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INCORPORATING RURAL USERS IN SMALL-SCALE GROWING CONTAINER DEVELOPMENT: A CASE STUDY.

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ABSTRACT

If the users of products developed for them are incorporated in the design process it is more likely that an acceptable and usable outcome will be achieved. A user-centred design process places a stronger emphasis on user involvement. In cases where the users live far away from the design facilities, certain logistical and financial constraints become apparent because an iterative process of feedback and development is required. Against this background, the Department of Industrial Design at the University of Johannesburg chose a project to use as case study to analyse the iterative design process. The case described in this article is a project which involves the development of small-scale agricultural products for users in a rural area of the Limpopo province. This development is being undertaken by the University of Johannesburg with the aim of developing water-efficient growing systems suited to the people in the area. Studying this project required multiple field trips allowing for observation, data gathering and prototype implementation. This article examines the strategic objectives of each of the role players who assisted in undertaking the research in an attempt to identify shared interests and provide recommendations and concerns associated with developing products for people in rural areas.

Key words: user-centred design, industrial design, product development, agricultural extension.

1. INTRODUCTION

Using a product or piece of equipment can sometimes be extremely frustrating. It is important that the user accepts the product and is able to use it easily for its intended task. Examples from everyday life to illustrate this point can be using a tin-opener, driving a vehicle, or trying to pitch a tent. Some everyday tools and gadgets are easy to use and some are not. The product discussed in this article is intended to assist with growing food to feed families. The easier and more naturally a product is to be used, the higher the likelihood it will be accepted. For this reason it is important that products are developed to suit the users effectively. These are important considerations within the field of industrial design, which entails the development of products intended for manufacture.

There are various design methods that are suitable for the development of products to suit users. One such method is the user-centred design process (UCD). This process is heavily dependent on the intended users forming part of the design process, thus providing important information which assists in the development of the product. Throughout the process changes are made and the product is further refined towards what users need, want, or find suitable. This results in an iterative process of a designer undertaking development, presenting the outcome to users for feedback and testing, after which more development is undertaken.

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Logistical implications regarding the undertaking of this user-centred design process is an important consideration when the distance between the intended user and the research facilities becomes extremely great. As the process requires multiple contact times, the research cannot be squashed into one session nor undertaken without user input. Furthermore, gaining access to the users might be problematic for various reasons, and permission to do so may be required.

The research on which this article reports sought to examine circumstances surrounding a current project involving the development of an appropriate small-scale agricultural system for users within rural areas far away from the industrial design facilities. The physical distance between the university doing the product development and the intended users of the products complicated the necessary logistics to organise such research, as it required a lot of money and the permission from different organisations. This product development falls within the current design research being undertaken in the Department of Industrial Design[17], in the Faculty of Art Design and Architecture at the University of Johannesburg (UJ), with collaborative assistance from the Tshulu Trust, an non-governmental organisation (NGO) in the HaMakuya area in the Limpopo province, South Africa. An exploration of the various relationships between the institution and the NGO that assisted in this research and allowed for it to be undertaken in Limpopo makes it evident how each institution has various resources and strategic drives which can in some way assist researchers or agricultural extensionists[18] in undertaking their projects. This approach is explained through the analysis of the contributions of the various role players (educational institution and NGO), and their involvement in the current research project. This is done in attempt to draw recommendations for future collaborative relationships to assist in handling the logistics of field testing and developing appropriate products.

2. THE INDUSTRIAL DESIGN PROCESS

The industrial design process[19] is a creative and inventive process concerned with the development of manufacturable products which are intended for batch or mass-production. These products are able to satisfy identified needs or solve identified problems, and are intended to benefit the end-user(s) in some or other way. The product developing process fuses/amalgamates engineering, technology, materials and aesthetics into products which should balance all user needs and desires (Fiell & Fiell, 2006). This process includes the conceptual exploration of solutions, and the systematic narrowing down of ideas into a refined product solution. UJ has a Department of Industrial Design, which trains graduates to develop products effectively. Students and academics are involved in the development of products, undertake academic research, and collaborate with the design and manufacturing industry. The tools utilised in this process include design sketching, model-making, physical prototyping and the use of computer models. As the products are developed to suit intended users, it makes sense to explore and identify the requirements of these users. A suitable design methodology would be one which places the needs and requirements of the users at the centre of the entire process.

