

## **AC 2008-1789: INTRODUCING UNIVERSAL DESIGN CONCEPTS IN AN INTERDISCIPLINARY LABORATORY PROJECT**

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# Introducing Universal Design Concepts in an Interdisciplinary Laboratory Project

## Abstract

Design for individuals with disabilities has been used by many institutions as a way to teach the design process to undergraduate students. These design projects often involve the design of an assistive device for a single individual to facilitate a particular task. The departments of biomedical engineering and industrial engineering at Western New England College have further developed an interdisciplinary laboratory design experience that involves the design of assistive technologies for workers performing light manufacturing work at Goodwill Industries of the Springfield/Hartford Area, Inc. Rather than focus on the design of assistive technology to increase the participation of a single worker with disabilities, students were tasked to develop devices to modify steps in a manufacturing process in an effort to maximize the number of workers with disabilities able to participate in each of the manufacturing steps. To facilitate the design process, biomedical and industrial engineering students were introduced to the concepts of universal design, the primary tenet of which is that products should be designed so that they can be used by the greatest number of consumers.

## Introduction

Many institutions have used the design of assistive technologies for individuals with disabilities as a method by which students learn the design process. Such design experiences commonly occur in first year introduction to design courses<sup>1,2</sup> and capstone design courses.<sup>3,4,5</sup> Faculty members in biomedical engineering and industrial engineering at Western New England College have previously described a 5-week design experience,<sup>6</sup> based on the NISH National Scholar Award for Workplace Innovation & Design,<sup>7</sup> that provided an opportunity for students to design assistive technologies for workers with disabilities at Goodwill Industries of the Springfield/Hartford Area, Inc., a local nonprofit agency performing light manufacturing work. These projects were completed in interdisciplinary teams as requirements in senior biomedical engineering and industrial engineering laboratory courses, rather than in the formal capstone design courses for each of the departments. A description of the second offering of this design experience is the subject of this paper.

The design experience has been modified in several ways. First, the experience spanned the entire semester, rather than a 5-week segment. Students in the biomedical engineering and industrial engineering senior laboratory courses (BME 405 Biomedical Engineering Senior Laboratory and IE 428 Industrial Design Laboratory III) participated on interdisciplinary teams for the design and development of the assistive devices in parallel with other assignments in their respective laboratory courses. Industrial engineering students in IE 428 also performed experiments on material handling, capacity planning, and line balancing, while biomedical engineering students also designed and performed physiological case-control studies as a component of BME 405. Secondly, because the goal of the NISH National Scholar Award is to foster innovation in the design of assistive technologies to increase the participation of individuals with disabilities in the workforce, it was important in the design to incorporate features that could maximize the number of workers able to participate in the manufacturing

tasks. This requirement led to the introduction of universal design concepts, based on the universal design principles.

Researchers at The Center for Universal Design at North Carolina State University have developed a definition and principles for universal design (Copyright © 1997 NC State University, The Center for Universal Design).<sup>8</sup>

*Universal Design:*

The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.

*Principle One: Equitable Use*

The design is useful and marketable to people with diverse abilities.

*Principle Two: Flexibility in Use*

The design accommodates a wide range of individual preferences and abilities.

*Principle Three: Simple and Intuitive Use*

Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.

*Principle Four: Perceptible Information*

The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.

*Principle Five: Tolerance for Error*

The design minimizes hazards and the adverse consequences of accidental or unintended actions.

*Principle Six: Low Physical Effort*

The design can be used efficiently and comfortably and with a minimum of fatigue.

*Principle Seven: Size and Space for Approach and Use*

Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

It has been recognized that the knowledge of universal design principles will be important for biomedical engineers in the increasingly global economy.<sup>9</sup> Although universal design is often associated with rehabilitation engineering,<sup>10</sup> the principles are applicable to the design of buildings, transportation systems, and consumer products that are easy to use regardless of ability level or language.<sup>11</sup> The use of these concepts are described here for the development of assistive devices to increase participation of individuals with disabilities in the workplace.

## Integration of Design Experience into Laboratory Courses

The departments of biomedical engineering and industrial engineering at Western New England College have shared a common design experience within their senior laboratory courses for many years. The project evolved from collegiality among the faculty from the two departments as well as an shared interest in the development of interdisciplinary projects.

In Fall 2007, this experience was facilitated by scheduling the laboratory classes at the same time so that students could interact with their teams during a designated class time. Lab sections met once per week for four hours, providing ample time for team activities. In this semester, there were 7 biomedical engineering students and 9 industrial engineering students enrolled in their respective laboratory courses. This number of students allowed for 4 teams of 4 students each. Three of the teams were balanced with 2 biomedical engineering students and 2 industrial engineering students each. The fourth team was made up of 1 biomedical engineering student and 3 industrial engineering students. The biomedical engineering program at Western New England College does not have specialized tracks, so there was no need to attempt to assign biomedical engineering team members based on specialized knowledge. Industrial engineering students brought an understanding of industrial production and ergonomics to the teams while biomedical engineering students contribute knowledge of biomechanics and engineering problem solving skills derived from their broad-based education.

