An Emerging Impact from an Engineering Education Outreach Collaborative "Bridge" Program: Graduate Student Participation in Wheelchair Mobility Research for Mexico

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ABSTRACT

The Quality of Life Technology Center (QoLT) Engineering Research Center and PROMISE: Maryland's Alliance for Graduate Education and the Professoriate (AGEP) formed an engineering education outreach collaboration to provide a summer research bridge for graduate students. The research "bridge" connects underrepresented minority graduate students in the College of Engineering and Information Technology at the University of Maryland, Baltimore County (UMBC) to the QoLT's research projects and mentors at Carnegie Mellon University and the University of Pittsburgh. This paper provides, as a case for the type of research that students undertake, a specific quality of life project conducted by a QoLT/PROMISE Bridge participant in Mechanical Engineering. For this project, the researchers dealt with a problem of the American Wheelchair Mission (AWM): failure of donated wheelchairs. The objective of the project was to develop a pilot program to improve the lifetime of assistive devices. The 4R model: Recycle, Reuse, Repair, and Retrofit, was chosen to complement areas of wheelchair mobility in Mexico for children with disabilities. The paper also includes examples of outcomes of successful participants in the collaborative. These examples are followed by suggestions for developing a collaborative engineering education outreach that can broaden participation of students from diverse ethnic backgrounds.

Keywords: rehabilitation, engineering, wheelchair, mobility, outreach

1. INTRODUCTION

The National Science Foundation has a number of programs that provide a variety of research and development opportunities for students. The Quality of Life Technology Center (QoLT) is an Engineering Research Center (ERC) sponsored by the National Science Foundation (NSF) that focuses on developing intelligent systems that provide older adults and people with disabilities with opportunities to live more independently. The QoLT Center, a research center that involves Carnegie Mellon University and the University of Pittsburgh, prototypes personal assistive robots, cognitive and behavioral coaches, human awareness and driver assistance technologies. PROMISE: Maryland's Alliance for Graduate Education and the Professoriate (AGEP), also sponsored by NSF, develops programs to increase the numbers and diversity of students who will obtain doctorates in science, technology, engineering, and mathematics (STEM), and exposes them to training opportunities that will prepare them to become professors. PROMISE is an alliance between the University of Maryland Baltimore County (UMBC: An Honors University in Maryland), the University of Maryland College Park, and the University of Maryland Baltimore. In December 2010, the director of the QoLT ERC contacted the director of the PROMISE AGEP with an invitation to meet and consider collaborative engineering education outreach projects that would connect diverse, underrepresented minority graduate students (e.g., African-American, Hispanic, Native American, Alaska Native, Native Hawaiian, Pacific Islander) to innovative rehabilitation engineering research. This call led to a collaborative meeting between the PROMISE director and the QoLT administrative team at the 2010 NSF ERC national meeting. In 2011, the first group of PROMISE AGEP graduate students participated in a meeting that included demonstrations of QoLT research, and met with QoLT faculty and administrators. These meetings resulted in the development of the QoLT Bridge Program, an outreach that facilitated PROMISE students' involvement in QoLT research projects. The PROMISE participants, graduate students in the College of Engineering and Information Technology at UMBC, participate in professional development training through PROMISE, and are exposed to research projects through the QoLT. This collaboration continues to be a strong outreach component for the QoLT and a strong research connection for PROMISE (Goldberg, Milleville, Ding, Simmons, Brown, & Collins, 2012; Tull, Rutledge, Warnick, & Carter, 2012).

