approach aims to improve human needs management in the Product Development Process (PDP). The main aim of this approach is to incorporate the users more closely...
into the development process already in very early phase, in order to obtain direct clarifications on the specification requirements and immediate feedback from them. Design approach methodology connect real needs, real objectives and real tasks of user when design relatively flexible and changes can be made at lower cost as early as possible into system design [25], [24],[26]. The implementation of UCD method in this study involves four phases, namely: (1) Analysis Phase: This stage ensures all business and user requirements of planting tools are taken into deep consideration, prior to the start of the design phase of planting tools. (2) Design Phase: The phase ensures design meets all business and user requirements. Also the phase should provide a comprehensive approach to the design of the system. (3) Implementation Phase: This stage involve user to test the system and interact with designs and implements them into working systems ready to go live. (4) Evaluation Phase: The phase involves continuous evaluation of the new system, monitoring the performance of planting tools against usability objectives the tools. User involved for further feedback and evaluation.

2. Research Method

2.1. Phase 1: Requirements Analysis
The first stage of the User-Centred Design is to gain and identified user needs data [27][28]. All of information obtained or gathered from user at this stage will be used to determine the initial design before the design phase begins.

2.2. Phase 2: Planting Tools Design
Design Phase is a step to determine seed planting tools design specification that will be developed and to make sure design fulfill user needs[30]. Technical design proposal involved as important proposal help to answer all attribute design and seeds planting tools criteria. Concept will be applied in design phase will be based on customers input which area productivity, practicality, reliability and ergonomic. Productivity concept accommodate seed planting tools design which able to be used in certain period of time and certain area. Practical concept accommodates seed planting tools which provide simplicity during planting period, less man power utilization and seed volume capacity covered average agricultural area. Reliability concept accommodate seed planting tools design able to answer customer needs toward specific requirement such as land contour, made of durable and long-life material and semi mechanical function. Reliability concept provide easy to be adjusted with worker posture, light, and comfort.

2.3. Phase 3: Implementation
Detail specification of seed planting tools design finished, next phase is involved user testing the tools, usability factor integration and feedback before final design move to evaluation phase[31]. User testing involve 15 respondents to gain direct feedback supported by Real Prototyping from data before research taken. Moreover, this stage expecting active interaction from user according to User Centered Design. Validity test using One Way Anova to identify improvement correlation and result to answer user needs.

2.4. Phase 4: Evaluation
The evaluation phase is continuous evaluation process and performance monitoring of designing user-based planting tools[32]. User actively involved testing the tool. They will be asked to utilize the prototype for a certain period of time. User feedback during testing will be used and very important in develop and evaluate the final design of user centered design method series.
3. Finding and Result

3.1. Planting Tools Design

Four attributes namely productive, practical, reliable and ergonomic were the final attributes result of designing the tools using user-centred design (UCD) method. Each of attribute has specific role build real prototype for a product that meet user requirement. Table below will explain the criteria of attributes obtained from user perspective.

| Design Attributes | Criteria |
|-------------------|----------|
| **Productivity**  | The wide of area that can be planted in a certain time unit period |
|                   | Period of resting time during the planting process in a certain time period |
|                   | The number of seeds that can be planted in a certain time period |
| **Practicality**  | Tool is easy to be used and operated |
|                   | Fewer human resources |
|                   | Maximum speed capacity |
| **Reliability**   | Able to be used for various types of soil contours |
|                   | Made of material that has a long technical life span |
|                   | Semi mechanical |
| **Ergonomically** | Convenient to be used for a certain time |
|                   | Light to be used during planting |
|                   | Easy to adjust to work posture |

User-Centred Design (UCD) stage is repetitive process to gain criteria which able to answer all the technical needs and meets user requirements. Picture below show detail of technical design originally from user input and feedback.

![Figure 1. Design of Seed Planting Tools](image)

Productive attributes consist of three criteria which are the wide of area available to be planted in certain period of time, resting time period during the planting activity in certain period of time and
number of seeds available to be planted in certain period of time. Practical attributes consist of planting tool is easy to be used, utilize fewer human resources and maximum seed capacity. Productive and practical attributes indicated by component number< 7, 9, 12, >. The specification of planting tool capacity is 600 ml or equal to 1 Kg seeds. Moreover, tools made of 1mm and ¼ inch diameter Galvani’s material. Total weight of planting tools ± 800 gr.

Reliability attributes define as an attribute which can meet user requirement for planting tools that can be utilized in all kind of soil contours, made from durable material and supported by semi-mechanical work systems to accelerate and simplify the planting process. In technical design, reliability attributes define on component < 1, 2, 3, 4, 5, 6, 8, 9 > with 1.2 mm and ½ inch stainless material as part of planting tools body and support semi mechanical system which design to issue number of seeds consistently with help from pull lever. In order to release the number of seeds, the tools also occupied with 8 cm and a tilt angle of 45° output system.

Ergonomically attributes play important role to create easy to be adjusted with user posture, comfort, and light planting tools. Ergonomic attributes indicated by component number < 10, 11, 12, > on technical design. The standard size of designed planting tool is 115 cm and can be adjusted up to ± 20 cm.

3.2. User Testing

User’s complaints which perceived and successfully identified in analysis stage are important and need to be accommodated at the evaluation stage. Pulse rate measurement used to observe Cardiac Output increase level [27]- [34]. The physical effect can be observed directly from average pulse during planting activity. Workload classification determined by comparing resting pulse and working pulse against maximum pulse. The pulse measurement respondent is 15 and use tens meter/stopwatch.

