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Erratum

May 1, 2019: The OPUS editors corrected the omission of two co-authors in the official OPUS record, that appeared in the manuscript. We regret the error. The Article was also corrected with author affiliations.

Implementing a Bottom of the Pyramid Eye Care Solution

Abstract

Eighty-nine percent of the world's visually impaired live in low-income regions (IAPB/WHO), and uncorrected refractive errors are the main cause of moderate and severe visual impairment. Poor eye care in developing nations hinders development and advancement by creating barriers to education and labor inefficiencies. In some developing countries, few individuals can afford, or even have access to, corrective eye care. We propose the global eye care problem can be addressed using bottom of the pyramid thinking.

The top 25 global eyewear providers are based in the United States, Italy, Germany, or Switzerland. And the majority of these providers, particularly the top five, operate with gross profit margins of greater than 60% (Luxottica Investor Relations). Furthermore, Eye care is a highly regulated practice in most countries, which limits access further and ties the purchase of glasses to a visit to a doctor for most consumers, which is pricy, time consuming, often distant and thus nearly impossible for many poor consumers. To combat the regulation issue, large eyewear manufacturers rely on local, independent distributors to sell their product. The addition of an additional middleman only increases the margin on which the product is being sold, making them more expensive and even less accessible.

In recent years, several companies have successfully leveraged e-commerce platforms to bypass distribution and regulation constraints, which has disrupted the traditional optical business model and displays promise as an applicable model in developing regions. Others have set up foundations and charitable arms that reach out to the poor through mobile units, bottom of the pyramid clinics, business in a box entrepreneurship and technological innovations.

Our approach cannot solve all eye care problems - but it can address the more common issues: vision deficiencies which can be fixed with simple spherical equivalents. Our proposal does not address astigmatism and other, more complex issues, but rather targets the "low hanging fruit" of simple corrective lenses, which are effective in the vast majority of cases. Moreover, our approach offers cost

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Patrick Long graduated May of 2018 from Bucknell University with a major in Accounting and minor in Mathematics, and will be working in public accounting in New York City. He would like to thank Professor Eric Martin, Professor Charles Kim, Paden Troxell, and the rest of the Project for Sustainable Eye Care team.

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effective and stylish glasses while creating an entrepreneurial opportunity and jobs for locals.

Exemplars

Karnani, Garrette, Kassalow, and Lee (2011) explored existing attempts at solving the lack of eye care in the developing world. We categorize these approaches into three archetypes: Bottom of the pyramid distribution, business in a box entrepreneurship, and technological reinvention.

Bottom of the Pyramid Mobile Distribution

Essilor International entered the Indian market in 1998 to pursue the potentially vast market for cheap plastic lenses in India's rural population. Coupled with local hospitals, they deployed over 1,000 vans to host two-day eye clinics across India. Each van cost over $50,000 and with glasses were sold at USD $4 a pair. Essilor was unable to cover operating expenses or generate profits. After attempts to raise prices, increase product lines, and franchise vans, the project has scaled down to six vans and is largely seen as a charitable venture. Throughout the process, overhead and other expenses were covered by Essilor International, as the mobile clinics didn't generate nearly enough revenue to make them a financially viable way to address the Indian eye care problem.

Business in a Box Entrepreneurship

Visionspring aimed to take reading glasses out of the exclusive hands of eye care professionals and make them more of a generic consumer product. The project independently commissioned sales representatives, equipping them with a "business in a bag"—a sales kit containing reading glasses, screening tools, marketing materials, and a uniform, to visit villages and sell reading glasses for under $4 a pair. Visionspring representatives provided basic screenings, using distance and near eye charts, to determine the appropriate strength of the lenses. After several years of growth and franchising, 18 percent of total costs were covered by earned revenue, with the difference being funded by philanthropic donations. The project, while effective at distributing glasses, did not generate profit.

Technological Reinvention

Adspecs provided a technological innovation that consisted of glasses made of clear sacs of silicon oil sandwiched between two clear plastic discs. As a wearer adjusts the dials on the glasses, he or she controls how much fluid is loaded into each sac, thereby changing its curvature and the strength of the lens. The glasses sold for $18 a pair, a high price with obvious drawbacks, and initially 30,000 pairs were sold to the Ghana Education Ministry, the U.S. government, and other organizations primarily for humanitarian aid. The project is focused on technology and design, and does not provide a method of commercial distribution.

