ABSTRACT
Growing awareness of the unique needs and challenges in the developing world has resulted in the development of products for those in poverty. Successful product design focuses development efforts on design principles that are important to a target market. Consequently, the better these principles are understood, the higher the probability is that resulting products will be successful. Recognizing that the identification of these principles is a major challenge, this paper presents a method for identifying them for any target market, but especially for the developing world. The presented methodology uses characteristics of products within the target market to extract information about the underlying design decisions resulting in these characteristics. This information is then used to identify the design principles. To verify the ability of the method to identify these principles, the method is applied to best selling products in the US and then applied to products created for the developing world. The resulting principles from the two markets are then analyzed and compared to highlight the similarities and differences between the identified principles. The authors conclude that the resulting list of principles will enable designers to better design and develop products for the developing world.

1 INTRODUCTION AND BACKGROUND
There are approximately 1.4 billion people in the world who live on less than $1.25 a day [1]. In recent years, government and multinational agencies acting on the Millennium Development Goals, along with many other groups, have sought to improve the quality of life of this group of people [2, 3]. As a result of these efforts, and a growing awareness of the needs and challenges of these individuals, many potential avenues of accomplishing this goal have been identified [4]. One of these potential high impact avenues is through the development of products that enable the poor to help themselves by increasing their income or improving their quality of life [5, 6].

There are two common approaches in this type of poverty alleviation through product design, appropriate technology development and market-based development. Appropriate technology is used to design a specific technology that is then given to the community [7–9]. While many of these solutions have provided temporary success, problems with lack of individual ownership, poor maintenance of the product, and lack of reliable supply chains have resulted in the eventual abandonment of many of these products [10].

Alternatively, a market-based approach is used to design and establish supply chains for income generating products – products that generate income for the user – that are then purchased by the customer [11–13]. Products developed through this approach have sustainably increased the income of more than 12 million people to the point that they are no longer in extreme...
poverty [11, 14]. However, the limited purchasing power of the target customers has restricted these benefits from expanding to those unwilling to take financial risks required to invest in these products [15–17].

In addition, many other difficulties arise when designing products for people living in poverty due to the geographical locations and cultural differences of those in poverty relative to the designers [18, 19]. The majority of those in poverty live in developing countries [1, 3], and travel to these locations can be expensive and time consuming. As such, if important design principles and needs could be understood without requiring designers to visit or live in these remote locations, the cost and time to develop products could be reduced.

The most successful design methods use design principles that are important to a target market to guide development efforts and decisions [20, 21]. The better these principles are understood, the higher the probability that design efforts will result in a successful product. In situations where these principles are not explicitly known or understood, designers will often focus on principles that they have observed in other design experiences [22]. However, when designing products for unfamiliar markets (e.g., US designers developing solar cookers for people in Peru), this approach has a higher risk of failure. Recognizing that this problem occurs due to challenges in identifying the most important design principles, the method presented in this paper helps identify these principles.

Two case studies are provided to illustrate the presented method. The first case study establishes a point of reference by applying the method to best selling products in the US. The second case study applies the method to products created by both appropriate technology and market-based design for the developing world. The resulting principles from the two case studies are then analyzed and compared to highlight the similarities and differences between the identified principles.

Through these case studies and subsequent comparisons, the authors conclude that the presented method enables designers to successfully identify the principles for specific markets, including the developing world. Using these principles to guide the design process, designers can overcome the challenges of designing for unfamiliar markets.

An outline for the remainder of this paper is now described. In Sec. 2 the method for identifying principles is presented. In Sections 3-5 the case studies, analysis, and comparison described previously are presented, followed by concluding remarks in Sec. 6.

2 METHOD FOR IDENTIFYING DESIGN PRINCIPLES

This section presents a methodology for identifying design principles for any market. As illustrated in Fig. 1, the presented method incorporates five major process steps and three intermediary filtering steps. A discussion of each of these process and filtering steps is provided in this section.