2. QoLT/PROMISE Bridge Graduate STudent Projects and Interactions

QoLT and PROMISE now have several students who have participated in collaborative initiatives in a variety of ways. UMBC graduate students participate in PROMISE AGEP professional development programs during the academic year and in QoLT research during the summer as part of the bridge program, current and prospective QoLT Research Experience for Undergraduate (REU) students apply to UMBC for graduate school and participate in programs sponsored by the PROMISE AGEP (e.g., preparing fellowship applications, improving public speaking, pathways to leadership), and QoLT graduate students at Carnegie Mellon University participate in professional development programs developed by PROMISE, e.g., the PROMISE Dissertation House (Tull, et. al, 2012.) Examples of two of the projects that UMBC's students have undertaken as summer students at the QoLT are as follows:

- One student developed an algorithm for a commercial "dataglove" (a wired glove) for stroke patients' in-home therapy hand exercises. He received honorable mention for the RESNA 2012 (Rehabilitation Engineering and Assistive Technology Society of North America) conference paper written on this project. His mentor for the QoLT was part of the Human Engineering Research Laboratories at the University of Pittsburgh.
- Another student worked with a faculty member and an advanced graduate student at Carnegie Mellon's Robotics Institute to develop a graphical user interface for labeling patient exercise data for the support of a sensor-based virtual coaching system for home rehabilitation. The purpose of interactive user interface was to provide a quick and cost effective method of labeling exercise video data for classification. Researchers are developing an intelligent home coaching system that will be able to recognize errors in the exercise performances of patients with knee osteoarthritis (OA). In order for the system to be able to detect these errors, it needs to identify examples of the types of errors that may occur. The UI was designed to be used by physical therapists to give subjective assessments of the quality of the exercises performed by patients.

Another project that represents the QoLT/PROMISE Engineering Education Outreach Collaborative covered issues of lifelong mobility through working with wheelchairs to serve children in Mexico. This project will be described in detail in Section 3 as an exemplar of quality of life technology research conducted by a PROMISE student from UMBC with his QoLT faculty mentor.

3. Sample Project: Implementation of the 4R Model: Lifelong Mobility Project

The following 4R Model project was connected to another Carnegie Mellon University (CMU) collaboration in partnership with the American Wheelchair Mission and the Teleton Children's Rehabilitation Centers

(Spanish: CRIT – Centro de Rehabilitación Infantil Teletón) in Mexico and funded by the Benter Foundation. The ultimate goal of this project is to assist the Teleton in Mexico by providing an adaptable protocol for their current system to improve the lifetime of wheelchairs. Figure 1 showcases the research collaboration image for the 4R Model project, and Figure 2 provides a photo of the kinds of wheelchairs that were used for the study.

Figure 1: Sponsors and University Teams

3.1 Sample Project: 4R Model Background

The American Wheelchair Mission (AWM) has been distributing wheelchairs to people with disabilities around the world since 2008. Distribution has been possible due to associations with organizations such as the Benter Foundation and Teleton Children's Rehabilitation Centers in Mexico. The research for this sample project is based is on an extension of a previous successful project conducted by a CMU team that assessed the impact of the AWM in two Teleton centers in Aguascalientes and Irapuato, Mexico (Ferris et al., 2010).

Figure 2: Donated Wheelchair

The Ferris et. al project focused on usability, fitting, availability of resources, and ways to improve the service extended by the Teleton centers regarding repairs. A broad overview of the recommendations suggested by the CMU team can be found below:

- Provide a user's manual
- Partner with AWM
- Include a user's quality control checklist
- Pilot a repair shop
- Include a recycling program
- Provide an education component for servicing wheelchairs

The information provided by the CMU team led to the 4R project described here that focuses on improving lifelong mobility and implementing a repair service in the existing Teleton centers. The 4R concept tries to accommodate every possible demand that a wheelchair user could request. The project revolves around a 4R model: Recycle, Reuse, Retrofit, and Repair (Pearlman & Dausey, 2011). This project also implemented the "Wheelchair Assessment Checklist (WAC)" for evaluation of collected wheelchairs in the Teleton centers, and the "Functioning Everyday with a Wheelchair (FEW)" survey instrument to help determine usage of the wheelchairs (Holm et al., 2002). New wheelchairs that will be issued at the Teleton centers in Mexico will be adapted with data loggers to monitor activity and better determine performance and possible failure causes once the users return to the center for maintenance or scheduled appointments (Karmarkar, 2009).

