AC 2011-1268: MOTIVATING DESIGN AND ANALYSIS SKILLS ACQUISITION WITH THE INFUSION OF ADAPTED PHYSICAL ACTIVITY PROJECTS THROUGHOUT A MECHANICAL ENGINEERING CURRICULUM

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Motivating Design and Analysis Skills Acquisition through the Infusion of Adapted Physical Activity Projects in a Mechanical Engineering Curriculum

Abstract

At the heart of the mechanical engineering discipline is the design (including analysis) of machines and machine elements that satisfy societal needs. At California Polytechnic State University students are challenged in their four-year curriculum by unique, open-ended design projects. Many of these projects focus on the design, analysis, building and testing of adapted physical activity devices that allow greater inclusion of persons with disabilities in recreational activities. Adapted physical activity gives persons with disabilities the opportunity to play and obtain physical exercise. These projects present design challenges that force students to consider a user-centered design approach with little in the way of existing reference designs to build upon; therefore the students are required to use a disciplined approach to the engineering design process. These projects also provide additional motivation as students can see the impact their involvement and profession can have on the lives of others. This paper describes how adapted physical activity design projects are used in four separate courses to enhance learning of the engineering design process, engineering analysis skills and experimental methods. Preliminary assessment results of this service learning pedagogy's effect on student attitudes, student motivation and student learning are reported.

Background

Assistive design projects have been used in Mechanical Engineering classes for many years (see Terpenny et al., 2001, Brackin and Gibson, 2002 and Widmann et al, 2009 for examples).[1,2,3] They provide open-ended design problems where students can fully explore all aspects of the design process and provide students with motivation to make a positive impact on their clients and society. When designing adapted devices for persons with disabilities, the students must consider the user, whose abilities and needs may be radically different from their own. Additionally, the user (or clients) with a disability often do not have a technical background; therefore, the students must fully develop the project's technical requirements by themselves. In contrast, sponsors of industrial based projects might formally give students a technical specification thus negating the need for the students to practice the important skills involved in requirements development. In the conceptual phase of the project, the students are forced to fully explore the possible solution space due the uniqueness of the problems encountered. For example, investigating the different ways someone with severe physical disabilities might throw a Frisbee provides a greater creative challenge than designing a piping and flow control system for an industrial sponsor. Additionally, students undertaking these projects must dig deeper in their patent and product research to find relevant ideas and products. Since these projects often involve radically new ideas, the students are better motivated to turn to conceptual modeling earlier in the design process to better understand the problem they are trying to solve and the efficacy of their concepts. Finally the students often need to start analysis early in the design process to assess the viability of their concepts. In these ways, adapted physical activity projects have the potential to motivate the use of a formal design process, the learning of which is typically a desired outcome of a design course. Furthermore, the students may be more motivated to engage in each step of the process since all steps will require careful consideration to achieve a complete solution that satisfies all the customer requirements.

In addition to providing a platform for learning design skills, students working on adaptive physical activity projects may also be highly motivated to improve the quality of life of a specific client who will benefit from the design. In this paper, the authors address the research questions: Do adapted physical activity design projects provide the opportunity and motivation for students to learn the mechanical design process, design analysis skills and can the projects be expanded to provide motivation in other parts of the Mechanical Engineering Curriculum?

In March 2008 the authors were awarded a Research to Aid Persons with Disabilities (RAPD) grant by the National Science Foundation entitled: Access by Design: Capstone Projects to Promote Physical Activity. This five year grant provides funding for undergraduate capstone design projects that allow access to recreational activities for persons with disabilities. Each year the grant provides funding for 10 separate design projects that are undertaking by mostly Mechanical Engineering, Computer Engineering, and Kinesiology students with occasional support from students from other engineering disciplines. The projects usually have specific clients with various levels and types of disability. Students working on these projects need to first understand the user's capabilities and then design solutions to allow the clients to gain a level of physical exercise using appropriate technology. Each project is completed using a formal design process and all designs are built, tested and ultimately given to the user.

