

## **Student Proposals for Design Projects to Aid Children with Severe Disabilities**

### **Dr. Steve Warren, Kansas State University**

Steve Warren received a B.S. and M.S. in Electrical Engineering from Kansas State University in 1989 and 1991, respectively, followed by a Ph.D. in Electrical Engineering from The University of Texas at Austin in 1994. Dr. Warren is an Associate Professor in the Department of Electrical & Computer Engineering at Kansas State University. He directs the KSU Medical Component Design Laboratory, a facility partially funded by the National Science Foundation that provides resources for the research and development of distributed medical monitoring technologies and learning tools that support biomedical contexts. His research focuses on (1) plug-and-play, point-of-care medical monitoring systems that utilize interoperability standards, (2) wearable sensors and signal processing techniques for the determination of human and animal physiological status, and (3) educational tools and techniques that maximize learning and student interest. Dr. Warren is a member of the American Society for Engineering Education and the Institute of Electrical and Electronics Engineers. He currently serves as the Chair for the ASEE Midwest Section.

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## Abstract

Children with severe disabilities have unique individual needs. Technology-based designs intended to quantify the well-being of these children or assist them with learning or activities of daily living are often by nature “one of” designs tightly matched to these needs. For children with severe autism, such designs must be incorporated into their environments in unobtrusive ways to avoid upsetting or distracting these children. This design space and its affiliated challenges offer a rich environment for engineering students to exercise their design creativity.

This paper presents an end-of-semester exercise for a Kansas State University *Introduction to Biomedical Engineering* class, where students propose senior-design projects geared toward children with severe disabilities. The goal of the exercise is to integrate concepts related to biomedical devices, design factors, care delivery environments, and assistive technology into a proposed design with clear practical benefit that can be implemented in prototype form by a senior design team over the span of about two semesters. The deliverable for the design exercise is a four-page paper in two-column IEEE format that adheres to a pre-specified structure. To focus these design-project ideas, students are asked to offer their thoughts within the framework of needs specified by clinical staff at Heartspring in Wichita, KS, a facility that serves severely disabled children, where nearly all of the full-time residents are autistic, and most are nonverbal. In addition to the educational benefits offered by this experience, the author’s intent is to help spur ideas for new senior design projects that can be supported with resources from existing NSF-funded grants which provide equipment and materials for such endeavors.

Six semesters worth of design ideas are presented here, along with the results of assessment rubrics applied to the final papers. The class is populated by students from various departments within the Kansas State University College of Engineering, so design proposals are varied and incorporate low-level to system-level solutions. Some of these design ideas have been adopted by design teams, whereas others await attention.

## I. Introduction

### A. *Motivation: Engineering Efforts that Benefit Severely Disabled Children*

Developmental disability prevalence during 1997 to 2008 was 13.9%.<sup>1</sup> About 1 in 6 children in the U.S. had a developmental disability during 2006–2008, ranging from mild disabilities such as speech impairments to serious disabilities such as cerebral palsy. Autism, a neurodevelopmental disorder that presents with various forms of physical impairments, is now a more widely recognized developmental disorder in the U.S.; estimated prevalence rates of 1 in 88 individuals<sup>2</sup> have been recently updated to 1 in 68 individuals, due in part to refinements in diagnostic criteria.<sup>3</sup> If 4 million children are born in the U.S. every year, then 58,823 children will be diagnosed with Autism Spectrum Disorder (ASD). The estimated lifetime cost to care for an individual with ASD is \$3.2M.<sup>4</sup> Since most costs relate to adult care, reducing the care burden for this group by early childhood investments in functional independence skills can reap

compounding rewards as this population ages, resulting in cost savings and increased quality of life for these individuals and their support community.

Autism significantly affects verbal and nonverbal communication and social interaction. Other characteristics associated with autism are engagement in repetitive behaviors and stereotypical movements, resistance to environmental changes or changes in daily routines, and unusual responses to sensory experiences. Children with autism may exhibit self-injurious behaviors or behaviors that can harm others. Sleep disorders in children with ASD are more prevalent (50-80%) than in age-matched neurotypical children (9-50%),<sup>5, 6</sup> and poor sleep quality in children with autism correlates with aggressive behavior, anxiety, and developmental regression.<sup>5</sup>

The design space related to children with ASD is extremely broad and addresses tools to

- maximize child safety in residential, educational, and therapeutic environments,
- establish situational awareness for these children, including quantifying their wellness during the daytime/nighttime,
- track parameters associated with outcomes-based therapies for children as defined in their individualized education plans (IEPs),
- assist these children with activities of daily living (ADLs),
- increase the effectiveness of educational activities,
- aid in the delivery and effectiveness of physical, social, and cognitive therapies,
- track children and paraeducators (paras) within their daily environments with a goal to optimize facility use, care-delivery processes, and the impact of human resources, and
- increase the well-being of parents, paras, clinicians, administrators, and others that work with these children.

