In recent years, many independent adults have indicated a need for a method of accurately controlling the doses of their intravenous medications. Those suffering from type II diabetes, and therefore are insulin dependent, or stroke patients, who use precautionary heparin injections, are some of the patients who most commonly use syringes. Self-dosing can be problematic for many people, especially those who are elderly, visually impaired, or hearing impaired, or suffer from arthritis, Parkinson’s disease, partial paralysis, or the loss of motor skills due to a stroke, heart attack, or other physical ailments. Clearly, there is a need for a reliable, easy-to-use, and inexpensive product to accurately fill syringes with insulin or heparin in a timely manner. Products currently on the market require patients to mechanically fill their syringes, using their fine motor skills to control the syringe mechanism.

This new product has several important basic requirements. It needs to be accessible for people who are hearing impaired, vision impaired, and who lack certain motor functions. Because most of the products already on the market accommodate those who are hearing impaired and vision impaired, the feature that will set this product apart from the others is that it will not require fine motor skills for operation. It must, of course, accurately dose the user’s medication to the nearest 0.01cc. The accessible syringe dosing device must also, as its title implies, be compact, easy to use, and cost effective. The device proposed here will employ a digital dosage display with easy-to-use buttons to increase and decrease the volume of medication by one unit. The product’s digital display will be controlled by a microprocessor, which will be connected to an electrical system with rechargeable batteries. The product will employ a gear system that will accurately draw the syringe to deliver a reliable dose to any patient. The projected cost of the product is between $40-60.
STATEMENT OF NEED

Products currently on the market require patients to mechanically fill their syringes, using their fine motor skills to control the syringe mechanism. This method increases the risk of errant dosing by relying on the patient’s physical ability to perform the dosing correctly. The current products, therefore, do not accommodate patients that lack the necessary fine motor skills. The product proposed here will provide a digital self-dosing device that will accommodate many of the physical limitations mentioned above, while remaining affordable and competitive in today’s market.

Market Research:

The following is a compilation of several of the principal competitors currently on the market. For our design it is necessary to note the good points of such products as well as the shortcomings upon which we can improve. The retail price of each is also an important figure, as it dictates the budget within which we are to produce a competitive product.

Count-A-Dose by Medicol: This product priced at $59.95 is not only the most popular one on the market, but is also the one that best satisfies our requirements. It is lightweight, portable, and easy to use. It accommodates sight and hearing impaired patients by using a clicking sound that can be felt and counts the dosing units. It even has a two-insulin bottle holder at its base for easy mixing. The product is visually appealing and includes a tape cassette with instructions. The product, however, can be improved upon. It only adds to the syringe in 1-unit increments and therefore can be a hassle while dosing. Furthermore, it still relies on a patient’s ability to use fine motor functions in operating the device. It also does not aim to minimize human error in dosing amounts. There is no definite indicator of the dosing on the device; rather it relies on the client’s ability to count the clicks. This may be problematic with patients with bad memories or attention disorders. Our device should therefore embody the Count-A-Dose’s basic design while increasing its functionality to encompass the stated shortcomings.

Load-Matic by Palco Labs: This product is priced at $49.95 and is very similar in appearance and aesthetics to the aforementioned Count-A-Dose. The design, however, is far more complex; the Load-Matic includes increment settings of either 1 unit at a time or 10 units at a time, using a movable operating drill gear. Although this does have some advantages, it also leads to more error in dosing. The 10-unit lever is not easy to fully depress, especially for clients with limited motor functions, and therefore under dosing is a recurring problem. Also, like the Count-A-Dose this device fails to minimize the human mechanical interactions and therefore needlessly increasing the risk of error. Our device should continue with the Load-Matic’s trend toward a quicker dosing mechanism but at the same time minimize the devices complexity and the human mechanical interactions.