The projects described in this paper have been undertaken at California Polytechnic State University, San Luis Obispo (Cal Poly). Cal Poly was founded in 1903 and is one of 23 campuses of the California State University System. Cal Poly is primarily an undergraduate institution with approximately 18,500 enrolled undergraduates and 1180 faculty. 5000 students are enrolled in the College of Engineering which is comprised of nine departments. The largest department, Mechanical Engineering, has approximately 1000 undergraduates, 60 Masters Students and 28 full time tenure and tenure track faculty. The department awards about 200 undergraduate degrees each year.

Curriculum Overview

Cal Poly's Mechanical Engineering program is anchored by a comprehensive curriculum that emphasizes fundamentals of engineering, laboratory "hands on" experiences and engineering design throughout the four year program. Students are admitted into the program as freshman and start their Mechanical Engineering classes during their first year and continue these classes through their senior year. Adapted physical activity design projects are used in two curricular threads. One curricular thread is in the area of Mechanical Design. Freshmen are introduced to the design process in ME134: Introduction to Mechanical Engineering. This is a laboratory class (weekly three hour lab meeting) where active learning (such as mechanical dissection) and design activities are experienced. In their sophomore year, the students take a course entitled ME234: Philosophy of Design where the students focus on applying the design process through the solution of open-ended design problems with a special emphasis on creativity and conceptual prototyping. In their junior year, students take two classes (ME328: Introduction to Design and ME329: Intermediate Design) which focus on the application of advanced strength of materials, fatigue analysis, and on the design, analysis and selection of machine components. Each of these junior level courses have a weekly three hour lab component where students solve open ended design problems in three or four-week projects (usually two per quarter). The last element of the Design thread is a full-year Capstone Design Project (ME428-ME430: Senior Design Project) where students design, build and test a solution to an externally supplied design problem.

A second curricular thread considered here is in Mechanics. After completing a mechanics course taught by the physics department, Cal Poly Mechanical Engineering students take ME211: Statics, ME212: Dynamics, CE204: Mechanics of Materials I and CE207: Mechanics of Materials II in their sophomore year. In their junior year, the students are required to take ME326: Intermediate Dynamics, ME318: Mechanical Vibrations and ME328: Introduction to design. In their senior year, they take ME422: Mechanical Control Systems. Students can choose to expand these threads in their senior year with a selection from a variety of technical electives. One example is ME410: Experimental Methods in Design.

Specific Courses and Associated Adapted Physical Activity Projects

This section describes in more detail the specific courses where students undertake the design and/or analysis of adapted physical activity projects and how the projects are integrated into these classes. The most extensive use of the projects is in the Mechanical Engineering, Computer Engineering and Interdisciplinary Engineering capstone design courses. They are also used in the Junior level machine component design class as four week conceptual design projects. In the sophomore dynamics class, the projects are used to motivate the learning of dynamics concepts and problem solving skills and finally the projects are instrumented in a senior technical elective course in experimental methods.

ME428/ME429/ME430 Senior Design Project

This full year (three quarter) course is a prototypical industrial-based capstone design classes (see Widmann and Mello, 2007 for details).[4] All projects have external sponsors who bring “real” world problems to the classes for teams of three to four students to solve through hardware-based engineering designs. Typically there are 60 different projects undertaken per academic year while about 10 of these are adapted physical activity projects. While the students work on their projects they are instructed about typical design processes that they are expected to apply in their work. The basic design process followed for all projects consists of:

- A *project definition* phase where students develop a list of requirements in conjunction with their sponsor to insure that the problem is fully understood and the user’s needs will be addressed in the design.
- A *conceptual design phase* where students creatively explore as many solutions to the given design task as possible.
- A *concept selection phase* where different ideas are evaluated and the best concepts are selected for detail design.
- A *detail design phase* where standard components are selected, detailed analysis occurs and drawings, schematics and software structures are created.
- A *manufacturing phase* where raw materials and standard parts are procured, custom parts produced, electronic circuits assembled and software created.
- A *testing phase* in which design requirements are verified and necessary modifications are made.