Because each child with ASD is very different and may exhibit multiple areas of disability, finding commercial solutions that meet their needs can be difficult or even impossible. On the other hand, the natural propensity toward “one of” designs needed by these children (i.e., designs that are each uniquely suited to one child) affords unmatched opportunities in engineering education, because engineering students can exercise their creative abilities in a relatively untapped design space that offers clear impact in terms of the quality of life of these children and their extended support community.

To that end, this paper addresses the notion of design proposals for children with ASD within the context of an *Introduction to Biomedical Engineering* class, where the diverse backgrounds of the students and their respective curricula contribute in a positive way to the novelty and practicality of the proposed design solutions.

### ***B. Introduction to Biomedical Engineering***

*ECE 571 – Introduction to Biomedical Engineering*, is a 3-hour course offered each Spring through the Kansas State University (KSU) Electrical and Computer Engineering (ECE) Department. The course is available to all students that have taken multi-dimensional calculus (e.g., *MATH 222 – Calculus III* at KSU) and a course that addresses fields and waves (e.g., *PHYS 214 – Engineering Physics II* at KSU). Originally offered as a 1-hour course for students enrolled in the Bioengineering Option in Electrical Engineering, this course was expanded to three hours in Spring 2010 and offered to students throughout the College of Engineering. Current enrollment is between 25 and 40 students each Spring semester, where five departments

primarily contribute to the student roster: Electrical and Computer Engineering, Industrial & Manufacturing Systems Engineering, Biological & Agricultural Systems Engineering, Mechanical Engineering, and Chemical Engineering. *Introduction to Biomedical Engineering* speaks to the application of engineering principles to measurement, analysis, and design issues faced by the medical and life science communities. The course provides an overview of biomedical engineering by briefly addressing topics such as

- basic anatomy and physiology,
- physiologic origins of biomedical signals,
- sensors and instrumentation for acquiring physiological data,
- techniques for imaging the human body,
- biomedical optics,
- biomechanics,
- biomaterials and tissue engineering,
- rehabilitation engineering and assistive technology,
- telemedicine and home health care,
- emergency and military medicine,
- medical information systems and electronic patient records, and
- medical ethics.

The instructor stresses career opportunities for engineers in clinical application environments.

### ***C. Heartspring***

The mission of Heartspring<sup>7</sup> (Wichita, KS) is to help children with special needs grow and learn on a path to a more independent life. Heartspring School serves severely disabled children with ASD, mental retardation, Down syndrome, visual/hearing impairments, and behavior disorders. Most of these children have significant, multiple disabilities, meaning concomitant impairments (e.g., mental retardation-blindness, mental retardation-orthopedic impairment, etc.), the combination of which causes such severe educational needs that the student cannot be accommodated in special education programs solely for one of the impairments. Professionals available to Heartspring children include teachers, paraeducators, psychologists, medical staff, nutritionists, speech/language pathologists, physical and occupational therapists, a developmental pediatrician, and a child neurologist.

The current Heartspring enrollment is 60 students (ages 5–22) from 11 states. These students sleep in residential apartments on the Heartspring campus, and most students receive one-on-one paraeducator support throughout the day. About 96% of Heartspring students have a primary diagnosis of ASD, 92% of Heartspring students work on functional activities of daily living such as bathing and teeth brushing, and 65% are non-verbal. Heartspring specialists use outcomes-driven approaches consistent with a child's IEP: applied behavior analysis; medical treatment interventions; physical, occupational and speech therapies; music; adapted physical education; art; vocational training; functional academics; community-based learning; and the development of functional independence life skills. Psychologists perform routine and specialized assessments as well as participate in the development of customized IEPs. Medical staff and consultants provide primary care, and a speech language pathologist collaborates with each students' team to develop communication plans to support all areas of learning.

### ***D. NSF Grant Support***

The senior design projects proposed by the students in *ECE 571 – Introduction to Biomedical Engineering* (i.e., the projects that are the subject of this paper) relate thematically to, and inform, two efforts supported by the National Science Foundation’s *General and Age-Related Disabilities Engineering* (GARDE) program:

1. CBET–1067740: “KSU Student Chapter of the IEEE EMBS as a Focal Point for Senior Design Projects to Aid Children with Disabilities,” which provides equipment and materials funding for senior design projects, where the Heartspring residential population serves as a primary means to focus these design ideas.
2. UNS–1512564: “GARDE: Research to Quantify the Health and Development of Children with Disabilities Around the Clock,” which offers support for the development of nighttime and daytime monitoring tools at Heartspring that are intended to help clarify the link between sleep quality and daytime performance in children with an ASD.