The Syringe Support by the Foundation Center Louise-Herbert in Canada: At $19.95, this product is perhaps best noted for its cost effectiveness. However, there is a definite detriment to its lower price. Its design lacks both audible and tactile indicators of dosing units. It also relies on a turn screw mechanism to draw the syringe back. This is a disadvantage because the patient must count, without indication, the number of turns the screw has been twisted; this may prove especially difficult for clients with limited motor functions. Furthermore, the device does not have an easy mechanism for mixing; the vial must be disengaged and then a new one fixed in place every time. Although this is a competitive product in terms of pricing, it does not meet product expectations in terms of accommodating disabilities, and is sizably susceptible to error (all information from [http://www.nfb.org/vodold/inslmeas.htm](http://www.nfb.org/vodold/inslmeas.htm), Insulin Measurement Devices).
Patent Opportunities:

The purpose of this section is to first determine what sort of product would merit a patent. The patent search can also be useful in generating ideas on how a certain procedure may be accomplished.

Patent Law stipulates that a new product may be introduced and patented as long as it possesses an aspect that is sufficiently unique, novel, and different than any product currently under patent. Note that simplistic mechanisms such as a gear transfer system can not be patented. Also the use of a previously patented device is not permissible without consent of the patent holder.

#6796970 Dose Setting Device - September 28, 2004 – Klitmose et. all

This patent describes a mechanism for a dose setting delivery system that automatically draws and then releases a preset dose. The dosage is set by rotating a screw to vary the piston length. The device then uses a push button to draw back the piston and draw in the correct dosage. The button is then pressed again to administer the dosage.

Analysis: Although this is a convenient method for administering preset dosages it does not include a convenient method for setting these presets. If such a method could be determined this mechanism (or a similar system) may however prove to be an effective dosing method for our device providing accurate and quick dosing with the push of a button.

#6796967 Injection Needle Assembly – September 28, 2004 – Jensen

This patent describes a needle injection mechanism that houses a needle discreetly and uses a sliding housing mechanism to push the needle into the patient and inject the dosage when so desired.

Analysis: This device incorporates a similar sliding box mechanism to that which we wish to incorporate. However the device is better suited for epi-pen injections than for dosing. The sliding box mechanism itself is not under patent however can be investigated further to help with our design.

#6716198 – Injection Device – Larsen

This patent describes an injection system that uses elastic torsion rods to draw back a specific dosing. The torsion rods are manipulated using a toothed gear couples system similar to the power transfer system we have proposed.

Analysis: Although the device does describe a dosing system it is once again geared toward the injection process and not so much the dosing procedure. The innovation itself was the elastic torsion rods, which are not really applicable to our device. We can however, use a similar gear system in our device. Since the gear is not patentable a simple gear system likewise is not patentable thus we can use this and other gear transfer systems to help us design our own.
PROJECT DESCRIPTION

Objective:
This new product will ease the lives of many people with disabilities. It will be accessible for people who are hearing impaired, vision impaired, and who lack certain motor functions. This instrument is a syringe-dosing apparatus used to measure and mix insulin before injection. This product will accurately dose the user’s medication to the nearest 0.01cc. The accessible syringe dosing device will also be; compact, easy-to-use, and cost effective. The device proposed here will employ a digital dosage display with easy-to-use buttons to increase and decrease the volume of medication by one unit. The product’s digital display will be controlled by a microprocessor, which will be connected to an electrical system with rechargeable batteries. The product will employ a gear system that will accurately draw the syringe to deliver a reliable dose to any patient. Once complete, the projected cost of the product will be between forty to sixty dollars. Since most of the products already on the market accommodate those who are hearing impaired and vision impaired, the feature that will set this syringe-doser apart from the others is that it will not require fine motor skills for operation. Large buttons on the user interface will allow operators to easily choose the proper dosing.

Methods:
Figure 1 depicts the block diagram showing the overall operation of the syringe-dosing product. The overall operation of the syringe-dosing product begins with the user interface (Figure 2). The user interface that is going to be implemented into this device will have a numerical LCD display with a precision of at least 0.01cc. The LCD display will be illuminated with one or two small light emitting diodes to increase visibility for the elderly and vision impaired. When reset the syringe will return to the start position and the display will zero out. The display will be approximately 5cm high and 7.5cm in length.