The experience was conducted over the entire semester in each of the laboratory courses. The design projects were developed in collaboration with Goodwill Industries of the Springfield/Hartford Area, Inc., a local nonprofit agency that employs individuals with disabilities in light manufacturing work. The projects revolved around a multi-step process for packaging of decking screws into boxes. Each team of biomedical and industrial engineering students was assigned the development of an assistive device to facilitate one of the steps of this packaging process. The teams followed a standard design process as they progressed through the project. At all times, the teams were reminded to include features in their designs that would maximize the participation of workers who had a variety of disabilities, thus applying universal design principles. The teams first brainstormed design ideas, choosing the best three to present to the laboratory instructors. Based on feedback from instructors, students made modifications to their designs. These designs were then presented by the students to the Supervisor of Rehabilitation and the Program Director of Employment Support Services at Goodwill Industries of the Springfield/Hartford Area, Inc. who chose the design they believed would best serve the largest number of workers. The teams received additional feedback from a NISH rehabilitation engineer who formally presented the seven principles of universal design to the teams. Incorporating feedback from the nonprofit agency and the rehabilitation engineer, the teams developed prototypes of their assistive devices. The deliverables at the conclusion of the project were a prototype and a report meeting the standards of the NISH National Scholar Award guidelines. Due to scheduling conflicts with the nonprofit agency, the prototypes have not yet been tested by the workers with disabilities. The prototypes will be tested prior to submission of final reports to NISH in April 2008.

## Design Projects

### *Device for the delivery of decking screws to the work area*

An initial step in the packaging process involves the removal of metal decking screws from a 25 ft<sup>3</sup> bin into a 2 ft<sup>3</sup> bin for delivery to a work area. This task currently involves a worker transferring the screws by hand from the large to the small bin which sits on the floor of the facility. The worker then lifts the small bin weighing 40 – 60 pounds from the floor, carries the bin several feet to the work area and then reaches (while standing) 3 feet from the body and dumps the contents onto the work surface. This task requires workers with fine motor skills and the ability to lift and carry heavy objects, making it undoable impossible for most of the workers at the facility. This primary objective for this device design and fabrication is to enable workers having a variety of disabilities, including those who have limited strength and reach as well as those with visual impairments or cognitive disabilities, to accomplish this task. The secondary objective is to eliminate several ergonomic concerns that were observed with respect to lifting and reaching of heavy objects.

The prototype device, seen in Figure 1, has many features to increase the number of workers able to perform this task. The device consists of two wooden bins mounted to a base that sits atop the platform of a wheeled hydraulic lift. The worker begins with the cart in the collapsed position as shown in Figure 1a. The task begins with the manual transfer of screws from the large bin to the bins on the collapsed cart. Once the bins are full, the worker raises the cart to its extended position through use of the foot pedal on the rear of the cart (Figure 1b). Once the cart is moved to the work area, the base holding the bins is extended over the work area utilizing drawer slides (Figure 1c). The worker empties the bins by lifting up on a handle on the rear of the bin (not shown) and rotating the bin about a pivot mounted on the front of the base. This design also seeks to prevent injury to the worker through the use of the device. Eliminating the lifting of the bins may decrease the possibility of back injuries to the workers. Team members evaluated the expected loads to choose the proper hydraulic lift and used NIOSH guidelines to evaluate ergonomic parameters of the design. The design team plans to provide markings on the bins to facilitate the device's use by workers with visual and cognitive disabilities. Design of this device incorporated several of the universal design principles, most notably those of equitable use and low physical effort. The use of markings to demonstrate proper use will incorporate the principle of simple and intuitive use.



(a)

(b)

(c)

Figure 1: Prototype device for moving screws to work area.  
 (a) loading position, (b) transport position, (c) delivery position

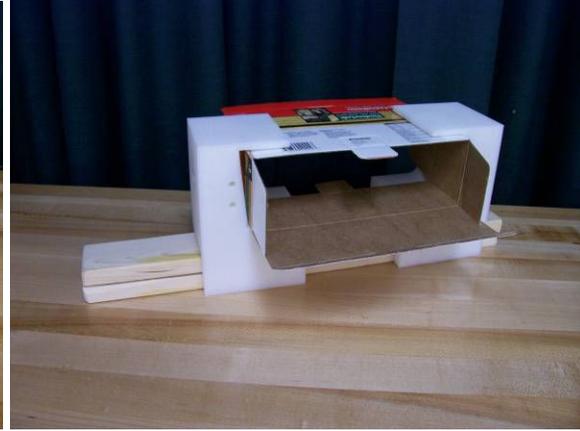
### *Design for the expansion of flattened tabbed packaging boxes*