## **II. Methods**

As noted above, the typical student population for an offering of *ECE 571 – Introduction to Biomedical Engineering* can represent five or more departments within the KSU College of Engineering plus, on occasion, departments outside of the KSU College of Engineering. The instructor can find it challenging to select and manage biomedical engineering topics when working with students with such diverse backgrounds. In response, the instructor has allowed the students to choose, as part of their semester project work, ‘teaching-to-learn’ topics that students teach to one another, where the topics of choice help to better represent the student demographics and interests in the classroom.<sup>8</sup> Additionally, the instructor has chosen in recent semesters to replace the final exam for the course with a project, where each student writes a proposal for a senior design project that (a) addresses a need typical of a severely disabled child at Heartspring and (b) can be accomplished within two semesters. The Heartspring context gives the ECE 571 students tremendous leeway when choosing the application area and design form factor. The following sections describe the details of the assignment and the rubrics utilized to assess the student work.

### ***A. Assignment Description***

The assignment description, as given to the students, follows:

The goal of this exercise is to combine the thoughts that we touched on this semester with ideas relevant to your area of study to propose a senior design project that creates a prototype technology solution for a disabled child at Heartspring in Wichita, KS. This short proposal will be in IEEE paper format (up to four pages in length) and follow the structure below. The anticipated time investment is 15-20 hours.

#### **Structure**

Each paper will adhere to the structure specified below.

**Abstract:** Short motivation and summary of the proposed work, followed by anticipated results.

**I. Motivation:** The problem/issue that needs to be addressed and why it is important, including a literature base that confirms the relevance of the proposed work.

**II. Background:** Short explanations of efforts already undertaken to address this need, accompanied by citations for this work.

**III. Proposed Work ("Just the Facts")**

A. Overview: Succinct summary (a few sentences) of the technology proposed to meet the need mentioned in the 'Motivation' section.

B. Description: More complete description of the proposed design, including features and behavior.

C. Plan: Development and testing plan, including a 1- or 2-semester schedule for the design and evaluation work.

D. Resources: Resources that will need to be put in place to be successful. These include other people, hardware/software that would need to be purchased, facility access, etc.

**IV. Discussion**

A. Novelty: Explanation of how your suggested approach differs from, and is an improvement over, previous ideas.

B. Design Issues: Engineering issues that will need to be addressed (e.g., consider the design factors discussed early this semester).

C. Tradeoffs: Advantages versus disadvantages of the approach. What are the primary benefits and expected impact of the idea? What can go wrong?

**V. Conclusion**

**References**

None of these sections should consist of an exhaustive, unabridged collection of resource materials, previous work, etc. Rather, the goal is to show that you have done enough background work to support the importance of your idea and indicate that some facet of the idea is new. Figures/tables are encouraged, and all graphics and ideas incorporated from other work must be cited.

**Application Areas – Starter Ideas**

- General tools to reduce the burden of care and/or assist with independent living
- Tools to monitor physiology and assess state of health
- Hardware/software to track and document student well-being and educational progress
- Communication enhancement tools
- Reinforcers that help a child want to learn, exercise, participate, etc.
- Resources to assist with activities of daily living
- Tools to aid learning
- Portable resources that a paraeducator can use to document student progress without adding to the care burden

**B. Assessment Rubrics**

This project has been used in six consecutive Spring offerings of *ECE 571 – Introduction to Biomedical Engineering* (Spring 2010 through Spring 2015). In all cases, students were given the grading rubrics (see Figure 1 through Figure 3) at the same time as the project statement so that they were clear about point allocations relative to the portions of the final deliverable. Note that each of these rubrics incorporates a section for required elements (elements to be included as mandated in the assignment description) and a section for other factors that relate to the sensibility and quality of their work.

As evidenced by the need for three figures, the grading rubric has changed over the semesters as the project has been improved. For example, in Spring 2012, the ‘Development and Testing’ category was added because students in prior semesters had not given adequate thought to the iterative technical work required to complete the design. In Spring 2013, the broad ‘Proposed Work’ and ‘Discussion’ categories were added; ‘Summary’ became ‘Abstract’; ‘Previous Work’ became ‘Background’; ‘Technology Summary’ became ‘Overview’; ‘Development and Testing’ became ‘Description’; ‘Schedule’ became ‘Plan’; ‘Technology Difference/Improvement’ became ‘Novelty’; ‘Engineering Issues’ became ‘Design Issues’; and a ‘Conclusion’ section was added. Further, ‘Thought Depth’ and ‘Creativity’ were bundled, and points were added to address the IEEE paper formatting. The IEEE formatting requirement, added to reduce the variability in proposal formatting, was further broken into these categories: title/authors/affiliations; margins/justification; columns; font size/type; line spacing; and headings/captions. In short, between the rubric and the discussion in class, students were given every opportunity to perform well in the area of paper mechanics.