Figure 2: User Interface

The user interface will have five buttons, all of which are reliable and easy to use for people with physical constraints. This ease of use will be accomplished by the incorporation of marked buttons with the proper spacing and unique tones for the depression of each button. Each button will be approximately one cen-
timeter in diameter. The on/off button will be used to shut off the entire unit and will be the first part of the entire circuit. A small depression in the middle of this button will alert the blind to its function. There will be two buttons for adjusting dosing volume, one for increase and one for decrease. The increase button will increase the dosing by a given amount of cubic centimeters and the decrease button will do the opposite. Three-dimensional impressions of a plus and minus symbol will be placed on these two buttons for the blind.

The reset button can be used at any time to recalibrate the digital display to zero. A large R will be placed on this button for the blind to show its function. To initialize the motor and pull up the proper dosing into the one cubic centimeter syringe the enter button will be implemented. This button will have an imprinted E on it. Finally, there will be a preset button used to scroll through a list of common dosing values. This button will have an imprinted P on it. New presets can be created at any time by using the increase/decrease to get to a proper dose, then holding down the preset button. To use a preset, depress the enter button. To delete a preset, scroll to the preset and hold the preset button.

After the data is input and the enter button is depressed the microprocessor will translate the dosing value into a number of rotations. The microprocessor will reset the LCD display to zero if the reset button is depressed. Presets will be stored in memory, and must not be erased when the device is powered down. This can be accomplished by having internal read memory in the chip or by always having the power supply on for the chip. The code for this computer chip will be written in C++ programming language. The microprocessor will be the heart of the syringe-dosing mechanism, accepting all inputs from the buttons, outputting to the digital display, and controlling the motor. This microprocessor must be very reliable, precise and have a long operation life. The microprocessor must include a LCD display driver, memory and be programmable.

The microprocessor and the nine or twelve volt rechargeable battery will drive the motor. A small radius pinion gear will be attached to the rotor of the motor. This gear will rotate a larger round gear, decreasing speed and increasing torque. The gear ratio will be determined by the amount of rotations needed to pump given insulin volumes. Finally, the large circular gear will connect to a tall straight, geared edge. This will attach to the top of the inserted syringe and provide the means of insulin or heparin uptake. Overview of gear setup can be seen in Figure 3.

Figure 3: Straight Spur and Rack and Pinion

http://www.geocities.com/Baja/8205/gears.htm
The power supply for this syringe-dosing mechanism will be a nine to twelve volt rechargeable battery. This will power the LCD display, the DC motor and the microprocessor. When the battery no longer has the current to operate the device properly, the LCD will display all zeros. Since the device is every important to the medical health of patients, an extra battery compartment will be provided for backup power. It is the operator’s job to make sure this battery is present and functional.

Outer casing for this device will be made of a heavy-duty plastic material. The case and all components will be built to withstand a fall of five feet onto a hard surface. The case will be designed specifically for the insertion of one cubic centimeter syringes. The case will also feature a part that will hold bottles of heparin or insulin while the dose is being retracted. The LCD display will be inserted below the outer surface of the outer casing to prevent cracking or shattering in the even of a drop. The enter device is not waterproof, but can be washed with a moist paper towel.

**Directions:**
1. Insert one cubic centimeter syringe into syringe-dosing device
2. Insert bottle of heparin or insulin into syringe-dosing device
3. Depress on/off button
4. Use increase/decrease buttons or preset to choose proper dose
5. Press enter to pump dose into syringe
6. Remove syringe and inject
Figure 1: Project Block Diagram

Syringe Dosing Project Block Diagram

User Interface:
Choose product, depress trigger

Battery:
Power component
PROFESSIONAL CONSIDERATIONS

It is important to note that most purely mechanical devices use a gear system rather than an actuator (or any other mechanism); this may indicate that this method is more successful; however, still one should consider other options.