Our Approach

Our work originally began in 2010 to develop a method for assessing sustainability of

engineering projects in the field of Design for the Developing World. The sustainability of several existing eye care programs, such as those mentioned above, were assessed and common faults identified.

In an initial step, our team travelled to San Pedro la Laguna in the Lake Atitlan region of Guatemala. The aim of the field visit was to manufacture a prototype of the lens-edging machine within the local context. During the trip, management students conducted informal market research on style preference and learned that circular lenses are least popular. This presented an issue, as our first lens-edging prototype was only capable of creating circular shapes. Eye care professionals with over 12 years experience working with communities in the Lake Atitlan region coordinated the trip.

Over the next several years, engineering students explored techniques for manufacturing eyeglass frames within the context of small communities in the developing world and students developed prototypes that incorporate injection molding, casting, 3D printing, and wire bending. Students also developed a business-in-a-box model and constructed a related business plan. They also developed a wire bending device and process for manufacturing low-cost eyeglass frames. Semester after semester, teams of students experimented with modifications to the various exemplars already addressing eye care in the developing world.

Meanwhile, teams continued to investigate different social enterprise models that could deliver these new technologies. A bilingual student joined the team as a translator and cultural expert on the teams' next trip to Guatemala, where they tested the ProSEC model and gained insight into existing local optician services. Students screened volunteers for refractive error using the diagnostic instrument prototype, produced glasses using the lens edger prototype, and delivered custom-made eyeglasses to those in need. A total of 23 eyeglasses were delivered during the 5 day visit.

Significant market research was also conducted to gain an understanding of local preferences and budgets. The team recorded 5,000 general observations of foot traffic; the team found that approximately 6% of individuals wore glasses. Of these 6%, the most prevalent frame styles were rectangular and ovular (93%) and the majority of frames were metal or wire (82%). From more than 75 in-depth interviews of those wearing glasses, the team found that style and price were the dominant factors in consumers' buying behaviors.

Our First Major Trial

In 2015, ProSEC began a relationship with the Jubilee House Community (JHC) associated with the Center for Development in Central America and Nueva Vida Health Clinic. The site, Ciudad Sandino, dates back to 1969 and became a refugee camp for those displaced by natural disasters, developing quickly in the Eighties. Many refugees became permanent residents and additional people

were sent to the location in subsequent years. What began as a field camp with tarps and less than 1,000 people is now a city of 100,000 people. Nueva Vida, which has a very similar history, is a town of 10,000 on the outskirts of Ciudad Sandino.

ProSEC and JHC planned to launch a pilot project in May 2016. During the winter months prior, mobile Health Promoters of the Nueva Vida clinic surveyed 79 residents of Nueva Vida for vision history, style preference, and pricing. Of the 79 total survey responses, 23 already had glasses. We learned the majority of total population preferred brown or black frames; preferred plastic to metal; and preferred rectangular lens, with oval being the next most preferred. The insights gleaned from analysis of this data informed frame styles ordered for the initial inventory and the target price point. The target price range is found to be C$150 to C$200 (US$5 to US$7) based on what respondents indicated they would be willing to pay.

During the Spring, students and faculty travelled to Ciudad Sandino, Nicaragua. A sample distribution of refractive error in the region was obtained by reviewing nearly 1500 clinic records. 84 percent of the population fell within the range +/- 2.00 diopters (D) and 98 percent were within +/- 5.00 D. This data informed the distribution of our initial lens inventory ordered for the pilot. This data also provided support for the proposed pilot.

The model planned for May 2016 was limited to servicing spherical correction or spherical equivalent correction for certain astigmatic patients. According to the data, 95 percent of people who required correction were eligible for spherical or spherical equivalent correction. Using this data, the team developed a budget for the pilot and ordered the necessary materials. Style preferences were considered when ordering frames, although the majority of respondents indicated that style was not important to them. The team also co-designed a workflow that allows the clinic to integrate the ProSEC service within existing space and operations.