2.1 Step 1: Identify the Target Market and Gather Information on Existing Products

The first step of the method is to identify the target market where new products will be distributed. After establishing the target market, existing products within this market are identified. For each of these products, as much information as possible describing the product’s fit, form and function is gathered. This may be accomplished through examination of the products, lead user surveys, customer reviews, product reports, and other market research. In situations where insufficient information is available on the target market, information from a closely related market is used.

Increasing the number and types of products being examined
will increase the understanding of the trends and culture within the selected market. However, information from similar products to those being designed can be more useful than information from unrelated products. For example, if the product being designed is a toy, focus should be placed on examining many different toys. However, by limiting the scope to toys, the information gathered on the target market is specific to toys and does not lend a strong understanding to general trends within the market. Similarly, expanding the scope away from toys can lead to unnecessary principles for designing a specific toy. Therefore, there is an important trade-off that must be considered between the product and product categories being examined and the information gathered through the method. If the goal of using the method is to better understand the market as a whole, it is recommended that a wider variety of products and product categories be considered. If the goal is to understand a specific market segment, then limiting the number of product categories can be beneficial.

Determining the number of products and the amount of product information that should be gathered can be a difficult decision. In testing by the authors, it was observed that most principles identified through the method could be obtained by examining 8-10 products. As such, it is suggested that a minimum 8-10 products be examined.

After determining the products to be examined, 2 or 3 products should be analyzed using Steps 1 and 2 simultaneously. For Steps 1 and 2 to be performed simultaneously, the user identifies characteristics as soon as a new piece of information is gathered. By tracking the number of unique characteristics identified relative to the effort required to gather and examine additional information, a trend of diminishing returns will be observed. Thus, when the rate of unique characteristics identified compared to additional pieces of information examined falls to a ratio of 1:20, a suitable stopping point has been found. Comparing the stopping point identified for each of the 2 or 3 products analyzed in this manner, the amount of information gathered for each of the remaining products should be close to the information gathered for the 2 or 3 test case products.

2.2 Step 2: Identify Product Characteristics

The second step of the method uses the information gathered in Step 1 to identify product characteristics. These characteristics define the fit, form, or function of the identified products. To illustrate this, assume the method is performed for a target market within a developing country and the product being reviewed was a stove. Potential characteristics of this product may be: the stove does not work well with traditional wood used in cooking fires or the stove requires frequent maintenance.

By identifying these characteristics, the designer is able to learn important information about the product and market. During this process, identifying characteristics using information that does not define the fit, form, or function of the products may lead to unimportant or misleading principles. To avoid this, information representing user emotion, product warranties, marketing strategies, etc. should not be used in the method. Step 2 is complete when all of the gathered information has been examined for characteristics.

Filter A: Remove Duplicate Characteristics. At the end of Step 2, the information is filtered to eliminate duplicate characteristics from a single product. Duplicate characteristics from different products should not be discarded.

2.3 Step 3: Extract the Generalized Product Characteristics

In this step of the method, the product characteristics identified in the previous step are converted into generalized product characteristics. This takes something specific to the product and makes it applicable to a wider variety of products. Returning to the example of the stove, one potential characteristic of the product was: the stove does not work well with traditional wood used in cooking fires. To convert this statement into a generalized product characteristic requires the words "stove" and "wood used in cooking fires" be replaced with general terms. Therefore, a suitable generalized product characteristic would be: the product does not work well with traditional energy sources. Without being expressed as generalized product characteristics, the principles identified in the final step of the method would be constrained to the individual products being reviewed. Step 3 is complete when all of the product characteristics identified in Step 2 have been stated as generalized product characteristics.

Filter B: Compile and Remove Duplicate Characteristics. At this point in the method, all generalized product characteristics are combined into a single set. Since general product characteristics across many different products may be the same, many duplicates are likely to occur. As such, the purpose of this filtering step is to remove duplicate characteristics from the combined set.