The simplest design is one powered by a linear actuator. It can directly draw back the syringe and therefore the error in the process is minimized. There are however limitations arising from this idea the most severe of which is that the resolution is limited by the minimum step size of the actuator. Also the force required to draw back the syringe may require a larger (and more expensive) actuator than that desired.

Slightly more complicated than this initial idea is the use of a stepping motor and control circuit (see http://www.cs.uiowa.edu/~jones/step/ for reference). The motor can use a gear system to increase both the resolution (by decreasing the smallest step possible) and the torque thus allowing for use of a weaker motor. From here there are several possibilities for how one can transfer the rotational force to a linear force.

The simplest transfer mechanism could be modeled by a fishing rod. High tension wire could be wound around a spool to slowly draw back the syringe. The two major disadvantages in this are the uneven wrapping of the wire causing a discrepancy in step sizes and perhaps of even greater concern the fact that “a rope can only pull”. Thus the motion would be limited to drawing the appropriate amount. The system would not be able to correct the possibility of drawing too much into the syringe.

A second method could correct these discrepancies and standardize the step size. Using a fine gear slide one can approximate one tooth per unit drawn and thus control the intake and output of the device.

A third design possibility is one that uses pressure or a pump of some sort to control the intake and limit it to the correct amount. The specifics of this method have yet to be considered and it is very much dependent on the technologies available for a narrow budget. One possibility is that an actuator or motor would still be used to draw back the syringe; however it would be directly controlled by a unit measuring the intake. This is, however, reliant on the ability to accurately measure intake and once again more research on how this can be accomplished for a limited budget is necessary.

We need to determine the following characteristics of our design:

**Size of the housing box (dimensions X, Y, and Z).**
This should be as small as possible while still being able to house the motor or actuator, the gear system (if necessary), the motor or actuator control circuit (which may be housed in a separate “remote”, and the syringe itself. It would be a good idea to expend some funds on reverse engineering current products and thus attaining preliminary figures for all of the above.

**Distance (d) needed to pull back the syringe in order to draw one unit (.01 cc) into the syringe.**
This is relatively simple to determine. If one knows the radius (r) of the syringe in centimeters and the dosing step unit (.01 cc) one can easily determined:

\[
d = \frac{.01 \text{ cm}^3}{\pi r^2} \text{ cm}^2
\]

Thus assuming diameter = ¼” = .635 cm

\[
D = \frac{.01}{\pi(0.31669)^2} = \frac{.01}{.32170} = .0315722 \text{ cm}
\]
However from measured amounts 1 cc = a drawback of about 5.75 cm. Thus d should be equal to about .0575 cm. 

This is a discrepancy we need to figure out (more likely then not 1 cc is nonstandard and from our approximation 1 cc = 1.8 cm³).

**Minimum force (Fmin) needed to draw back the syringe.**

To be sure that our device works properly we should allow at least a 50% excess in required force, however, a two to three fold excess would be more preferable (especially since Fmin is extremely hard to determine as noted below). Note that this force will need to be supplied by our motor (our actuator) although the gear system should sufficiently increase the torque to allow for a lower power motor. To determine the force required we should set up a test apparatus as shown below in Figure 4.

Figure 4: Test apparatus

The syringe should be placed into a sliding box similar to that which will house the final product we will then measure the force required to overcome the static friction and start the box opening. Note that this can not be done until the housing structure is complete. A preliminary test can be done to determine the frictional component of drawing back the syringe be itself, however this would overlook the likelihood that the frictional component of the box itself is much greater than that of the syringe. Since our outer shell most resembles that of the Count-a-Dose™ product currently on the market it would perhaps be in our best interest to buy this product and perform preliminary tests on it to get some idea of the aforementioned constraints. On one final note one must test the syringe and apparatus while actually drawing a liquid as that this will create more resistance than simply drawing air.
There are two possible mechanical sources that we can use to carry out our application:

Stepping motor – A stepping motor may be the more practical of the two as that a simple gear system can be used to reduce the motion to fine increments and increase the torque. Also a simple stepping motor costs far less than a linear actuator (preliminary estimate of approximately 5$ as advertised at alltronics http://www.alltronics.com/stepper_motors.htm).