The initial inventory for the experiment consists of 1000 1.59 polycarbonate hard multi-coated optical lenses and 300 mixed style eyeglasses frames. The lenses were stocked so that prescriptions on the higher ends of the scale (+4.00, -4.00 etc.) would not be depleted before a resupply. The 300 mixed style eyeglass frames were donated by Modern Optical, and had an estimated total cost of $1,500. Additionally, unisex frame styles were selected in order to avoid depletion issues. A third of these frames were donated to ProSEC by Modern Optical International. ProSEC purchased the remainder of the frames, all of the lenses (some lenses were donated by Essilor Foundation), and a lens edging and lens beveling machine. The total cost of this “business-in-a-box” was approximately USD $2,569.80.

One member of the team traveled to Nicaragua to train and equip JHC staff to produce our custom eyeglasses at the Nueva Vida Health Clinic. During the three-week trip, several machine malfunctions delayed progress. JHC maintenance staff sourced a replacement motor and repaired the machine. These equipment malfunctions were unforeseen, and the team noted that they were fortunate to have local expertise able to fix the machines, and that in future endeavors this expertise should be identified beforehand. By the final day, two staff were trained and able to deliver the first pair of ProSEC glasses to a patient. By December, nearly 100 eyeglasses were sold through the ProSEC pilot service.

One of the experiment's biggest successes was a visit to a rural clinic, an effort between JHC-CDCA and the Club Rotario Ciudad Sandino over the course of 2 days at 3 sites. 150 patients were seen, ranging in age from 8 to 85. This resulting in 50 pairs of glasses ordered during the clinic, 35 pairs of readers being distributed, and 86 pre-made distance glasses being distributed; for a total of 159 pairs of glasses provided, 50 of which were ProSEC. Additionally, 60 patients had to be turned away due to lack of time.

As the initial supply depleted, the ProSEC team worked with JHC staff to resupply stock based on inventory tracking performed by JHC. Three hundred additional 6001.59 CR39 hard multi coated optical lenses were procured. In addition, Modern Optical International donated 300 mixed style frames to ProSEC. Notably, larger, "hipster" style frames went quickly and had been highly demanded, meaning they were entirely depleted in the first round. Patients were more style conscious than predicted through the surveys, especially when given the option. Lenses and frames were sent to Nicaragua with a university service trip one year after the initial trip. Meanwhile, past patients were given quality of care follow ups to explore how the clinic could be improved and what benefits the patients were deriving from their glasses.

One issue the JHC employees noted at this point was that the lens cutter did not work properly. Because the final shape was often slightly oversized entirely or in certain areas, additional work was being performed on the beveling machine. To quicken this process, they used the beveling machine manually to target particular areas of the lens. This process required a great deal of time and placed too much load on the beveling machine. To combat this issue, the team decided to order a manual-edging device for $100, which arrived a few weeks later and resolved the issue.

As of March 2017, approximately 150 eyeglasses were distributed through the ProSEC service in Nueva Vida, which translated to about C$32,000 (US$ 1,050) in sales, which went directly to the Jubilee House Community. This achievement fulfilled the initial goal of the pilot and proved the initial model.

The total investment from Bucknell University in the JHC clinic was $2,569.80. These costs include all the necessary fixed costs of operating the clinic as well as an initial supply of inventory, but do not include travel costs or salaries for our staff.

The total value of inventory in the investment was $2,128.00, which included 1000 lenses and 300 frames. This was sufficient to make (ideally) 300 pairs of glasses with an additional 400 lenses left in inventory.

Insights

Our Nicaragua experiment demonstrates that affordable eye care is possible with existing supply chains, and developing technology to build frames and lenses is not necessary or cost efficient to the model. In 18 months, the Nicaragua experiment has seen a $2,569.80 investment provide glasses to 150 patients, generate $1000 in revenue in the clinic would not have otherwise had, employed at least one additional member of the community at the clinic. Our approach is financially and operationally feasible.