2.1 User-centred design

[17] Products developed within the UJ Department of Industrial Design developed for Master's and Doctoral projects have included water purifiers, efficient wood-burning stoves, and retained heat cookers.
[18] An agricultural extensionist is someone who facilitates and undertakes agricultural extension with the overall goal of creating and maintaining food security and alleviating poverty (Abdu-Raheem & Worth, 2011).
[19] Also known as the product design process.

UCD is a product design methodology which is aimed at maximising the probability of product acceptance and success by including the intended users in as much of the product design process as possible. Designing meaningful and innovative solutions that serves the intended users begins with understanding their needs, hopes and aspirations for the future. Using qualitative research methods allows for the designer to develop deep empathy for people for whom they are designing (IDEO, 2011). This process is then followed in the development of suitable solutions around these user-specific requirements as illustrated in Figure 1.

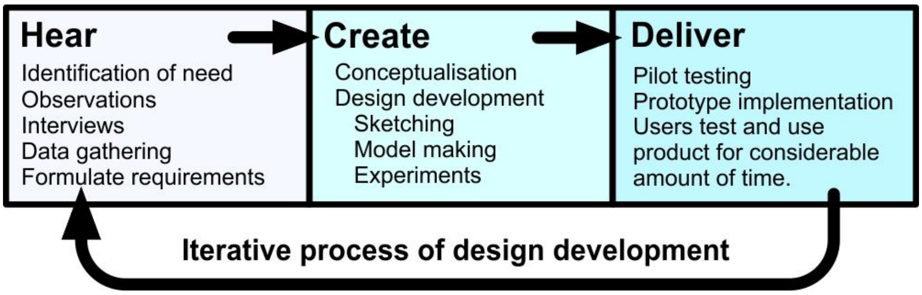

Figure 6: Steps of the design process. Adapted from IDEO (2011)

Once a design is at a point where it can be physically tested, prototypes can be made and delivered to the intended users for critique regarding various aspects such as desirability, feasibility, viability, personal preference, usability and functionality (IDEO, 2011). This valuable feedback can be used to further refine the product until it has reached a point where it suits the intended users and is able to be manufactured utilising appropriate methods and materials. Furthermore, it should be possible to distribute the product should at a suitable price point, resulting in an affordable product. This process is summarised in Figure 2.

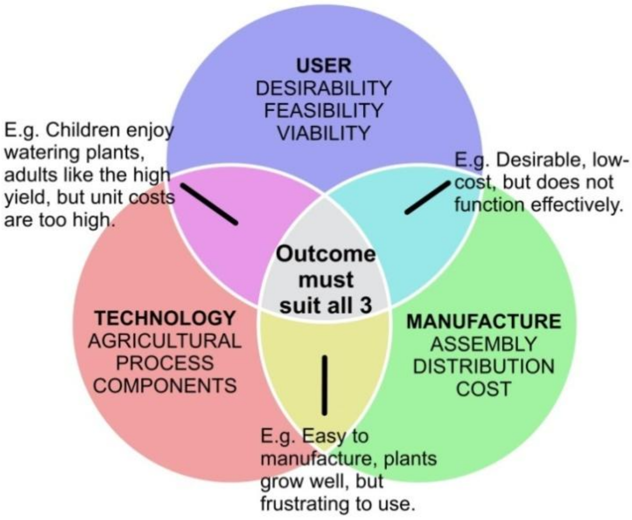

Figure 2: For product success, the design outcome must suit the user, technology and method of manufacture.

Rushing this process and failing to satisfy all three areas may result in product failure; therefore the process is not to be rushed, and should take as long as is necessary to yield a suitable outcome. This is illustrated in Figure 2 as the user, technology, and process of manufacture.