3.2 SAMPLE PROJECT: 4R MODEL APPROACH AND CRITERIA

This project was limited to improving the lifetime of assistive devices and examined a workshop concept that can address the 4R model: Recycle, Reuse, Repair, and Retrofit (Figure 3), to complement areas of wheelchair mobility in Mexico for children with disabilities (Pearlman & Dausey, 2011). The main focus revolves around the retrofit concept, and the logic that allows service providers to determine steps toward renewing a broken wheelchair.

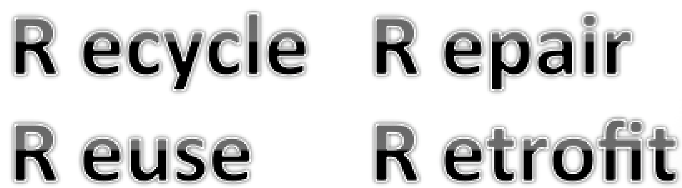

Figure 3: 4R Model

3.3 SAMPLE PROJECT: 4R MODEL FLOW PROCESS

The simplified logic diagram in Figure 4 shows the process that is used in the recycling phase of a wheelchair that comes into the Teleton center in Mexico. The model attempts to address the following questions:

- What should be done with the wheelchair?
- Is the wheelchair usable or reusable?
- What tools are required to fix it?
- What should be done with the remaining wheelchair parts?

The first question addresses the source: is the wheelchair a donation from a Teleton patient or did it come from someone in the public who is presenting a wheelchair that is no longer required by a patient. If the wheelchair qualifies as a donation, it is evaluated using the Wheelchair Assessment Checklist (WAC), which addresses the question of availability for reuse. The WAC assigns numerical values to six different aspects of a wheelchair. The evaluation primarily rates functionality and condition in order to catalog components within the threshold of usability. This process may reveal that a wheelchair is not in peak condition, however it identifies components that are salvageable and reusable. The third part of the process proposes keeping an inventory of universally used tools. A standard toolset composed of wrenches, sockets, hammers, screwdrivers, and pliers will likely suffice to complete repair of a wheelchair. Figure 5 shows the shop tools from the Teleton center in Mexico.

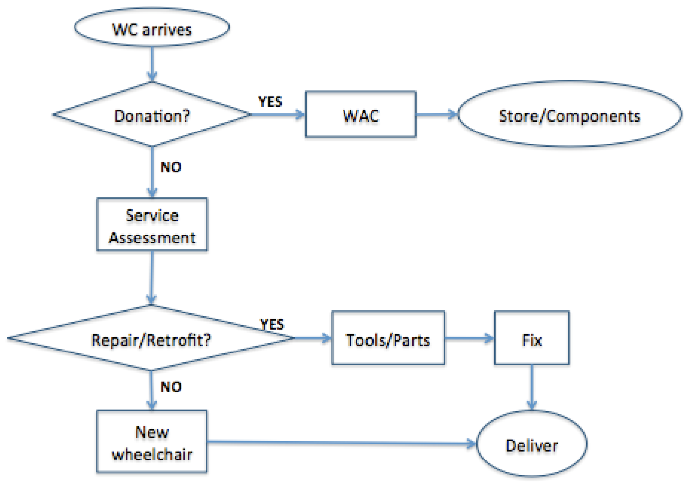

Figure 4: Logic Diagram

Figure 5: Teleton Center in Mexico Shop Layout

Spare components are often available after stripping and recycling a wheelchair, and leaving parts that are no longer required from the donated chair. A solution for use of these parts will be discussed in the Recycling and Assembly Logic sections below.

3.4 Sample Project: 4R Model Recycling Method

The users of wheelchairs from this project with the Teleton centers are under 18 years of age. The project proposes the extension of the recycling/repair service to people who are external to their program, since the service utilizes a universal design oriented concept.