2.4 Step 4: Identify Possible Root Causes of the Generalized Product Characteristics

In this step, the underlying design decisions, or root causes, that may have resulted in the general product characteristics are identified (e.g., root causes of low cost may be used local materials or avoided feature creep). There may be many possible root causes for each general product characteristic. By identifying as many of these root causes as possible, the resulting design principles will be more complete. To assist in identifying a more complete set of root causes in a shorter period of time, it is suggested that this step be performed by multiple people. Ensuring the completeness of the identified root causes can be time
consuming. Therefore, it is important to find a balance between the time spent and the completeness of the root causes identified. Through testing by the authors, it was observed that most root causes of a single characteristic could be identified in 2 to 3 minutes. As such, to balance the trade-off between the time spent and the number of important root causes identified, it is suggested that no more then 3 to 5 minutes be spent on a single general product characteristic.

Filter C: Compile and Remove Duplicate Root Causes. In this filter, all root causes of negative characteristics are restated to result in the equivalent positive characteristic. Following this, all root causes are combined into a single set and filtered to remove any duplicates.

2.5 Step 5: Identify the Design Principles

Using the filtered list of root causes from the previous step, the design principles are now identified. To accomplish this, the guidelines that may have resulted in each root cause are identified, and labeled as the design principles for the corresponding target market. To illustrate this, the example root causes mentioned in Sec. 2.4 are revisited. For the root cause of used local materials, a potential principle that would result in this design decision is to consider available materials and local supply chains. Similarly, for the root cause of avoided feature creep, a potential principle is to maintain simplicity.

Since the principles identified are derived from the root causes of positive characteristics in the target market, these principles can guide the design of new products for the selected market. After Step 5 is completed by identifying the design principles from all of the root causes, the user can then use the principles as guidelines in designing new products for the target market.

3 CASE STUDY: PRODUCTS IN THE US

This section presents a case study using ten best selling products in the US to identify design principles through the presented method. These products were analyzed by examining a total of 1,764 customer reviews, and resulted in the identification of 19 principles for the US.

3.1 Product Information

The purpose of this study was to test the method presented in Sec. 2 and provide principles for developing products for the US. Ten best-selling products on Amazon.com were selected from ten different product categories. The specific product categories and selected products used in this case study are presented in Tab. 1.

<table>
<thead>
<tr>
<th>Product Category</th>
<th>Product</th>
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<tbody>
<tr>
<td>Automotive</td>
<td>iTrip FM Transmitter</td>
</tr>
<tr>
<td>Baby</td>
<td>Baby Einstien Take Along Tunes</td>
</tr>
<tr>
<td>Cell Phones</td>
<td>5 Pack LCD Screen Protectors</td>
</tr>
<tr>
<td>Electronics</td>
<td>Garmin Nuvi GPS</td>
</tr>
<tr>
<td>Heath &amp; Personal Care</td>
<td>EatSmart Digital Bathroom Scale</td>
</tr>
<tr>
<td>Home, Garden &amp; Pets</td>
<td>Cuisinart 5-in-1 Griddler</td>
</tr>
<tr>
<td>Office Products</td>
<td>Brother Professional Label Printer</td>
</tr>
<tr>
<td>Sports &amp; Outdoors</td>
<td>Swiss Army Champion Plus Knife</td>
</tr>
<tr>
<td>Home Improvement</td>
<td>Kohler Pullout Kitchen Sink Faucet</td>
</tr>
<tr>
<td>Toys &amp; Games</td>
<td>Culli Sophie the Giraffe Teether</td>
</tr>
</tbody>
</table>

For eight of the ten products, 200 of the highest rated customer reviews were examined. The other two products only had 98 and 72 reviews available (Brother Professional Label Printer and Kohler Pullout Kitchen Sink Faucet respectively). The decision to read 200 reviews for each product is best understood by examining Fig. 2. This plot shows the total number of product characteristics identified per customer review for the iTrip FM Transmitter. By examining the data presented, it was observed that after reading the first 100 customer reviews that the majority of the product characteristics were identified. Similar results were observed in the first 5 products reviewed in that only 2.3% of the characteristics were identified after the first 100 customer reviews. For this reason, it was determined that examining more than 200 customer reviews would not result in a sufficient increase of characteristics to justify the time required to examine each additional review.