To illustrate the design process in practical terms the focus now moves to a case study of a research project in which the Department of Industrial Design at the University of Johannesburg is involved. The project involves the development of a small-scale agricultural growing system intended for users within the HaMakuya area in Limpopo. This research project is currently being undertaken and has not yet come to an end.

3. SMALL-SCALE GROWING CONTAINER DEVELOPMENT: A CASE STUDY IN LIMPOPO

According to the Food and Agriculture Organization (FAO) of the United Nations, one third of the total population of South Africa are vulnerable to food shortages because of the lack of suitable infrastructure in the deep rural areas and insufficient volumes of food being produced, since South Africa is a net food exporter (FAO, 2005). It is said that home-grown vegetables could alleviate this problem, but planting vegetables at home is only done on a small scale because of the small portion of the country that gets enough and reliable rain for successful rain-fed vegetable production (FAO, 2005). Members of households in many of the rural areas still have to travel considerable distances to gather water for household use. The water is usually collected from public standpipes which are scattered throughout the rural area, and the water is transported to the households in plastic containers. The amount of effort involved in this process makes it unsuitable for the irrigation of vegetable patches because the water is usually used for household purposes. There are, however, appropriate and more water-economic technologies that allow for growing fresh produce. These technologies are not suited to being used in low-income or rural areas and they are generally very expensive. This situation creates an opportunity for the development of more appropriate products to allow people in rural areas to grow their own fresh produce.

3.1 Previous small scale growing projects in Limpopo: institutional and household gardens.

Within Limpopo, the South African Department of Rural Development and Land Reform (DRDLR) has undertaken a comprehensive rural development programme with the aim of creating vibrant, equitable and sustainable rural communities. This has seen the creation of institutional gardens in four schools in Makhado, and the creation of 100 household gardens in the Mopani District (DRDLR, 2012). These institutional and household gardens provide the opportunity to develop valuable skills for people to grow food, as well as it grants them the opportunity to generate an income. As there are many more households within the rest of Limpopo, there are many opportunities for the creation of household growing systems to allow the people to grow their own food. Through the implementation of additional suitable projects in Limpopo, it will assist with the Department of Agriculture’s strategic plan regarding the availability, accessibility and affordability of safe and nutritious food at household levels (Department of Agriculture, 2014).

Worldwide, although there has been a drastic international improvement in the reduction of food insecurity, there are still almost 900 million people who suffer from undernourishment and around 2 billion people suffering from negative health consequences of micronutrient deficiencies (FAO, 2012). This, coupled with the growing world population which is estimated to reach nine billion by 2050, will eventually lead to unprecedented water demands to satisfy the requirements of all of the people. In agriculture this might involve the consumptive use of water needing to be reduced by minimising evaporation and transpiration (FAO, 2008).

3.2 Appropriate technologies for economical water use

Because the efficient use of water by agricultural systems is of crucial importance to future food security, there will always be a drive to increase the water efficiency of agricultural systems, both large and small. Conventional soil-based cultivation systems are not water efficient mainly due to loss by excessive irrigation, percolation, and evaporation, thus the use of soilless culture may be an alternative to soil-based cultivation (Albaho, Thomas & Christopher, 2008). Soilless culture falls within the family of agricultural practices of hydroponics, which the Merriam-Webster Dictionary defines as "the cultivation of plants in nutrient-enriched water, with or without the mechanical support of an inert medium such as sand or gravel" (Hydroponics, 2014). There are several advantages and disadvantages of this hydroponic method of agriculture which have been presented by the Department of Agriculture, Forestry and Fisheries (2011:6):

Advantages of hydroponics

a) No soil is needed; therefore it can be used in areas irrespective of soil quality.
b) The water stays in the system, increasing water efficiency and limiting water loss.
c) It is possible to control the nutrition levels in their entirety – lowering nutrition costs.
d) No nutrition pollution is released into the environment due to the system being contained.
e) Stable and high yields.
f) Pests and diseases are easier to control.