Re-envisioning Target Market

One of the keys to success in Nicaragua was market segmentation. By only attempting to treat vision problems that can be corrected with spherical equivalents, we were able to avoid the expensive and time consuming process of recognizing, diagnosing, and treating more complex and serious problems like astigmatism and cancer while still improving the quality of life and providing care to the vast majority of the market. In addition, this model served a previously un-served segment of the local population, the rural poor - an important segment, who although eye care services and products existed before, had been priced out of the market.

Re-envisioning Supply Chain

Efforts to design lens cutting tools, frames, and other clinical components resulted in the conclusion that we were unable to produce these items better or for cheaper than they are already on the market for. However, extremely low cost frames and lenses can be sourced from high volume manufacturers, and adequate lens cutting and beveling machines can be purchased at a feasible price. In order to develop an effective clinical setting, we did not need to reinvent the wheel, but rather leverage existing low cost resources in a new way.

Regulations

Although ProSEC designed and produced a highly effective, low cost diagnostic tool, the device was unable to be implemented in the Nicaragua experiment due to regulatory barriers. In addition, teams of students brought supplies to Nicaragua as donations, fully complying with the exoneration process.

However, we recognize this as a limit to the project's sustainability. Shipping for items to be resold comes at great expense and complications. As donations this is overcome, with small fees being attached to the services provided rather than the product itself.

Even at the Bottom of the Pyramid, laws require licensed doctors to use legitimate medical equipment to diagnose patients. Because of this, the experiment was set in an existing medical clinic with up to date, optical diagnosis equipment.

Working with Field Partners

More about the value of working with a partner we already had ties to - the project still requires great commitment and constant communication as we work through obstacles - fan, shade, overheating, regulator on electricity.

This model provided additional capacity and income to an already established clinic. Compared to existing solutions, working through an existing resource like JHC has allowed ProSEC to leverage their facilities and expertise in order to cut overhead costs and the complicated and expensive clinic set up process. See ***Figure 1*** below to see where ProSEC defines our place in the ecosystem of sustainable eye care solutions.

Given the initial start-up funding (our USD $2,569.80), our partners were able to fund subsequent rounds of re-ordering; and although we have not asked them to pay back our initial investment, they very possibly could within the next few years. Given the small but healthy margin the glasses are sold at, a repayment of USD $1-2 per pair would sustainably repay our initial investment.

Re-envisioning Costs, Prices and Margins

We reduced costs, albeit in an experimental setting, to approximately USD$7 which is competitive with other larger scale efforts that seem to hover around USD$4. That cost has risen over time to approximately USD $10, though sales have not been drastically impacted. These costs are achieved by the university operating as the middle-man in terms of the overall value chain. Our partners are simply unable to access the suppliers we can, and unable to commit the capital necessary up front.

Improvement on Existing Archetypes

Our Nicaragua trial demonstrates a new and effective solution to the global eye care problem that shows some signs of success. By limiting overhead costs and empowering local organizations, we can

provide glasses at a low price while still covering costs and providing a small profit to sustain local entrepreneurs and grow the project.

Bottom of the Pyramid Distribution

Our bottom of the pyramid distribution, as previously discussed, was aimed only at simple, correctable vision problems. Our model differs from Essilor in that we chose one central location to operate out of instead of enlisting a fleet of vans. While our approach has the drawback of only being able to serve one community (and those able to travel to it), we avoided the overhead costs that Essilor faced. We believe our approach can be replicated in another location using the same methodology, thereby serving several communities.

Business in a Box Entrepreneurship

We expanded upon VisionSpring's business in a box methodology by rethinking what components we could take out of the box and instead take from existing partners. Our "box" contained the frames, lenses, and assembly equipment necessary for eye care, but we used the diagnostic equipment, facilities, and labor of our partner on the ground. This allowed us to cut the initial cost of implementing the eye care clinic. Additionally, our selling price of $7-10 USD was based off both demand and our costs so that the clinic would have adequate funds to resupply inventory and continue operations without outside funding. Visionspring, by contrast, priced their glasses at $4, a number that was not able to, nor designed to, cover their costs in a sustainable way.