Student: \_\_\_\_\_ Total: \_\_\_\_ / 130 = \_\_\_\_ / 100

<b>Required Elements</b>		<b>Subtotal: ____ / 90</b>
Summary	__/5	
Motivation	__/10	
Previous Work	__/10	
Technology Summary	__/10	
Technology Difference/Improvement	__/10	
Engineering Issues	__/10	
Resources	__/10	
Schedule	__/10	
Tradeoffs	__/10	
References	__/5	
<b>Other</b>		
Quality	__/10	
Thought Depth	__/10	
Relevance	__/10	
Creativity	__/10	
Electronic File Upload	Y / N	

**Figure 1. Spring 2010 and Spring 2011 grading rubrics.**

Student: \_\_\_\_\_

Total: \_\_\_\_ / 130 = \_\_\_\_ / 100

<b>Required Elements</b>		<b>Subtotal: ____ / 90</b>
Summary	__/5	
Motivation	__/10	
Previous Work	__/10	
Technology Summary	__/5	
Technology Difference/Improvement	__/10	
Engineering Issues	__/10	
Development and Testing	__/10	
Tradeoffs	__/10	
Schedule	__/10	
Resources	__/5	
References	__/5	
<b>Other</b>		<b>Subtotal: ____ / 40</b>
Quality	__/10	
Thought Depth	__/10	
Relevance	__/10	
Creativity	__/10	
Electronic File Upload	Y / N	

**Figure 2. Spring 2012 grading rubric.**

Student: \_\_\_\_\_

Total: \_\_\_\_ / 150 = \_\_\_\_ / 100

<b>Required Elements</b>		<b>Subtotal: ____ / 100</b>
Abstract	__/5	
Motivation	__/5	
Background	__/10	
Proposed Work		
Overview	__/5	
Description	__/20	
Plan	__/10	
Resources	__/10	
Discussion		
Novelty	__/5	
Design Issues	__/10	
Tradeoffs	__/10	
Conclusion	__/5	
References	__/5	
<b>Other</b>		<b>Subtotal: ____ / 50</b>
Quality	__/10	
Thought Depth / Creativity	__/10	
Relevance	__/10	
Adherence to the IEEE format; proper citations; mechanics	__/20	
Electronic File Upload	Y / N	

**Figure 3. Spring 2013, Spring 2014, and Spring 2015 grading rubrics.**



### III. Results and Discussion

#### A. Proposed Projects

Figure 4 through Figure 9 list the titles of the proposed design projects for the last six years, where projects are listed in alphabetical order according to the students' last names. The topics are extremely diverse in terms of application area and development type, being influenced by the students' degree areas, technical experiences, ages, and personal experiences with special-needs individuals and their caregivers.

The rough categories represented by these 160 design proposals are listed in Table 1. The four most common categories (AACs, health monitoring, and behavior/location tracking) were given substantive discussion time in class and account for 80 (half) of the design proposals. However, the creativity of the student base is apparent when considering the breadth of the remaining ideas. Note that some design proposals address multiple categories, but each proposal is tallied in Table 1 according to its primary category.

**Table 1. Categories addressed in the final project proposals.**

<b>Category</b>	<b>Count</b>
Alternative and Augmentative Communication (AAC) Devices	23
Activities of Daily Living (ADLs)	9
Behavior/Therapy	10
Comfort/Environment	3
Entertainment/Art/Play/Music	5
Health Monitoring/Assessment	20
Learning/Education	13
Mobility/Movement/Exercise	8
Sleep Enhancement/Tracking	9
Social Interaction/Emotions	10
Technical Support	13
Tracking – Behaviors/Activities	21
Tracking – Location	16
<b>Total</b>	<b>160</b>

- Stacey Ahern. “Virtual Music Touch Screen Device”
- Taren Blew. “Computer Software to Help Children with Disabilities Communicate”
- Yvonne Cook. “Interactive Touch Screen Sand-Art Program Proposal”
- Nick Felder. “‘Mr. Wrist’ Band for Tracking Child Voice Patterns”
- Dana M. Gude. “Automatic Toothpaste Dispenser with Automated Singing Character”
- Jim Grannell. “Portable Hardware to Track and Monitor Student Progress”
- Brandon Gumm. “Simple Devices to Improve Children’s Lives”
- Karl Hertel. “Improved Bed Designs for Heartspring Children”
- Matthew James. “Sleep Monitoring Device and Active Database System”
- M’hammad Lershaid. “Active Communication Enhancer”
- Brian Krueger. “Positive Reinforcers to Optimize the Behavior and Learning Processes”
- Chad Miller. “Integration of Martial Arts with Therapy and Education”
- Brian Moore. “Proposal to Research Methods to Reduce the Cost of Portable PECS Devices”
- Lauren Phillips. “GPS Tracker in a Shoe or a Hat”
- Robert Richards. “Augmentative and Alternative Communication Device”
- Matt Rohr. “A Device to Increase Physical Activity in Children with Disabilities”
- Steve Rubenthaler. “Accelerometer to Track Sleep Patterns in Children”
- Sarah Shultz. “Developing a Computer Game to Help Autistic Children Recognize Emotions”
- Jared Thomas. “Electronic Communication Board to Aid the Mentally Handicapped”
- Alan Winter. “The Gloved Recording Device: Proposal for an Improved Data-Gathering Procedure at Heartspring School in Wichita, KS”
- Katy Wittich. “Database for Documenting Student Behaviors”