Disadvantages of hydroponics

a) Higher initial costs compared to growing in existing soil.
b) Careful monitoring of nutrients needs to be undertaken.
c) Different types of plants require different nutrients and growing conditions.

The advantages listed above merit an immediate attempt to develop or adapt agricultural technologies to suit the people who may benefit from them. The disadvantages should not form barriers preventing the progression of these technologies, but should rather be carefully considered and resolved through system adaptations and developments. There are many water-efficient technologies used with the undertaking of hydroponics; however, these are considered to be extremely technical, difficult to use, and expensive (Benton, 2004). Through developing the system components to better suit usability, cost and manufacture, system configurations may be arrived at which are affordable enough for use by people in the rural areas.

The need for interventions which may assist in the maintaining and increase of food security and the alleviation of poverty should be pursued (Abdu-Raheem & Worth, 2011). If these interventions are in the form of manufactured products, the application of the UCD process may be able to yield acceptable product designs. The input of the people living in the rural areas should therefore be required throughout the process of developing the designs. Furthermore, it would require iterative cycles in the design process in order to come to a suitable final product. The water-efficient aspects of hydroponic systems may prove effective for systems for people living in rural areas. The designer would require access to these users in order to undertake the UCD process.

3.3 Field research access

The Tshulu Trust, an NGO based in HaMakuya, Limpopo, is able to house and facilitate university researchers during field trips at their research facility on the banks of the Mutale River. These facilities can accommodate and provide support for researchers who intend to undertake research in the area. The facilities include accommodation, solar and generator power, transportation, and field assistance with translation, data gathering and data capturing. The Tshulu Trust aims to achieve sustainable livelihoods by improving the ability of community members to utilise their natural and cultural resources in an optimal and sustainable manner (Tshulu Trust, 2013). Tshulu supports community members through salaries and any profits earned through the undertaking of eco-tourism within the area. This relationship allows for research to be undertaken within the area, as previous agreements and discussions have already taken place between the NGO, and the rural chieftaincy within the area. In the case of the development of small-scale agricultural products, it means that this area would serve as an ideal location for prototype implementation, administration of questionnaires and focus group meetings.

3.4 Logistical implications

The distance between the UJ and HaMakuya is approximately 600 km (Figure 3). Because of the poor quality of the roads, it takes a day and a half to travel this distance. Furthermore travelling on the roads in and around the rural areas requires a suitable 4x4 vehicle.

Figure 3: Distance between design facilities and intended users (Adapted from Google Maps 2014)

As the UJ Department of Industrial Design does not possess its own vehicle, and vehicles within the UJ vehicle fleet do not include 4x4 capable vehicles, a suitable vehicle needs to be sourced and organised as part of this preparation. Fortunately, the Department of Industrial Design shares space with the UJ Sustainable Energy Technology and Research (SeTAR) Centre, which does possess a 4x4 capable vehicle. This centre provided their vehicle for undertaking the field work, which allowed for trips to HaMakuya to take place. Additionally, financial assistance was made possible by another research entity within UJ, the Manufacture and Research Centre's *Building Blocks Project*, which falls under the UJ Department of Engineering in the Faculty of Engineering and the Built Environment. This financial assistance was used for covering the services provided by the Tshulu Trust, as well as for petrol, and any data gathering materials which may be needed. It is therefore evident that various areas of assistance are made available which can allow the field research to be undertaken.

3.5 Role players assisting in the field research

It would not have been possible to undertake this research and development without the assistance of the various role players who assisted with financial and logistical aspects of the project. The role players are listed in Table 1 to illustrate the overall strategic objective of each, in conjunction with how each has assisted. The strategic objectives were retrieved from the organisational overviews of each.