In this project, children are called for an appointment that has been scheduled according to their programmed visits to the doctor. The process of providing the wheelchair can be implemented while the children are in their consultations, and there is a commitment to have the wheelchair ready at the end of the doctor's appointment. This recycling method can be extended to people not participating in the program, as it allows "walk-ins" to request a service at any time during regular hours of operation. The "walk-in" service is an add-on to the protocol, and the project takes on a role that is similar to a collection center by obtaining extra wheelchairs from people who don't need them, don't use them, or want to discard them.

Once the patient arrives for a doctor's appointment or wheelchair maintenance, the protocol should follow the logic diagram from Figure 4.

- *Is the wheelchair a donation?*

If the answer is yes, the WAC should be implemented to determine functionality of the assembly (the chair.) Based upon the condition, either store the entire assembly, or remove and store reusable components. If the answer is no, a condensed WAC could be applied, with consideration of issues that are identified by the patient.

- *Can the wheelchair be repaired or retrofitted to continue working as an entire assembly?*
  If the answer is no, the chair is immediately reclassified as a donation, and there is a recommendation for the patient to be prescribed with a new wheelchair. If the answer is yes, there will be a process to verify that the spare components are in stock, and the reassembly process will continue in order to provide a functional wheelchair for the patient.
- *Are there any salvageable parts remained from those that were removed from the wheelchair?*
  If there are no salvageable parts, the components will be sent to a recycling center. Therefore, the assumption to salvage parts lies within a plan to retrofit a small component or section of what was removed. Once retrofitted and deemed usable, the parts would be stored. Figure 6 shows some of the failures.

Figure 6: Wheelchair Failures

3.5 SAMPLE PROJECT: 4R MODEL ASSEMBLY LOGIC AND STORAGE

This section proposes a solution to what could be done during the reassembly process of a wheelchair. Figure 7 shows the components of a wheelchair. It was important to maintain a record of the environments in which the wheelchairs are being used in order to determine service. For example, both front casters may need to be replaced if the wheelchair is being used in a rural area where roads are made of dirt, versus an urban area where most streets are paved. Another issue is use, i.e., a stationary wheelchair used only at home versus a wheelchair that traverses several miles on a daily basis. The task of selecting the proper components comes from the instant feedback of the user (patient), or their relatives. Different usage environments require different kinds of replacement parts. A color-coding method addresses to define all possible scenarios within the stock and a tracking system matches spare components to specific wheelchair models. Implementation of Quick Response (QR) Codes invokes a simple tracking mechanism that can accommodate large amounts of data. Use of QR Codes reduces the work of computing individual characteristics and providing electronic tracking information; the process is simplified by attaching a label to each component after documenting it in a computer. The Teleton Center uses a database and adding a scanner and printer to their hardware could streamline the process. The information would be uploaded to the database, and a printed QR label could be attached to the component being registered. Figure 8 shows an example of what could be printed using a QR code; the message on the right shows the information that being read by the scanner.