Deliverables for this class include a *Design Requirements Document*, a *Design Report* and *Critical Design Presentation and Review* with the project sponsor, a *Final Project Report* and hardware demonstration through a tradeshow-style *Senior Design Expo*. Student workload is typically high due to the open ended nature of the projects, the amount of detail work necessary and the iterative nature of the design process. Upon completion of the class, students should be able to:

1. *Apply a formal engineering design process to solve an open-ended, externally supplied engineering design problem.*
2. *Work effectively on an engineering team.*
3. *Develop, analyze and maintain an engineering project schedule using a Gantt chart and appropriate software.*
4. *Use Quality Function Deployment (QFD) to evaluate customer requirements*
5. *Formally define an engineering problem*
6. *Generate an engineering specification document.*
7. *Apply creative techniques to generate conceptual design solutions.*
8. *Apply structured decision schemes to select appropriate engineering concepts in a team environment.*
9. *Design subsystems within constraints of strength, size, materials, performance, cyclic loading, etc.*
10. *Evaluate potential design solutions through the use of engineering and physical science analysis techniques and tools.*
11. *Apply current industrial design practice and techniques such as DFX, FMEA and/or TQM to engineering design problems.*
12. *Construct and test prototype designs.*
13. *Develop and implement a design verification plan and report.*
14. *Communicate and present engineering design project results orally, graphically and in writing*
15. *Students will improve their ability to discuss and take a stand on open-ended topics involving engineering ethics and product liability*
16. *Discuss engineering professionalism and its responsibility to society*
17. *Understand the codes of ethics and their implications in engineering practice*

While the students are engaged in designing adapted physical activity solutions to their client's needs a service-learning pedagogy is employed. Service-learning occurs when "Students engage in community service activities with intentional academic and learning goals and opportunities for reflection that connect to their academic discipline" (Cress et al, 2005)[5]. Reflection is an integral part of learning and helps to develop critical thinking skills (Jacoby, 1996; Tsang, 2000; Tsang, 2002).[6,7,8] The development of these critical thinking skills enables engineering undergraduates to develop a broader appreciation of and ability to deal with the constraints facing the engineering profession and the ever changing world. Currently senior project design students are asked to reflect on their experiences in the form of monthly 500 word essays that respond to an instructor supplied prompt such as commenting on team experiences or on the experience of meeting their client.

Over the last three years, students have completed or are in the process of completing 32 Adapted Physical Activity Projects funded by the RAPD grant. Three examples of the projects are described in more detail below. A complete list of projects completed and used in Mechanical Engineering Courses can be found in the Table 1 along with the number of students and the courses impacted.

Table 1: Adapted Physical Activity Projects Completed in Mechanical Engineering Classes

Project Name: Description	Students	Date	Classes
Adjustable Sit Ski: Modular X-country ski machine for person with paraplegia	4	June 2008	ME428
The Universal Play Frame (UPF) Mk.V: Frame to attach to any wheelchair to allow mounting of other adapted “toys”.	3	June 2008	ME428
Frisbee Launcher Mk II: A Frisbee thrower attachment for UPF for playing adapted Frisbee golf.	3	June 2008	ME428 ME212
Rock n’ Bowler: UPF Attachment to allow adapted bowling for persons in motorized wheelchairs.	3	June 2008	ME428
UPF Golf II: UPF attachment to allow adapted golf for persons in motorized wheelchairs	3	June 2009	ME428
UPF Baseball: UPF attachment to allow adapted baseball for persons in motorized wheelchairs.	3	June 2009	ME428
UPF Soccer: UPF attached to allow “kicking” of soccer balls	3	June 2009	ME428 ME212
Power Soccer: Universal attachment to motorized wheelchairs to allow team-based soccer matches	3	June 2009	ME428
The Foot and Hand Cycle: An exercise machine for persons with limited muscle strength and balance difficulties.	4	June 2010	ME428 ME441
Performance Sit Ski: Adapted Cross Country ski machine for U.S. Paralympic Ski Team Athlete	3	June 2010	ME428
The Adapted Paddle Launch Vehicle: A vehicle to help a person with disabilities transport a kayak from a car and into the water and back out.	4	June 2010	ME428
The Strider: A exercise and mobility device to allow a child with Spinal Muscular Atrophy to move independently in an upright position.	3	June 2010	ME428
Foam Wars II: Motorized wheelchair enclosure to allow a version of adapted paintball	4	Dec. 2010	ME428
The Foot and Hand Cycle II: An exercise machine to allow adapted cycling design for a specific client	4	Dec. 2010	ME428
UPF Mark VI: A new Universal Play Frame with improved stiffness and ability to interface with more wheelchairs	3	Dec. 2010	ME428
Adapted Bocce: A device to allow an adapted version of Bocce Ball	72	Fall 2009	ME329
Adapted Darts: A device to allow an adapted version of standard darts	70	Spring 2010	ME329

