The development of universal design principles for appropriate technology in small and medium enterprises (SMEs)

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Abstract. The Indonesian government has considered appropriate technology (AT) as a cost-effective strategy to increase productivity, including for farmers in processing agricultural commodities. However, its acceptance and effectiveness still need to be improved so that AT can be used for the general population. The existing AT designs seem to fail in considering the characteristics and capabilities of their users. This paper proposed expanding universal design principles for AT in small and medium enterprises (SMEs). After conducted random observation and interviews with SMEs in Subang Area, this study refers to relevant literature studies from various previous studies. This study’s results are new universal design principles: flexibility in use, practicability, ease of service, perceptible information, tolerance for error, low physical effort, low energy, adjustability, mobility, and modular and straightforward and intuitive use. A conceptual model proposed in this study describes the relationship among user characteristics, the concept of universal design, and the effectiveness of using appropriate technology.

1. Introduction
Appropriate technology (AT), defined as technology suitable for community needs, environmentally friendly, and produces added value from an economic aspect, can be found in agricultural commodities’ process into value-added products on a small to medium scale. The use of AT is expected to increase work effectiveness and business productivity. The problems of applying AT in small and medium enterprises (SMEs) are generally divided into three categories: entrepreneurial, technological, and administrative issues [1]. One way to overcome technical problems is to provide technology that suits SMEs’ needs [2]. The Indonesian government has considered an AT as a cost-effective strategy to increase productivity. An AT has been widely recognized as a technology solution for providing technology that has adequate performance at an affordable price suitable for SMEs [3].

Statistical data shows that workers in Indonesia’s small and medium industries are quite diverse in terms of education level, age, and gender [4]. Based on gender, it is still dominated by female workers, namely 53.23% and male workers as much as 46.77%. The education levels of workers also vary from elementary to tertiary education, with the largest number being dominated by elementary school graduates. In terms of age, most are in the range of 15-65 years.
In this case, the characteristics of the users are factors that influence the use of a technology [5]. The integration of user needs in product design is one of the problems for SMEs [6]. Several previous studies have shown that the current AT design development generally focuses more on the technical and functional aspects of the machine and the economic spec [7, 8], and not all of them are designed to accommodate users’ dimensions of different individuals. The incompatibility of the device design with the users can result in physical fatigue and mental fatigue, leading to decreased effectiveness and productivity. In the long term, it will result in health problems [9].

It is anticipated that the difference in terms of AT users could cause AT to be less than optimal. One of the concepts that can be employed to increase AT’s use in Indonesia for various users is the universal design concept, defined as a design of products and environments to be usable to the greatest extent possible by people of all ages and abilities [10]. The concept of universal design was introduced by Mace [10]. This concept can be applied to creating products, buildings, public spaces, computer programs, and services that can be used by all groups of users as much as possible without the need for particular adaptations or designs [11].

AT design with a universal approach has not become a standard application in Indonesia. The current design only focuses on technical and functional aspects and has not impartially considered the needs of those who have different abilities, age ranges, and gender. The perception that the application of universal design is expensive, resulting in insufficient efforts for the application and development of universal design [12]. However, the application of universal design will indirectly ease all AT users. Thus, the universal AT design is expected to accommodate various types of users and SMEs based on diversity of demography, physical abilities, cognitive abilities, behavior, and working conditions to increase the effectiveness of using AT. This study aims to develop universal design principles for AT in small and medium enterprises (SMEs) and a conceptual model that describes the relationship among user characteristics, the concept of universal design, and the effectiveness of using appropriate technology, referring to the relevant previous literature.

2. Method
Identification and development of universal design principles and conceptual models for using AT can be done through observation and literature study. For observation, you can go through UKM in Subang area. Meanwhile, literature studies can be accessed through several publishers such as Science Direct, Springer, MDPI, Taylor, and Francis online. As a form of direction, use search words, namely universal design and appropriate technology. Besides the manuscripts obtained by these two keywords, other related papers are also used as support. The collected literature is then analyzed, and articles related to the topics to be discussed are selected.

3. Results and Discussion
3.1. Universal design principles
The Center for Universal Design North Carolina State University (CUD) has developed universal design principles to guide the design and implementation process [10]. There are seven universal design principles: equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, and size and space for approach and service.

The principles and context of universal design will evolve and vary according to different needs [13]. To facilitate the implementation of AT in Indonesia, use universal design principles that are under the AT conditions in Indonesia. The results of the initial observation dan interview on the use of AT in five SMEs in Subang Area showed that some equipment for the AT was underutilized. The complaints that were generally raised were high energy costs, impracticality, and technological complexity. The existing AT designs seem to fail in considering the characteristics and capabilities of their users. There is an opportunity to develop a universal
design principle in line with the AT in Indonesia. In this research, some universal design principles for AT are proposed according to the needs in Indonesia. The seven universal design principles from the CUD are a combination of ergonomics concepts (reflected in principles two, five, and six), affordability of space (focus seven), and communication (principles three and four) [14]. Apart from these seven universal design principles, some researchers also propose universal design principles, as shown in Table 1.