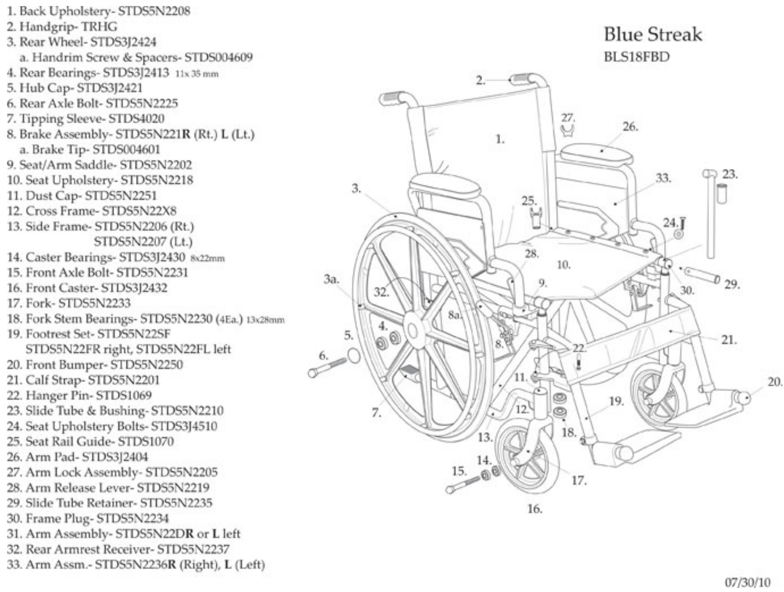

Figure 7: Wheelchair Components

Figure 8: QR Code and Information

3.6 SAMPLE PROJECT: 4R MODEL FOLLOW-UP OPTION, TEST RESULTS, AND DISCUSSION

This section describes the tracking method that can be used once parts are pulled from the stockpile in a Teleton Center. It is a build-up of data from the QR label and options for additional data:

The model will try to address the following information:

- Date – This keeps track of when the part left the maintenance center, and it helps to determine usable lifespan once it returns, if it gets replaced.
- Maintenance center information – This will help determine the kind of spare parts that are being recollected at every center.
- Hiding of the labels – A wheelchair with stickers on every component will eventually create a problem for the maintenance center and stickers can be dislodged due to expiration date of glue, extreme usage, or friction. If this happens, the component will not be able to be identified in the database. A solution would include use of a standard hiding place within components for a label, e.g., hollow tubes can place stickers within the tube, at the bottom, or on the right side, based on horizontal or vertical placement of the tube in the wheelchair assembly.

- User's manual – This option will not be included in the QR label. The center should provide a quick-fix manual in case a patient is unable to return to a maintenance center and requires a general fix for the wheelchair. This would assist any patients who might live far from Teleton centers, and use the wheelchair to travel to and from the center.

A test-run was implemented as part of the research prior to making the project-based trips to Mexico. The team used a wheelchair that had similar characteristics to those donated by the AWM. The parameters that were executed, and considered are listed below:

- Allotted time for evaluation = 30 minutes.
- Wheelchair evaluation using the WAC.
- Removal of every major component of right side of wheelchair.
- Reassembly of every removed component of the wheelchair.

The time requested for evaluation was more than enough to perform this task. The model considers that two patients were in consult while the shop operated during an 8 hour day. It also assumes that the wheelchair only has a problem in a small section, since a larger problem would prevent the wheelchair from passing the WAC. The wheelchair obtained a passing score in the WAC, and was deemed usable. This meant that it was going to be returned to the owner/patient. Once the WAC score was verified, every major component on the right side of wheelchair was removed. This allowed the team to verify the tools that should be kept in stock in order to operate a successful shop. After removing what was considered appropriate, the wheelchair components were reassembled, and the wheelchair was labeled as "inspected." This project proposed the extension of a wheelchair's usability by modifying and retrofitting them for users. The project provides and applies a system that can be used in places where wheelchair users have limited resources and the possibility of acquiring new equipment is uncommon. The protocol proposes an addition to the existing control sequence that the Teleton in Mexico currently has for wheelchairs. The system can ultimately increase the performance of the service that the Teleton Centers provide, and the project's protocol contributes to improving the quality of the wheelchairs that are obtained for serving people with disabilities.

This project was part of a QoLT/PROMISE summer bridge program internship, and the graduate student from UMBC was directly involved in the initial phases of the development. The project continued for several weeks after the internship ended. The test-run was successfully performed, including verification of the protocol that would be utilized, with consideration of the necessary equipment. There were two trips planned to Mexico to implement this project, both had a one-week duration, with some downtime in-between the stints. The first trip implemented the specified protocol, and the downtime between trips was used to assess and update the protocol. The second trip used the updated version of the proposed system, and re-tested the system and the 4R model. This project represents a first year Mechanical Engineering M.S. student's contribution to a rehabilitation engineering project through the QoLT/PROMISE Bridge, and represents a collaboration between an Engineering Research Center and an AGEP program.