Linear Actuator – A linear actuator would be the most direct way to draw back a syringe. The unit would require no gear mechanism or gear slide to increase power and decrease movement and transfer torque into linear force. However linear actuators can be pricier and may not be sufficiently fine tuned to control small movements. Thus we need to first determine the distance needed to pull back the syringe in order to draw one unit before determining which method is more applicable.
The following is a rough estimate of the cost of building the accessible syringe dosing device:

<table>
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<tr>
<th>Item</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>DC 12 Volt Motor</td>
<td>10.00</td>
</tr>
<tr>
<td>Microprocessor</td>
<td>15.00</td>
</tr>
<tr>
<td>Case</td>
<td>5.00</td>
</tr>
<tr>
<td>Gears</td>
<td>2.00</td>
</tr>
<tr>
<td>LCD display</td>
<td>4.00</td>
</tr>
<tr>
<td>Buttons</td>
<td>1.00</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>37.00</strong></td>
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</table>
# Timeline

<table>
<thead>
<tr>
<th>ID</th>
<th>Task Name</th>
<th>Duration</th>
<th>Start</th>
<th>Finish</th>
<th>Predecessors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Purchase order</td>
<td>15 days</td>
<td>Mon 1/17/05</td>
<td>Fri 2/4/05</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>program microprocessor</td>
<td>14 days</td>
<td>Mon 2/7/05</td>
<td>Thu 2/24/05</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>build circuit board</td>
<td>10 days</td>
<td>Mon 2/7/05</td>
<td>Fri 2/18/05</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>build gear system</td>
<td>14 days</td>
<td>Mon 2/7/05</td>
<td>Thu 2/24/05</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>design case</td>
<td>7 days</td>
<td>Mon 2/14/05</td>
<td>Tue 2/22/05</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>build case</td>
<td>10 days</td>
<td>Wed 2/23/05</td>
<td>Tue 3/8/05</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>test systems separately</td>
<td>10 days</td>
<td>Mon 2/28/05</td>
<td>Fri 3/11/05</td>
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<tr>
<td>9</td>
<td>complete design build</td>
<td>14 days</td>
<td>Wed 3/9/05</td>
<td>Mon 3/28/05</td>
<td>3,4,8</td>
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<tr>
<td>6</td>
<td>test systems together</td>
<td>10 days</td>
<td>Mon 3/14/05</td>
<td>Fri 3/25/05</td>
<td>5</td>
</tr>
<tr>
<td>10</td>
<td>instructions for use</td>
<td>4 days</td>
<td>Tue 3/29/05</td>
<td>Fri 4/1/05</td>
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<tr>
<td>11</td>
<td>test final design project</td>
<td>23 days</td>
<td>Wed 3/30/05</td>
<td>Fri 4/29/05</td>
<td>6,9</td>
</tr>
</tbody>
</table>

Within the timeline diagram, each task is represented with a bar, indicating the start and finish dates based on the table above.
CONCLUSION

Products currently on the market do not accommodate patients that lack the fine motor skills necessary for correct use. This is perhaps the most important unique aspect of the project. Currently marketed products also lack a digital user interface, which the project described here will include. The product described here will provide a digital self-dosing device that will accommodate many of the physical limitations mentioned above, while remaining affordable and competitive in today’s market.

Our team projects that the design of the product will be completed by December 2004, and the product will be ready for testing by March 2005. The members of Team #1 are excited to be a part of such a meaningful and necessary product. Our team looks forward to the opportunity to move forward with the product described here with the help of funding from the 2004-2005 National Student Design Contest.
ACCESSIBLE SYRINGE DOSING DEVICE

BME 290 SENIOR DESIGN TEAM #1

This design project is currently funded by the 2004-2005 National Student Design Competition, conducted by the Rehabilitation Engineering Research Center on Accessible Medical Instrumentation (RERC on AMI).

Visit us at design.bme.uconn.edu/Spring05/Team1/Index.htm