3.2 Design Principles for the US

Using the information gathered from customer reviews for the products presented in Tab. 1, the remaining steps of the method (Steps 3-5) were completed. The resulting principles are presented below, and a detailed discussion is provided in Sec. 5. As will be discussed in Sec. 5, only the bolded principles in the list below are unique to the US.

1. Maintain simplicity
2. Design to a clearly defined product scope
3. Consider all human interactions with the product
4. Consider product aesthetics
5. Consider all potential uses of the product
6. Consider the maintainability and repairability of the product
7. Consider modularity of the product and product platform
8. Perform failure analysis and testing throughout the design process
9. Keep clear documentation
10. Consider the knowledge and skill of the end user
11. Consider available technologies
12. Consider the culture of the target market
13. Consider manufacture and assembly of the product
14. Consider the product lifetime
15. Consider all system interactions within the product
16. Consider all system interactions outside the product
17. Consider the performance of competing products
18. Perform necessary market research before and throughout the design process
19. Adhere to safety regulations and requirements

4 CASE STUDY: PRODUCTS IN THE DEVELOPING WORLD

The motivation for the presented method is to improve the development of products for those in the developing world. To that end, this section presents a case study implementing this method for the developing world. The information gathered in Step 1 of the method came from surveys given to designers with experience designing products for the developing world, and resulted in the identification of 21 design principles.

4.1 Product Information

Finding information for products in the developing world can be difficult. In order to obtain the needed product information, 12 individuals from both academia and industry with experience designing products for the developing world took a survey or were interviewed. Criteria for identifying appropriate candidates for these interviews/surveys was participation in designing a product for the developing world that was actually implemented in the target market. In order to gather the necessary information, questions asked to the designers focused on the function, design, and the user’s interaction with the final product. The designers were only asked about their experience with implementing the product, and not their opinions on the design process. This allowed the information gathered to be similar to the customer reviews since both are based on experience with the product. The interview/survey questions are presented in Tab. 2.

In order to obtain a broad view of design principles for the developing world, individuals that participated in the interviews/surveys had experience designing products for Africa, Asia, Central and South America, or the Pacific Islands. The specific products that were represented within these interviews/surveys ranged from solar-powered stoves to biodiesel plants to housing and road development.

4.2 Design Principles for the Developing World

Using the information gathered through the interviews/surveys, the remaining steps of the method (Steps 2-5) were completed. The resulting principles are presented below, and a detailed discussion is provided in Sec. 5. As will be discussed in Sec. 5, only the bolded principles in the list below

<table>
<thead>
<tr>
<th>#</th>
<th>Survey/Interview Question</th>
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<tbody>
<tr>
<td>1</td>
<td>Briefly describe the product/project you worked on (purpose of product/project, uses, location to be implemented, etc.)</td>
</tr>
<tr>
<td>2</td>
<td>Describe the positive characteristics of the implemented product (things that helped it succeed)</td>
</tr>
<tr>
<td>3</td>
<td>Describe the negative characteristics of the implemented product (problems that were encountered)</td>
</tr>
<tr>
<td>4</td>
<td>Were there any additional characteristics that dictated the success or failure of the product/project?</td>
</tr>
<tr>
<td>5</td>
<td>Name a few things that design engineers should know about designing for the developing world</td>
</tr>
</tbody>
</table>
are unique to the developing world.