Universal design principles show the influence order of regulations on product design. Thus, the functionality factor is a significant consideration factor that influences design. The aesthetic aspect and the commercial value of the product are the most different factors than the universal design principles of CUD. This is because if designers do not consider the aesthetics and commercial values such as the economic benefits of development and production costs during the design stage, the competitiveness of the product will decrease, and the product will naturally be eliminated from the competitive market [13]. In general, universal design principles from [15] are almost similar to CUD principles but emphasize the usability and safety aspects of a product design. Several different factors are the addition of the adaptability factor and the factors of secure, safe, and private use. The universal design principles proposed in this study are tailored to the needs of users and the characteristics of the location and their use in SMEs. The most prioritized aspects of the universal design principles for AT are ergonomics, mobility, and practicality.

Practicality and mobility aspects are important because considering the variety of user conditions and various topographies, distances, and easy access is necessary to develop a compact mobile, easy to install, easy to increase the capacity, and easy to maintain. One of the added
principles is the modularity factor. The importance of using a modular system in universal design is also emphasized by [16]. The modular system provides benefits in ease of upgrading and maintaining, the comfort of product diagnosis, increased efficiency in reuse and recycling, and ease of repair [17]. The low energy factor as a technical aspect is also added to the universal design principles, considering that energy issues are quite crucial in several locations in Indonesia.

3.2. Conceptual model

The Indonesian government program related to the development and application of appropriate technology has been running for 20 years. Many different types of AT have been developed and used by the general public, farmers, and the business sectors. However, its acceptance and effectiveness still need to be improved so that AT can be used for the general population. There are still many obstacles in its implementation [18,19]. This is because the AT being disseminated is still not based on the recipient’s condition and the SMEs’ needs. One of the efforts to increase business productivity is by increasing the effectiveness of using AT in SMEs.

Several previous researchers have tried to develop frameworks and models related to universal design. In general, the developed frameworks and models focus a lot on universal product analysis and testing. Some researchers have tried to develop a framework in action-function diagrams to compare universal product designs with available product designs such as those on the market [20]. Next, the researchers developed an evaluation model based on qualitative and quantitative user values and needs [21]. Finally, the researchers also developed a universal product assessment method using psychometric parameters [22]. However, there has been no research that has developed a comprehensive model for implementing a universal design that covers design aspects and includes the elements of individual, technical, and work environment diversity.

The AT equipment characteristics that focus on this study are the equipment used in the post-harvest processing of agricultural products at the SMEs scale. Thus, the AT must be following the needs of its users. A conceptual model that elaborates individual factors, technical factors, work environment, and design factors are proposed based on previous literature searches. The effectiveness of AT in SMEs aims to explain the causal relationship between one aspect and another. This model is used to test whether the use of the universal design concept in designing AT will significantly affect increasing work effectiveness at SMEs. A complete conceptual model can be seen in Figure 1.

SMEs generally have a smaller business scale, fewer employees, and fewer resources than large industries. SMEs also have unique characteristics, namely the high heterogeneity of workers’ demographic factors [23]. Besides, the existence of SMEs in Indonesia is spread from urban to rural areas [4]. SMEs generally have limited production space, so AT must also consider the work environment besides the factors of comfort, safety, convenience, and practicality.

Increasing work effectiveness at SMEs by improving the AT needs more attention because until now, the contribution of SMEs to the Indonesian economy is significant [24]. Some of the factors that become obstacles for SMEs to develop are technology and cost factors [25]. The results of other studies also state that AT, which has been widely applied, ultimately produces poor yields due to low data resistance and lack of technical support in the event of a breakdown. A study conducted by [26] shows that someone will adopt AT if they think that there will be support both technically and physically for the technology. The technical factors in this model consist of cost, durability, and technical support.

Design is one of the main factors in product development. In the last few decades, human characteristics have become an essential factor that has begun to be considered in the product design process. Product development for human use is a complex process that requires knowledge from various technical fields tailored to consumers and producers [27]. When designing a technology, the user factor is the first thing that must be considered. This is because users will
interact directly with the technology, so that technology must also be compatible [28]. In this model, the individual factors considered are physical, cognitive, demographic, and behavioral aspects.

For individuals, the technology to use must support the work that they need to complete. The more functions it has following the individuals’ tasks, the more likely they will use technology. Users will adopt technology when it is appropriate for their duties and improve their performance [29]. In the SMEs’ context, the AT equipment must also support the work to be carried out effectively, comfortably, safely, healthily, and effectively. The design factor consists of the principles of the modified universal design.

4. Conclusion
The new universal design principles proposed in this study are the flexibility of use and practicality, and ease of use. Various other measures such as clear information, fault tolerance, physical defects, low energy use, modification adjustments, mobility, modular use, and simplicity are intuitive. Based on the literature study, a conceptual model that describes the relationship among user characteristics, the concept of universal design, and the effectiveness of using appropriate technology is proposed. This study is part of ongoing research on applying universal design concepts to designing post-harvest SME equipment and its application in Indonesian SMEs. The next stage is to develop a hypothesis based on the proposed framework and empirically validate the proposed model.

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