**Figure 4. Spring 2010 proposal titles.**

- Michael Claussen. “Durable Tablet Device”
- Xiongjie Dong. “Assistive Technology to Teach Autistic Individuals to Communicate”
- Nathan Goetzinger. “Proposal for the Use of a Pathway Guidance System at the Heartspring School”
- Emma Hawkins. “Adjustable Hearing Aids for Autistic Children”
- Josh Linn. “Multiple Subject GPS Location System and Locator Display Hub for Monitoring the Location of Special Needs Children in a Development Center Facility Environment”
- MaKayla Maurath. “Technology Aid to Reduce Assistive Burden”
- Thad Millsap. “X-Box Kinect for Physical Therapy, Social Interaction, and Learning”
- Jim Neihart. “Improvement on a Skin Conductivity Wristband to Monitor Stress”
- Tommy Nelson. “GIVING BACK A VOICE: A Portable AAC Program for Disabled Persons”
- Daniel Nottingham. “Head Cam to Collect Student Data”
- Andrew Satterlee. “Active Floor Tiles and Wireless Shoes”
- Megan Shroyer. “Proposal for Designing an Online Data Collection and Storage System”
- Luke Stauffer. “Accelerometers to Alert Personnel of Self-Abusive Behavior”
- James Strieby. “The Use of Tablets in the Education and Care of Autistic Children”
- Mandy Tadros. “iPad-Like Device as a Teaching Tool”
- Darui Yang. “Multifunction Activity Room to Gather Student Data”
- Moises Zapattini. “Tool to Aid Bathing and Dressing”

**Figure 5. Spring 2011 proposal titles.**

- Kaleb Anderson. “Audible Instructions to Assist in New, Situational Learning”
- Jordan Bever. “Emotion Detecting Device with Real-Time Visual Feedback”
- Sarah Carr. “TI eZ430-Chronos™ Watch to Monitor Children with Disabilities”
- Curtis Bryant. “Data Entry Device for Paraeducators”
- Nicole Chaska. “Smart Phone Communication. Using Smart Phone Technology as a Communication and Data Retrieval Device for Children with Disabilities”
- Lauren Cody. “Using EEG Producing Headbands to Track Autistic Children’s Emotional Responses to Situations, Activities, and People”
- Christopher Dolezal. “Weighted Vests for Autistic Children”
- Andrew Drumm. “RFID at Heartspring”
- Tim Gustafson. “Electronic Location Tracking System”
- Kristen Hale. “Waterproof Device to Monitor Weight Loss for Children with Autism”
- Karmen Harris. “Implantable RFID Tags to Track Students”
- Larissa Hall. “iPad Carrying Case”
- Ashley James. “High-Tech Band-Aids”
- Taylor Kelly. “Special Education Progress Monitoring Software”
- Abigail Lewis. “The Relaxed Rider. A Stroller for Autistic Children”
- Cameron Lucero. “Technology Aiding Disabled Children at Heartspring in Wichita, KS. Senior Design Proposal”
- Brandon Mais. “Developing an Interactive iPad App to Assist in Daily Task Management for Children with Developmental Disabilities”
- Geoffrey Miller. “Q-Sensor Wrist Watch/Head Band Event Counter”
- Bryn Mayfield. “Hammock Swing with Ergonomic Inserts”
- Zac Myers. “Shock Resistant iPads”
- Jacob Nagely. “Sleep Sensors to Aid Heartspring Children with Sleeping Problems”
- Wesley Orr. “Sensor System for Beds”
- Shuo Ouyang. “Short Proposal for a Technology Project to Aid a Disabled Child”
- Mark Prieb. “Multi-Purpose Sleep Activity and Event Counter Wristband”
- Devin Rood. “Heartspring Smart Shirt”
- Derek Skinner. “iPads for Paraeducators”
- Chris Sorrells. “Technology to Help Manage Epilepsy”
- Kenneth Telford. “Education Improvement Proposal to Assist Children With Autism at Heartspring”
- Gordon Terry. “RFID Tracking System for Special Needs Patients”
- Erin Vetter. “Devices to Monitor Stress Levels in Children”
- Andrew Waldman. “Utilization of the Affectiva Q Sensor for Children with Autism”
- Audra Walker. “Boardmaker Network Technology”
- Scott Whittle. “Creating a Combined Health and Tracking System”
- Alex Wurtz. “Automated Data Gathering and Processing”
- Chenyu Zheng. “Self-Injurious Events Counter Proposal”
- Eric Zinke. “Virtual World Using Microsoft X-Box 360 Kinect Technology”