Table 5: Role players in undertaking research

	Role player	Strategic thrust	Assistance in project
Institution	UJ Department of Industrial Design	Design for Development.	Home department where research is undertaken
	UJ Manufacture and Research Centre Building Blocks Project	Open Community Manufacturing: Open Design & Distributed Manufacturing	Funding to cover prototype development and field research
	UJ Sustainable Energy Technology and Research (SeTAR) Centre	Sustainable Energy Technology and Research	Vehicle support for undertaking field research
NGO	Tshulu Trust	Sustainable Rural Development	All aspects linked to field research Accommodation, field transport, translation, data capturing

With regard to the strategic thrusts of the different role players it is evident that there is a general trend towards community, development and sustainability. The partnerships created throughout the undertaking of a project of this nature seems to allow for each party to progress in their own strategic drives, in illustrating their involvement in areas such as sustainability, community development, and manufacturing.

3.6 Resources and tools within the Department of Industrial Design

The Department of Industrial Design has a comprehensive workshop which houses many different types of machinery capable of creating models, prototypes and batch manufacturing of items from wood, metal and plastic. Furthermore, CNC[20] machinery allows for laser-cutting and 3D milling of various material types. The UJ design studios house highly capable computers, with computer-aided design software packages and high-speed Internet. Lastly, the manufacturing sector within Johannesburg's limits allows for the outsourcing of many different types of manufacturing, allowing for effective design development facilities and prototype batch manufacturing to be within reach of students, staff and researchers within the university. The circumstances in HaMakuya are the opposite: at times problems are encountered with cellular coverage (for data, Internet and voice calls), electricity provided by diesel generators during designated times and no paved roads, and none of the facilities or manufacturing outsourcing opportunities. Manufacturing and assemblage need to be carefully planned, as all computers, tools, hardware, and equipment required in the field must be transported from UJ in a suitable vehicle.

[20]CNC, or Computer Numerical Control involves the operation of machinery, based on computer inputs. This allows for the manufacturing of items to be determined by computer designs. It results in highly accurate and reproducible items.

3.7 Technical development and testing

A suitable water-efficient irrigation technique which forms part of various hydroponic systems was identified to be that of passive sub-surface irrigation which relies on a soilless growing medium comprising Coir[21] and Perlite[22] (or any suitable inert wicking medium) to allow for root anchorage and nutrient or water wicking. This would allow for the growing medium to wick nutrients upwards without the need for any pumps or circulation components. This configuration can be utilised for hydroponics when a nutrient solution is used or conventional cultivation with soil, if the soil is able to wick water sufficiently. Since this type of system does not rely on any power sources, moving parts or intricate valves, it seems to be the most user-friendly option to begin with. Several different variations of this system were tested at UJ (Figure 4). Through this testing the systems could be learnt and adapted into what may be considered more user-friendly, low cost and functional systems by which to grow fresh produce effectively.

Figure 4: Experimental testing of different hydroponic systems

This system incorporated standard components, and utilised a standard 10-litre plastic bucket with an included reservoir, and filling of the reservoir made possible through the use of a filling tube. The growing medium inside the container wicked the water/nutrients upwards through the incorporated wicking chamber, as illustrated in Figure 5.

[21] Coir is a natural fibre manufactured from the husks of coconuts which can effectively be used as a growing medium.
[22] Perlite is a porous material which is widely used as a growing medium for hydroponic applications, as well as an additive in conventional soil systems. It is created through the heating and expanding of volcanic glass.

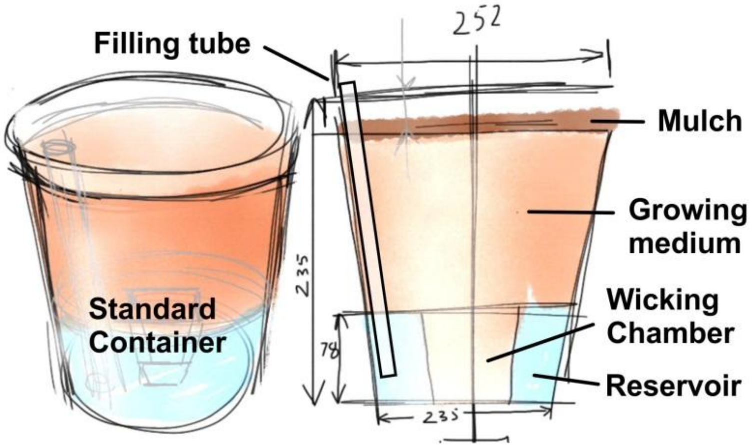

Figure 5: Prototype growing container

After approximately six months of experimenting with various prototypes, a system configuration was at a point where it could be tested as a batch at UJ (Figure 6), and depending on the effectiveness of the in-house test, changes could be made before implementing prototypes in Limpopo.