1. Maintain simplicity
2. Design to a clearly defined product scope
3. Consider all human interactions with the product
4. Consider product aesthetics
5. Consider all potential uses of the product
6. Consider the maintainability and repairability of the product
7. Consider modularity of the product and product platform
8. Perform failure analysis and testing throughout the design process
9. Keep clear documentation
10. Consider the knowledge and skill of the end user
11. Consider available technologies
12. Consider the culture of the target market
13. Consider manufacture and assembly of the product
14. Consider the product lifetime
15. Consider all system interactions within the product
16. Consider all system interactions outside the product
17. Consider the purchasing power of the user
18. Consider the environment of the target market
19. Consider consistently available energy sources of the end user
20. Consider the availability and maintainability of supply chains
21. Consider the safety of the end user

5 COMPARISON OF CASE STUDY RESULTS

The case studies in Sections 3 and 4 identified a total of 24 principles. By examining the lists of principles presented in Sections 3.2 and 4.2 it can be seen that there are both similarities and differences between the principles identified for each case study. Fig. 3 illustrates this overlap between the principles for the two studies. A discussion of the similarities and differences between the two sets of principles identified is provided in this section.

5.1 Similarities in the Design Principles

As is illustrated in Fig. 3, 16 design principles for both case studies are identical (See principles 1-16 in Sections 3.2 and 4.2). Interestingly, these principles represent more than 76% of the design principles for each market. Since the majority of guidelines for designing a product should be similar for most markets, this result was not surprising. However, designing for unfamiliar markets is still difficult despite the similarity in principles.

While many of the principles identified are present in both markets, some arose more frequently in one market than the other. Noting which principles arise more frequently for a given market can assist in understanding which of the principles are most important. For example, principle 12 in both studies (understand the culture of the target market) only arose once in the US case study. However, in the developing world case study nearly every survey/interview mentioned the need for the product to be culturally acceptable. Therefore, while it is important to understand the culture of the target market for any design, it is much more important when designing for an unfamiliar market, especially for the developing world.

5.2 Differences in the Design Principles

Figure 3 illustrates that 3 design principles for the US and 5 design principles for the developing world are unique (See principles 17-19 in Sec. 3.2 and principles 17-21 in Sec. 4.2). These unique design principles provide an even deeper insight into the two target markets than the similar principles discussed in the previous section. A summary of the unique principles for each market is provided below.

Unique US Principles:
1. Consider the performance of competing products
2. Perform necessary market research before and throughout the design process
3. Adhere to safety regulations and requirements

Unique Developing World Principles:
1. Consider the purchasing power of the user
2. Consider the environment of the target market
3. Consider consistently available energy sources of the end user
4. Consider the availability and maintainability of supply chains
5. Consider the safety of the end user

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A close examination of these unique principles for both case studies revealed that principle 3 from the US and principle 5 from the developing world in the lists above focus on safety aspects of the product. However, there are distinct differences in the safety concerns addressed. For the principle from the US, the focus is that the product should adhere to safety regulations and requirements. While this should be followed in designing products for the developing world, often times developing areas will not have safety regulations and requirements. Therefore, the design principle from the developing world states that the designer should consider the safety of the end user. Although safety regulations and requirements are provided as a means of ensuring the safety of the user, these two principles highlight the differences in how individuals in these two markets approach the principle safety.

It is important to note that all of the design principles that were different between the two studies could be applied to both markets. However, because they were not explicitly identified through the method, they are not considered to be the most important principles for both markets. Although the method does not guarantee to identify every possible principle, it will identify those principles that have the highest importance to a given market.

6 CONCLUDING REMARKS

In order to assist designers in creating products for the developing world, a generic method for identifying design principles for any target market was presented. The method presented in Sec. 2 uses product characteristics from a selected target market to identify these principles. The method was implemented in two case studies, products in the US and products in the developing world (Sections 3 and 4 respectively). Through a comparison of the principles identified for the two markets, it was found that 16 of the 24 total principles identified were common to both markets. Although these similarities are interesting, the principles that were unique illustrate the major differences in what is important to each market. Through these case studies, and the ensuing comparisons, the authors conclude that the method is capable of identifying the principles for any given market. As such, the authors also conclude that the identified list of principles can be used to guide development efforts.

The future work building from the developments presented in this paper will focus on expanding the presented methodology to incorporate a systematic procedure of ranking identified principles according to importance in the target market.

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REFERENCES