**Figure 6. Spring 2012 proposal titles.**

- Mutaz Altashkandi. “Using iPad to Help Children with Disabilities”
- Dakota Bixler. “Roping in the Elopers: Creating a Super Device”
- Andrew Blattner. “Autistic Children & Google Glass”
- Lindsey Brummer. “Positive Stimuli Identification System for Autistic Children”
- Natalie Casey. “RFID Sensor to Track Children’s Location and Vital Signs”
- Victor Cassone. “Adjustable Workstations Triggered by RFID”
- Katherine Crane. “Short Proposal for a Technology Project to Aid a Disabled Child”
- Landon Davis. “Alternative Keyboards for Disabled Children at Heartspring”
- Brady Eakes. “Proposal for Heartspring to Implement RFID Technology to Aid a Disabled Child”
- Neelou Hadavandifard. “Smart Book of Emotions for Autistic Children”
- Tyler Harris. “Relationship of Sleep and Learning in Autism”
- Michael Heatwole. “A System to Track Children’s Actions and Eating Behaviors”
- Joe Hund. “RFID Tags and Assistive Technology”
- Lauren Hylton. “The iWatch: A Proposal for a Technology Project to Aid Disabled Children”
- Jace Larsen. “Mobile Robotic Toys for Children with Autism”
- Matthew Morley. “An Unobtrusive Sleep Monitoring System for Disabled Children”
- Greg Nitcher. “RFID Systems for Use in the Heartspring Facility”
- Jesus Sanchez. “RFID Technology Enhancing Healthy Eating Habits for Autistic Children at Wichita Heartspring Center”
- Emily Schnell. “Wearable Wireless Sensors to Monitor and Record Self-Injurious Behavior of Children with Autism Spectrum Disorder”
- Paul Shackelford. “Exercise Monitor and Self-Injury Event Counter Devices for Children with Autism Spectrum Disorders”
- Luke Southard. “Using Interactive Videos to Establish Independent Morning Routines for Disabled Children”
- Chris Thier. “Portable Systems in Assistive Technology”
- Kadi Thomsen. “Proposal to Research Knowledge Management Systems Relating to Healthcare”
- Jennifer Weber. “RFID Tag Technology to Assist Autistic Children”

**Figure 7. Spring 2013 proposal titles.**

- Jess Aschenbrenner. “Everyday Activities Game Proposal”
- Lanting Cai. “Play with Educational Robots for Disabled Children”
- Christian Castor. “Proposal for a Senior Design Project to Create an Artificial Intelligence Computer System to Assist in the Diagnosis of Disabilities in Children”
- Caitlin Clark. “Triangulation Robot: An Opportunity to Interact and Exercise for Children with ASD”
- Joao Costa Percia. “Wireless Communication System for Non-Verbal Disabled Children”
- Caroline Deats. “A Proposed Implementation of Musical Therapy for Autistic Children”
- Jack Ezell. “Proposal Overview for Wristwatch Language Activity Monitoring System for Use at Heartspring”
- Aaron Frith. “Social Robotics to Assist in the Learning and Practicing of Social Behaviors for Autistic Children”
- Ankush Gakhar. “Using Humanoid Robots and Yoga to Develop Life Skills in Autistic Children”
- Patrick Hawn. “Design of Tracking/Epilepsy Wristband Monitor for a Heartspring School”
- Dylan Johnson. “Design Proposal for a Video Game to Assist in Social Intelligence and Conversational Education of Autistic Children at Heartspring”
- Dylan Kraus. “Pressure Sensitive Lunch Trays to Monitor Eating Habits of Disabled Children”
- Jack Leung. “Class Response System”
- Josh Mais. “Using New Technology to Develop Teamwork and Communication Skills for Children with ASD”
- Ryan Manes. “An iOS and Android Application for Users of Alternative and Augmented Communication”
- Andres Martinez. “Technology to Aid Data Gathering and Processing at Heartspring”
- Melissa McGuire. “Senior Design Project Proposal: Sensing Gestures and Vital Signs of Heartspring Students with Wearable Gloves”
- James Mullin. “Mobile Application to Improve Communication and Treatment for Individuals with Intellectual and Developmental Disabilities”
- Dan Reust. “Improving Applied Behavior Analysis Techniques for Treatment of Autism Spectrum Disorder Through the Use of Simulation”
- Valerie Rito. “Synchronized Mobile Application for Progress Tracking in Students with Autism”
- Adam Robl. “Inventory Tracking Method for Equipment and Devices for Facilities Aiding Children with Severe Disabilities”
- Joshua Shiach. “Infrared Monitoring System”
- Glenn Sipes. “Proposal to Implement Kinect for Windows as an Automated Monitoring System”
- Jiazhang Song. “Prototype Technology Solution for Enhancing the Ability of Accessing the Internet for Children with Motor Skill Disabilities”
- Sarah Stoltz. “Computer Visual Imaging of Food Intake to Analyze Nutrition of Autistic Children”
- Joseph Tillman. “App to Track Student Process at Heartspring”
- Hannah Tritschler. “A Device to Aid in Functional Communication Training for Autistic Children”
- Megan Walden. “Soccer for the Blind and Visually Impaired”
- Josh Westhusin. “Concept for a Device to Allow Wheelchair Travel Over Sand”
- Kevin Wolters. “Finding Individualized Food Selectiveness Causes for Developing Children with Autism Spectrum Disorder”
- Zheng Zhao. “All-in-One Cordless Wrist Monitoring Device for Disabled Children”