Another step at the beginning of the packaging process is the conversion of flattened tabbed packaging boxes into expanded boxes ready to be filled with decking screws. The primary objective of this project is to design and fabricate a device to enable workers who have a variety of disabilities such as the limited use of use of one of their hands/arms, limited fine motor skills, or visual impairments, to perform a task that currently requires a sighted person with use of both hands to accomplish. As a secondary objective, this design seeks to minimize the potential for repetitive motion disorders as there are currently hundreds of boxes expanded and tabbed each day. The boxes have a standard width and height, but the length of the box varies depending on the length of the screws to be packaged (from 4" to 10" in length). Thus, the device must be flexible to accommodate a variety of box lengths.

A prototype of the box expanding device is shown in Figure 2. A flattened box is placed between the two sides of the device which slide along a track (Figure 2a). Moving one side toward the other expands the box to its rectangular shape (Figure 2b). The device hold the box steady while the worker folds in the large side tabs (Figure 2c) and the smaller central tab (Figure 2d).



(a)



(b)



(c)



(d)

Figure 2: Prototype device for expanding flattened boxes.

- (a) insertion of flattened box into device, (b) expansion of box to its rectangular shape,  
(c) box after folding in large side tabs, (d) box after folding in small center tab

Based on the success of this prototype after team testing, a second prototype device was developed. This new prototype uses lever-type door handles and a slotted track to provide a positive latching mechanism to hold the box in place as shown in Figure 3. The slotted track is designed so that either side of the device can be pushed toward the other as in the previous prototype. To reverse the direction of travel, the worker pushed on a lever-type door handle to disengage the bolt of the handle, allowing it to clear the track tabs. The lever-type door knobs were chosen since these are recommended for individuals having poor grip strength. This prototype is currently under construction, with the sliding sections made from aluminum to be lightweight and the slotted track made of steel to provide stability to the device. A rubber mat will be added to the bottom of the track to prevent slipping of the device while in use.

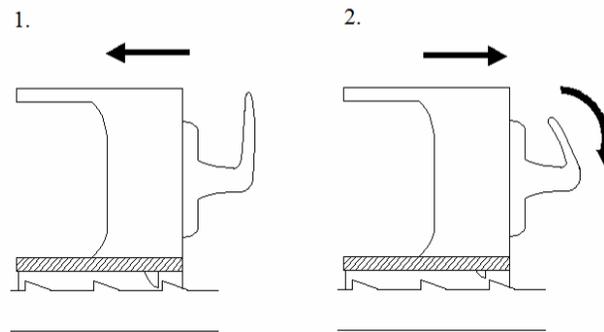


Figure 3: Proposed locking mechanism for sliding side piece of box expanding device. Left: Design of slotted track allows the side piece to move toward box and lock box into place. Right: Door handle must be disengaged to allow door bolt to clear track slots to remove box from device.

This design also incorporates many principles of universal design, namely the principles of equitable use, flexibility in use, simple and intuitive use, and low physical effort. The device expands flattened boxes to their rectangular shape and securely holds the box in place while the worker folds in the tabs. The device is flexible in that it can be used for boxes having different lengths and by either left- or right-handed individuals. The lightweight sides and lever-type door handle will allow workers with limited strength or use of their hands to participate in this step of the manufacturing process. In addition, the low physical effort required to use this device may help to prevent repetitive motion disorders.

## Discussion

The designs described incorporate universal design concepts in the development of assistive technologies for workers with disabilities at Goodwill Industries of the Springfield/Hartford Area, Inc. Feedback is, in general, positive as the students can see the direct result of their designs on the participation of workers. The usefulness of this project on the resulting capstone senior design projects will be evaluated at the completion of the capstone courses in each discipline at the end of the spring semester. It is interesting to note that this design project is unique for industrial engineering students who, in general, are taught to streamline assembly processes, eliminating personnel when necessary. In this project, they were required to include all workers in the process, and increase the number of individuals who could perform the assembly tasks when applicable.

## Conclusion

Faculty members at Western New England College have modified an interdisciplinary laboratory design project, performed by senior biomedical and industrial engineering students, to introduce the concepts of universal design to the design of assistive devices for workers involved in the

packaging of decking screws. Supervisors at the nonprofit agency provided customer feedback on the designs that would best maximize participation of worker in this packaging process. The resulting designs incorporate a number of the universal design principles, providing students valuable knowledge they can use in evaluating the usability of their designs for their capstone design projects and beyond.

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