UPF Attachment: The Frisbee® Launcher Mark II, completed June 2008

Student Team: Three Mechanical Engineering students in consultation with one Kinesiology student.

The Frisbee® Mark II is a specialty sports attachment designed for the Universal Play Frame (UPF) V; it represents a significant refinement of the first prototype (Frisbee® Mk. I, completed June 2007). The launcher, shown in Figure 1, attaches to the UPF and is designed to allow people with partial quadriplegia to throw Frisbees® and play disc golf. The Mk. II affords the user greater control over the Frisbee® as it is launched and provides much higher levels of safety for both the user and their assistants. This project was completed as part of the Mechanical Engineering Capstone Course and is in regular use by the Friday Club. The machine works in a similar fashion to a skeet launcher. A rotating plate holds the Frisbee. A helper loads the launcher with the Frisbee and winds the rotating plate, thus storing energy in a tension spring. The user can then orient the launcher in two planes to control the distance and direction of Frisbee flight. This is accomplished through the rotation of two hand wheels located in a convenient position for the user. Finally, the user can release the plate through a simple lever and launch the Frisbee.

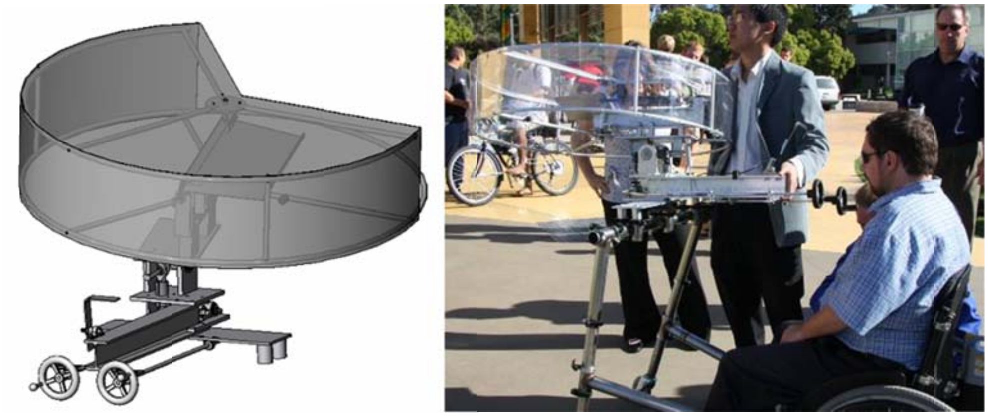

Figure 1: UPF Frisbee Attachment for adapted disk golf.

UPF Attachment: Soccer, completed June 2009

Student Team: Three Mechanical Engineering students in consultation with one Kinesiology student.

The Special Olympics identified the need for an attachment to the Universal Play Frame that allows people with disabilities to play soccer. A team of Mechanical Engineering students, the Frame Soccer Independent Engineering group, designed and developed a soccer attachment for the UPF Mk. V that allows users with partial quadriplegia to play soccer in the least restrictive environment. Athletes using this device are required to raise and lower a handle that is mechanically connected to a spring loaded bumper (Figure 2) via cable and ratchet wheel. The athlete aims the soccer ball in the desired direction and pulls a release lever to propel the bumper forward. The soccer attachment is designed to give the user control, exercise and the ability to play soccer from a wheelchair.