4. ADDITIONAL PROJECTS BETWEEN QOLT AND THE PROMISE AGEP

The QoLT and PROMISE AGEP plan to continue to support graduate students' research opportunities through the Bridge Program. The directors have discovered that these research experiences provide early-stage graduate students with educational opportunities, expansion of system-level thinking, visualization and implementation of large-scale projects, leadership experiences, and growing levels of responsibility for research outcomes that they didn't have as undergraduates. As students work through their respective degree programs at UMBC, they are able to maintain connections with their QoLT faculty mentors, and are eligible for consideration for QoLT postdoctoral appointments. Successes to date include the following:

- An undergraduate student participant in the QoLT Research Experience for Undergraduate (NSF REU) program was recruited for graduate study at UMBC. That student is now an M.S. student in UMBC's Human-Centered Computing program in the Department of Information Systems.
- A former UMBC Mechanical Engineering M.S. student participant in a QoLT meeting at the Rehabilitation Robotics State of the Science Symposium at the National Naval Medical Center was

further inspired to pursue rehabilitation science research. The student is now combining his mechanical engineering background with rehabilitation science as he pursues his doctorate at the University of Maryland Baltimore, home of the University of Maryland Medical Center.

- A former UMBC Systems Engineering M.S. student who participated in the QoLT/PROMISE Bridge is now participates in the QoLT full-time as he pursues his Ph.D. in the Human Engineering Research Laboratories at the University of Pittsburgh.
- A former QoLT graduate student at Carnegie Mellon participated in the PROMISE/QoLT Dissertation House initiative and will be joining UMBC as an Adjunct Assistant Professor at UMBC while she participates in other projects at a local agency.

These examples, along with the 4R research presented as a case study, represent the success of a collaborative effort to involve students from underrepresented minority backgrounds in quality of life technology research.

5. Suggestions for Engineering Centers That Want to Broaden Participation to Include Diverse, Underrepresented Minority Researchers

In an effort to expose more students to research that focused on addressing issues of disability and quality of life, the QoLT wanted to include researchers from diverse backgrounds and ethnicities. After identifying the National Science Foundation's AGEP program that was designed to develop underrepresented minority Ph.D.s in STEM fields, the QoLT reached out to the PROMISE AGEP to establish a collaboration. Other centers who want to broaden participation can learn from the QoLT. For the purposes of this section, we will refer to engineering centers like the QoLT as an Engineering Research Center or ERC. Some suggested steps from the QoLT/PROMISE collaboration are outlined here:

- Contact the director of the AGEP or similar diversity program with an invitation to meet at a local or national meeting where he/she or a team can learn more about the ERC and the people involved with the research. This is the "Administrative Outreach" stage.
- Invite the AGEP director to bring a group of students to a meeting or symposium that showcases the research and allows the students to meet peers or near-peers who have a passion for the center's work. Include a lunch where the ERC's outreach coordinator can talk with the students about opportunities for research during the summer or during the academic year. This is the "Student Outreach" stage.
- Develop a financial arrangement that will allow students from the AGEP or similar program to conduct research (travel, lodging, stipend) at the ERC. The arrangement must include approval from the graduate student's faculty advisor, and could include an independent study component where the student and the faculty advisor from the home institution remain connected throughout the duration of the ERC project. The ERC should financially sponsor opportunities for the coordinator of the AGEP and the faculty advisor at the home institution to visit the ERC and observe their students during research presentations. The AGEP coordinator or director should also be invited to participate in periodic meetings during the year with administrators of the ERC. This is the "Implementation Stage."

These stages: Administrative Outreach, Student Outreach, and Implementation, are outreach steps that can connect an NSF ERC or other engineering center to a program that broadens participation like the NSF's Louis Stokes Alliance for Minority Participation (LSAMP), LSAMP Bridge to the Doctorate program, or AGEP. The QoLT/PROMISE Bridge program is an example of a collaborative engineering education outreach initiative between an NSF ERC and an NSF AGEP that has broadened participation among diverse groups, and has made contributions to quality of life technology research.

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