Technological Reinvention

Adspec's attempt was ultimately undone by the high cost of their silicone oil glasses, which, although they were adjustable to the users prescription, didn't treat they users vision problem any more effectively than the spherical equivalent lenses would. We discovered that a well stocked supply of sourced frames and lenses is a more effective solution than investing heavily in technological development. Additionally, traditional glasses from a traditional manufacturer allow for the user to have fashionable and inconspicuous glasses, which Adspecs certainly are not.

Service-learning Insights

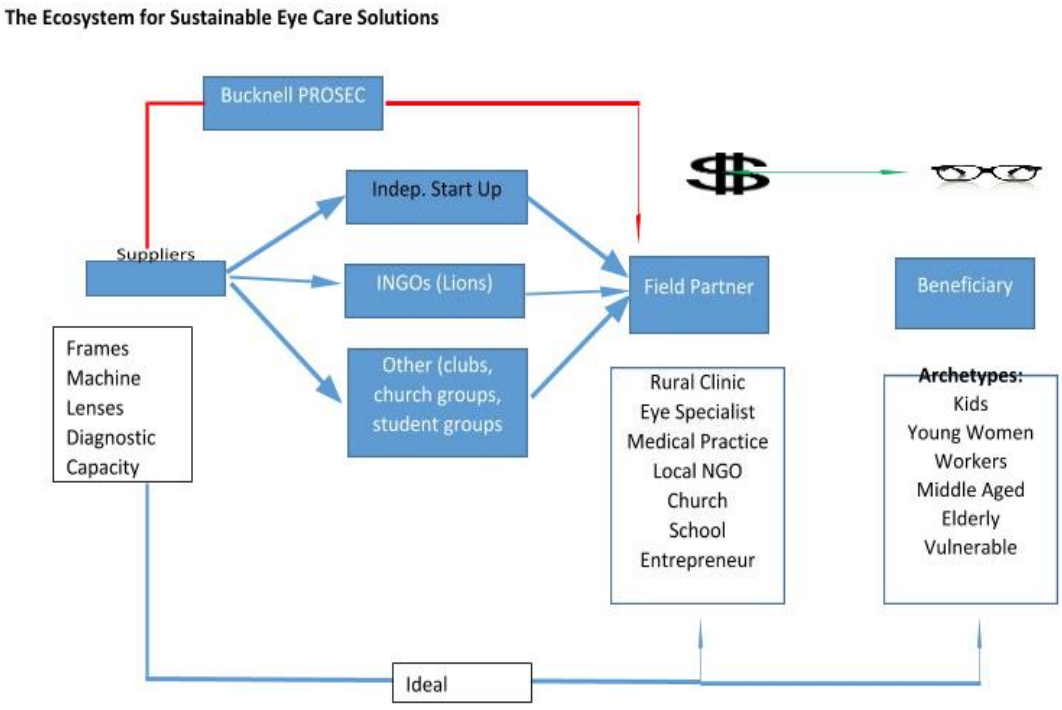
This project highlighted several components of service learning. First, we recognize the importance of a strong relationship with our local partner. On a recent visit our partner cautioned our move to replicate this with an untested partner, suggesting that because we had such a strong relationship over many years, they spent a great deal of time working on this project - more than they might have if we were a relatively new player. Second, we recognize the importance of 'chaining' together projects over time. This entire project is the outcome of work completed by five professors and over twenty students across three colleges over eight years. Each contributed niched research and

service that built upon the work of others. These individual and small group efforts diverged and converged over time to the main mission. But the many perspectives brought to the table, and the constant reinvention of the project strengthened it over time. Finally, we recognize the possible perception and concern that our work could be seen as circumventing the medical community. As such, we stress the importance of working with local and international trained medical staff. We, of course, never present ourselves as being medically trained, but realize that some beneficiaries might make such an assumption. This needs to be clear in work like this. Our solution is to partner with the medical community wherever possible.

Next steps

We are looking into several different directions moving forward expanding upon each of the archetypes of interventions we highlight above. We are considering expanding the current operation and adding more field clinics. We are also considering replicating the entire process in another site, perhaps in another country. We continue to refine and perfect the equipment used in an effort to perhaps develop our own at lower costs. In addition, we are exploring public, private and nonprofit / NGO avenues for the future to understand differences across sectors.

Figure 1



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