Figure 6: Prototype testing at the University of Johannesburg

3.8 Trips to the field

The first field trip was undertaken at the same time as when the prototypes were being tested at UJ. The purpose of this trip was to begin observing conditions in the area, and to begin identifying possible intervention approaches. It also included discussions with Tshulu, to determine who the area would be willing to participate in the testing. Tshulu representatives agreed to assist with pilot testing of the prototypes once they were ready for implementation, before any prototypes were distributed to surrounding rural households. No product implementation was possible during this first trip, as only small preliminary test prototypes were in operation at UJ.

The second field trip, which involved the first round of prototype implementation, with seven growing containers, was undertaken six months later in October 2013. This trip included pilot prototype training and implementation as well as pilot questionnaire runs. Figure 7 shows a

Tshulu representative receiving one of two hydroponic test sets (four of the seven total growing containers). This pilot prototype set included hydroponic nutrients, mixing containers, all hardware that would be needed, and instructional leaflets. Instruction on use and maintenance was discussed with Tshulu representatives, and together the researcher and the Tshulu representative planted various seedlings (including beans, tomato and spinach).

Figure 7: A Tshulu representative receives one of two hydroponic test sets.

Based on the information obtained from the pilot questionnaire, the data gathering tools could be refined. Subsequently, user-specific qualitative data could be gathered regarding patterns of purchasing and growing of fresh produce in the rural areas. This would inform specific technical aspects of moisture content, planting depth, and volumetric restrictions of growing containers. The questionnaire was refined through working with translators from the Tshulu Trust and pilot participants from the nearby community centre. After completion of this research trip, the Tshulu field assistants would complete 110 questionnaires later that month and these questionnaires would be translated, captured, and digitally sent back to the university. The questionnaires were completed and captured into digital format a month later in November 2013.

The intention is to finalise an implementation of ten growing sets, each comprising three growing containers to be provided to households in another planned field trip (30 growing containers). Half of these systems should rely on hydroponic nutrients for feeding the plants. The other half of the systems will serve as control systems which will include standard potting soil mixed with a suitable wicking material allowing for similar wicking action as the hydroponic sets. Both of these system types will be comprised of the same hardware, allowing for comparisons between the two to be drawn. Once these have been used by rural users for a considerable amount of time, and the results are promising, the design can be finalised and the system can be considered for distribution in the rural areas.

3.9 Complications in the process

Since the last field trip which was undertaken in October 2013, several drastic management changes have taken place within the Tshulu Trust, which may possibly affect the future of the ongoing design development of the planting system. Furthermore, the current available UJ departmental for field research will only be able to cover two more field trips, after which the future funding is still to be acquired; this does not include the cost implications of manufacturing test prototypes and the purchasing of materials. Logistical implications are an ongoing concern. These are the availability of vehicles and field assistance, and managing of gathered data – all of which may prevent the field visits from being undertaken.

Due to technical problems relating to computer connectivity issues within the area and problems with computer viruses, it took several months for the files to be sent (February 2014). Of the 110 intended questionnaires, only 86 could be retrieved. The remaining questionnaires are no longer available. The 86 intact questionnaires have been statistically analysed and can provide valuable insight into people's personal preferences regarding various types of fresh produce.

3.10 Synthesis of the field research

On the one hand the research would not have been possible without support from the various role players. On the other hand, it places the research in a position where it is dependent on these role players, where if something were to go wrong, the research would cease. The case study which is presented in this article provides an example of how the logistical implication of undertaking research can be problematic at times. Although the case study has not yet reached a point where a manufacturable outcome is possible, it shows that attempts are being made to suit new technologies to the circumstances in these areas.