Table 2 show the measurement result from existing planting tools and new design planting tools. Based on the table below, average resting pulse show alteration from 73 pulse/minutes to 68 pulse/minutes. Average of working pulse from average 108.12 pulse/minutes to 97 pulse/minutes. The average of maximum pulse from 198 pulse/minutes to 158 pulse/minutes. Heart rate reserve is one way to classified work load based on resting pulse until maximum pulse rate show changing from average 37.5% to 26.44%. The data show that work load felt by user decrease.

NORDIC Body Map used as prevalence parameter to the body parts that experience symptoms because repetitive work[36][37][38][39][40][41][42][43]. NORDIC measurement conducted by distribute questionnaire to 15 respondents to understand which part of user body experience the pain. Before measurement conducted, the respondents have been used the seed planting work repetitively for more than 1 months. Table 3 show NORDIC Body Map data consist of complaints above 50% (need improvement) such as right elbow (50%), right wrist (37.5%), upper back (37.5%), lower back / waist (50%), thigh (37.5%) and knee (37.5%). The decreasing of complaint percentage from limb using NORDIC Body Map show an indication of direct impact from improvement process towards the work posture related to work productivity.

Tables 3 below show the result from pulse measurement and fatigue level measurement. The measurement of the pulse indicated by % HR Reserve and % CVL has decreased from 37.5% to 26.44%, which indicate that the users’ workload is reduced. The measurement of fatigue level with the NORDIC Body Map against the limbs also show significant decreases such as right shoulder limb from 75% to 50%, right elbow from 87.5% to 50%, right wrist from 75% to 37.5%, upper back from 87.5% to 37.5%, lower back/waist from 100% to 50%, thigh from 62.5 to 37.5% and knees from 75% to 37.5%.

| No | Parts of Body            | UoM       | Old Planting Tools Average | Designed Planting Tools Average |
|----|--------------------------|-----------|----------------------------|---------------------------------|
| 1  | Pulse Rate Break         | (pulse/minute) | 73                           | 68                             |
| 2  | Working Pulse            | (pulse/minute) | 108.12                       | 97                             |
| 3  | Maximum Pulse Rate       | (pulse/minute) | 195                          | 158                            |
| 4  | Heart Rate Reserve       | (%)       | 37.5                         | 26.44                          |
### Table 3. Fatigue Level Measurement Based on NORDIC Body Map

| No | Parts of Body | Old Planting Tools | Designed Planting Tools |
|----|---------------|---------------------|-------------------------|
|    |               | Complaints Number  | Complaints Number (%)   | Complaints Number | Complaints Number (%) |
| 1  | Neck          | 3                   | 37.5                    | 2                | 25.0                    |
| 2  | Right shoulder | 6                  | 75.0                    | 4                | 50.0                    |
| 3  | Left shoulder | 3                  | 37.5                    | 2                | 25.0                    |
| 4  | Right elbow   | 7                  | 87.5                    | 4                | 50.0                    |
| 5  | Left elbow    | 2                  | 25.0                    | 2                | 25.0                    |
| 6  | Right wrist   | 6                  | 75.0                    | 3                | 37.5                    |
| 7  | Left wrist    | 3                  | 37.5                    | 2                | 25.0                    |
| 8  | Upper back    | 7                  | 87.5                    | 3                | 37.5                    |
| 9  | Lower back/waist | 8              | 100.0                   | 4                | 50.0                    |
| 10 | Thigh         | 5                  | 62.5                    | 3                | 37.5                    |
| 11 | Knee          | 6                  | 75.0                    | 3                | 37.5                    |
| 12 | Ankle         | 4                  | 50.0                    | 2                | 25.0                    |

3.3. Validation

One-Way Analysis of Variance (ANOVA) statistical tests used to validate planting tools [42]. The hypothesis test was carried out to observe whether there were significant differences between user requirements and the design of planting tools. The hypothesis developed as follows:

- $H_0$: There is no difference between the user requirements and planting tools design
- $H_1$: There is difference between the user requirements and planting tools design

### Table 4. One Way Variance Analysis Test Result

| Design Attributes | F-values |
|-------------------|----------|
| Productivity      | 0.467    |
| Practicality      | 0.368    |
| Reliability       | 0.625    |
| Ergonomically     | 0.354    |

Validity test was conducted on 15 respondents and agreed to be measured productivity, practical, reliable and ergonomic aspects. Productive attribute test, respondent receive challenge planting corn seeds in the specific area determined by researcher instruction. Parameter observed are the number of seeds planting in certain unit of time period using existing planting tools and the Used-Centered Design planting tools. Practical, reliability and ergonomic tests are carried out simultaneously with observation and direct measurement level of fatigue to all respondents when productive testing is carried out. Recap of validity test translated into F Value to get hypothesis compiled in the beginning of the study. As shown in table 4, the F value ranges from 0.354 to 0.625. Because $F_{Count} > F_{Table}$ where $F_{Value} > 0.274$ then hypothesis one ($H_1$) is accepted. It means that the design of seed planting tools meets all user requirements and different from previous designs.
4. Conclusion

Planting tools potentially developed as the main planting tools in grain farming. It helps answering user's needs about tools which able to provide convenience, comfort and increase productivity. The implementation of the user centered design method as an approach from product design and development is one of the solutions during seed planting tools design which are capable answering user requirement needs. In addition, the user centered design provides focus on users’ requirements during development process, reducing all changes needed that might happen in the end of the development process and helping to measure design effectiveness. Further research should be conducted with considering overall aspect of design that have not been involved in this study.

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