**Figure 8. Spring 2014 proposal titles.**

- Thomas Bolton. “Potential Research into Behavioral Imaging Devices to Assist in the Individualization of Treatment Plans for Children with Autism Spectrum Disorder”
- Chloe Boudreaux. “Proposal for a Sturdy Fidget Chair”
- Augusto Braga de Almeida. “Software for Alphabetization with TEACCH Interface”
- Whitney Cox. “Alert System for Caretakers of Autistic Children With the Implementation of Geofencing”
- Nathan Fisher and Garrick Devin. “Design Proposal for Detecting Stress in Autistic Individuals via Measurement of Electrical Conductance with Sensors Embedded in a Wearable Ring”
- Kevin Garman. “Design Proposal of a Bronchial Monitoring System for Children with Severe Asthma”
- Jordan Gutsch. “Using Virtual Reality Systems to Teach Children with Autism”
- Morgan Hoffman. “Wearable Patch Sensor for Disabled Autistic Children to Monitor Stress”
- Storm Jackson. “Senior Design Project Proposal: Learning Tool for Autistic Children”
- Aaron Jenkins. “Modifying Toys to Increase Mobility in Toddlers with Disabilities”
- Peter Jensen. “Wearable Technology for Monitoring and Analysis of Physiological and Behavioral Data in the Care of Autistic Children”
- Rachel Klassen. “Proposal to Implement the Apple Watch to Provide Visual Scheduling and Tracking of Autistic Children”
- Anne Maier. “Research Proposal for a Senior Design Project to Aid Heartspring Residents with High Anxiety through Deep Touch Pressure”
- Samuel Martin. “Tracking Self Stimulatory Behaviors in Disabled Children using an Augmented Human Key Device”
- Matthew McKernan. “Creating and Monitoring Healthy Eating Habits for Children with Autism”
- Matthew Moran. “Assistive Technology for Disabled Children with an Emphasis in Learning Tools and Aid with Daily Activities”
- Alex Newell. “Proposal for Sensory Beds for Autistic Children”
- Thomas Ortiz. “Proposal to Research Durable Medical Equipment (DME) to Help Improve the Quality of Life for Young Children with Disabilities”
- Sriram Perumal. “Tracker Based System to Monitor Children with Autism”
- Blake Rumbaugh. “Tracking of Self and Peer-Injurious Events within an Arm Guard”
- Sydney Schinstock. “Short Proposal for Design Project to Aid in Quantification and Intervention of Stimming and Hyporesponsiveness”
- Joseph Seidl. “Proposal for an Alternate Seating Design to Aid Children with Autism in Classroom Settings”
- Colton Sheffer. “A Customizable Communication Tool for Autistic Children”
- Aman Singh. “Wireless Noise Monitoring Sensor with Phone Application”
- Jacob Sobering. “Xbox® Kinect as a Room Monitoring System to Prevent Self Injurious Behavior in Autistic Children”
- Jacob Slous. “Stress Monitoring vs Activity”
- Allison Sommer. “Method to Reduce Anxiety in Autistic Children: Deep Pressure Therapy”
- Skyler Thompson. “Creating the Technology to Track and Predict Autistic Behavior and Outbursts”
- Logan Van Horn. “Disabled Children Learning Daily Skills through a Computer Game Avatar”
- Ryan Waldron. “Designing and Implementing a new Data Collection Software at Heartspring to improve the learning process of the students and make the day-to-day operations easier for the Educators”
- Austin White. “Automatic Verbal prompting watch for kids with Intellectual Disability”

**Figure 9. Spring 2015 proposal titles.**

## B. Assessment Rubrics

Performance averages for the rubrics in Figure 1 through Figure 3 are tallied in Figure 10 below. The upper part of the figure displays performance results for the required elements in the proposals, whereas the lower part of the figure displays performance results related to paper mechanics and quality/creativity. Note that a one-to-one alignment does not exist between the earlier versions of the rubrics and the latter version. Addressing the bottom of the figure first, it is apparent that students performed generally well with regard to paper mechanics, although thought depth was lacking in many of these proposals. Similarly, a lack of thought/depth is apparent when viewing the overall averages for the overview, schedule, resources, design issues, and tradeoffs categories illustrated in the upper portion of Figure 10. These categories relate to the primary content of the proposals. Either the students were unfamiliar with thinking through projects at this level of detail, they did not invest adequate time in the proposal preparation, or both. Total percentages (lower graphic, right column, red font) mirror the fact that most grades on this assignment were A's, B's, and C's.