It is recommended that researchers or extensionists who seek to develop solutions incorporate as much user input as possible in an attempt to achieve products that will be accepted by the users. Although some problematic circumstances may be encountered, there will be a greater likelihood of product acceptance if the user always remains at the centre of this process. It is proposed that agricultural extension projects that require the development or refinement of products intended for rural users should incorporate industrial designers in the process, in order to develop appropriate products that suit the user, as well as appropriate materials and manufacturing processes.

3.11 A way forward: collaboration between universities and agricultural extension officers

The agricultural extension officers who operate within the rural areas have a thorough understanding of the agricultural requirements of the people within the rural areas. It is recommended that universities discuss projects with these extensionists who in turn will be able to provide valuable insight into the area, as well as provide access to implementation sites where the projects are most suited. For the furthering of the case study discussed, implementing growing systems in institutional and household gardens would prove extremely beneficial and allow with direct partnership with government departments, and allow rural users to trial the water economic agricultural components.

The collaboration between academic institutions and Limpopo Department of Agriculture can allow for the effective development of appropriate small-scale agricultural products allowing households to grow their own agricultural produce. As stated in the National Policy on Food and Nutrition Security, 20% of South African households are found to be food insecure, leading to the setting up of multi-sectoral programmes (Department of Social Development & Department of Agriculture, Forestry & Fisheries, 2013). One of the programme avenues calls for the alignment of investment in agriculture towards local economic development, particularly within rural areas with subsidisation of inputs for increased food production. Academic institutions specialising in product development, for example the University of

Johannesburg's Department of Industrial Design, could assist with the product development of artefacts allowing for household food production.

It is recommended that prior to the implementation of future products associated with agricultural extension practices, Extensionists partner with academic institutions which can assist with the undertaking of implementation trials and associated data gathering. This could allow for data generation pertaining to the suitability of the implementation and appropriateness of the technologies. This would lessen the impact the resources required by the Limpopo Department of Agriculture, and would allow for the utilisation of skills and equipment already at the disposal of the academic institutions. This may pertain to product design, prototype development, technical testing and field testing.

4. CONCLUSION

The aim of this article was to illustrate the importance of the input of intended end-users in the development of a product. The product design process was presented, illustrating methods and tools, and the specific UCD methodology was explained. It is evident that incorporating users from areas that are far removed from the industrial design facilities introduce logistical concerns. A case study illustrated some of the logistical challenges. Access to the rural areas where the end-users live was made possible through assistance from various institutional entities within the university, as well as logistical support from an NGO in the rural area. Thus, a UCD process was started. The assistance from these role players included financial and logistical aspects, as well as data gathering and translation within the field. Without this support the UCD process would not be possible, possibly resulting in the development of products that do not suit the intended users.

The end-users had to be included in this design process and this caused logistical problems because they live in a remote area. The process of incorporating the users may include various iterative cycles involving product prototypes to be supplied to users, and feedback received, leading to further necessary changes to be made. The development of a product requires multiple field trips which span over an unknown period, making logistical and financial planning difficult. University and NGO participation allows for the identification of possible partnerships where assistance can be obtained while still focusing on strategic drives.

An analysis of the strategic objectives of each of the role players allowed for the observation of similarities in the research undertaken, and the strategic drives of each role player. These generally included community development, rural development and sustainability. By supporting the undertaking of the field research, these role players are able to illustrate their commitment to the strategic drives. It has been explained that although the field research was made possible through support from various institutions, there are associated risks in depending on this assistance, because if support is no longer available, the research cannot continue. The partnership between universities and extensionists is proposed as an effective way forward for undertaking appropriate product design with the people identified by extensionists as those who require the intervention.

Different institutions and organisations may share a common goal; therefore, it makes sense for such entities to collaborate. In this way development can be enhanced and strategic thrusts achieved. Through effective partnerships and careful product development, users in even the remotest parts of the country should be able to utilise products which they accept and find enjoyable to use.

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