Assessment Rubric Averages - Content														
	Number of Students	Abstract	Motivation	Background	Proposed Work				Discussion				Conclusion	References
					Summary	Overview	Description	Schedule/Plan	Resources	Difference/Improvement	Novelty	Design Issues		
Spring2010	22	80.0	87.6	75.7	81.9			77.6	72.9	73.8		76.7	68.1	78.1
Spring2011	17	87.1	84.1	85.3	88.2			75.29	71.8	71.8		63.5	68.2	92.9
Spring2012	41	98.0	93.4	88.0	90.2		77.1	81.75	74.6	77.3		79.5	79.0	97.1
Spring2013	22	73.6	72.7	67.7		63.6	66.6	59.5	64.1		72.7	69.5	65.0	75.5
Spring2014	31	82.6	87.1	64.8		72.9	64.5	59.0	54.5		72.3	58.4	43.9	82.6
Spring2015	32	84.0	82.0	69.3		72.7	77.3	69.0	64.0		76.0	71.0	62.0	88.0
<b>Total</b>	<b>165</b>													
<b>Overall Average</b>		<b>85.6</b>	<b>85.5</b>	<b>75.4</b>	<b>87.5</b>	<b>70.4</b>	<b>72.2</b>	<b>70.8</b>	<b>66.9</b>	<b>75.2</b>	<b>73.8</b>	<b>70.5</b>	<b>64.7</b>	<b>82.8</b>

Assessment Rubric Averages - Other Elements										
	Number of Students	Other Elements							Total %	
		Quality	Thought Depth	Creativity	Thought Depth / Creativity	Relevance	IEEE format; citations;	Citations/ Attribution		Length
Spring2010	22	89.5	84.3	86.7		100.0				81.1
Spring2011	17	87.1	83.5	84.1		100.0				81.0
Spring2012	41	82.2	82.9	77.6		100.0				84.4
Spring2013	22	78.6			71.4	100.0	79.8			72.8
Spring2014	31	81.6			71.6	99.4	86.3			71.7
Spring2015	32	88.0			82.3	100.0	81.0	90.0	85.3	78.3
<b>Total</b>	<b>165</b>									
<b>Overall Average</b>		<b>84.2</b>	<b>83.4</b>	<b>81.5</b>	<b>75.6</b>	<b>99.9</b>	<b>82.6</b>	<b>90.0</b>	<b>85.3</b>	<b>78.5</b>

Figure 10. Tabulated results from the yearly assessment rubrics.

### ***C. Other Lessons Learned***

Other thoughts, some anecdotal, have emerged from the offering of this project.

- Ideas offered by these students have immense untapped potential in terms of designs that can substantively impact quality of life for severely disabled children and their caregivers.
- Students that are creative and willing to invest time in their proposal seem less inclined to limit their proposal to a subject area that is traditionally addressed in their degree program.
- Students have more personal experience with the struggles of the disabled and their caregivers than one might assume.
- The increase in rubric structure over the semesters has resulted in proposals with better organization and more consistent lengths. Presenting these rubrics up front avoids assessment questions that students often ask.
- The requirement that the students submit their papers in two-column IEEE format with a given font size and page requirement has been especially helpful, avoiding numerous questions about report style and expectations that used to arise at the end of the semester.
- After speaking with students about this assignment and the writing time involved, it is clear that their expectations for the time they should invest in the writing do not well match the time required to create a high-quality product. This speaks to the value of the assignment from a skills perspective and indicates that students need more opportunities to write in their undergraduate curricula.
- Some students find it difficult to be creative, seeming to be constrained by the notion that they need to be told that new ideas are okay. Other students are often unaware of the creativity truly embedded in their proposals, which makes one wonder if a two-stage assignment would make more sense for some, where they are given additional time to invest effort in the creation of a design proposal equal to the strength of the initial idea.
- Students from different curricula within a college of engineering can have very different notions of what constitutes a ‘fair’ amount of time to invest in this type of project within the context of a 3-hour class. It is therefore important that the overall time commitment be spelled out at the beginning of the assignment so that students do not wait until the end of the semester to begin the process.
- This type of open-ended assignment is a sensible way to allow students from different curricula to have a voice in the areas of biomedical engineering that are addressed in this type of introductory course.

### **IV. Conclusion**

The needs of children severely impacted by ASD are tremendous and varied, providing a wide-open design space for students in all engineering curricula. Many such projects are, by nature, “one of” designs. This paper addressed an end-of-semester design exercise for a Kansas State University *Introduction to Biomedical Engineering* class, where students were tasked to identify a design that could aid a severely disabled child at Heartspring (Wichita, KS) and then propose a two-semester senior design project to implement the process. Six years of design proposal ideas were included in this paper from students in multiple engineering departments within the Kansas State University College of Engineering. These proposals spanned the gamut of areas germane to



disability design, addressing alternative and augmentative communication devices, activities of daily living, behavior enhancement, therapy, child comfort, entertainment, health monitoring/assessment, education, mobility/exercise, sleep/location/behavior tracking, social training, and technical support tools. The creativity and relevance of some of these proposals makes them ideal for implementation, and the implementation of only a few of these ideas would well embody the broader impact mandate affiliated with the funding offered by the NSF grants (NSF CBET-1067740 and UNS-1512564) that are closely related to, and can be informed by, these efforts.

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