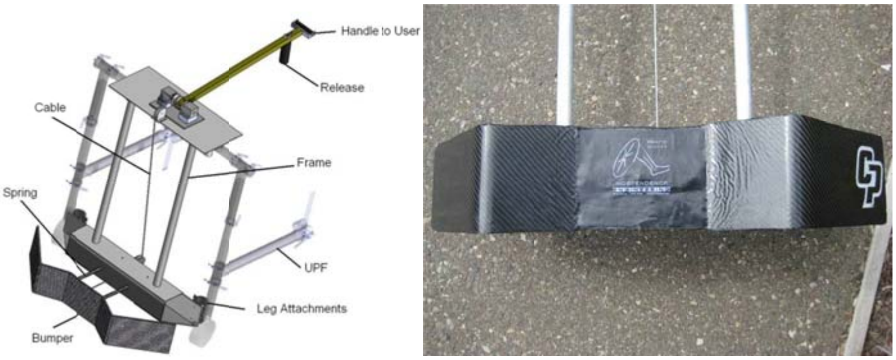

Figure 2: UPF Soccer Attachment for Adapted Soccer

UPF Attachment: Rock-n-Bowler, completed June 2008

Student Team: Three Mechanical Engineering students in consultation with one Kinesiology student.

The Rock n' Bowler (see Figure 3) is a specialty sports attachment designed for UPF. The Rock n' Bowler allows a person with partial quadriplegia to bowl. This device is a "high-end" attachment for the Universal Play Frame, giving the user a great deal of control over the spin and placement of the ball. Perhaps the most unique feature of the Rock n' Bowler is the powered spinning rail system that can be used to add spin to the ball. As the ball rolls down the ramp, it comes in contact with two rails spinning in the same direction that "hook" the ball. An electric motor from a cordless power drill was used to drive the rails because it allows the user to easily control the speed and direction of the rails in order to change the "hook" on the ball. The Rock n' Bowler is designed to give the user a feeling of inclusiveness when participating in the sport of bowling.

Figure 3: UPF Rock-n-Bowler Attachment

ME329: Intermediate Design

In this junior level class, students are primarily tasked with learning technical details about the design and analysis of various machine components such as shafts, gears and bearings and learning how to design systems using these elements. Students participate in weekly three hour laboratory periods where they work on small teams (3 or 4 students) to design systems with basic machine components. At the same time the students follow a structured design process similar to that outlined above, but more focused on the Conceptual Design Phase, Concept Selection and Detail Design and Analysis. Manufacturing in this class is limited to fast prototyping methods such as the use of foam board, Legos and other inexpensive and easy to use materials. Some typical examples of projects include the design of transmissions for wind turbines, small metal forming machines or prototype Martian rovers driven by DC motors.

During the last year, adapted physical activity projects have been introduced in ME329 to further motivate the use of a structured design process, bring more focus on concept generation and to increase student motivation. It also serves to introduce large numbers of students (the entire class of approximately 72 students) to a service-learning design activity. The two projects included were (1) the design of an adapted bocce game (Fall 2009) and (2) the design of adapted dart throwing machine as shown in Figure 5 (Spring 2010). In each case the students had four weeks to design and build a prototype machine that demonstrated the feasibility of their concept. The dart throwing project description is included in Appendix A for reference. In both cases students were given a fixed set of materials which included sets of Legos, a selection of DC motors and a set of rules. The teams could then augment this supply with inexpensive items as long as they did not exceed a certain total price. For each project, 24 teams of three students each developed a design and prototype which was tested. Results were documented by the teams in the form of a design report. In both classes, the students were involved in a second “paper” design project. The Bocce designers were tasked with designing a speed reducing power transmission for a wind turbine and the Dart throwing students next designed a small all-electric metal forming machine. In each case the students were surveyed regarding their attitudes about the projects after the course was complete. In the fall of 2010, senior design project student teams took on both the Dart throwing and the Bocce projects as full year efforts. These teams were given the reports from the junior design class as reference to begin their projects. In the case of the Adapted Dart throwing project, the student team all participated in the junior level dart throwing project and are highly motived to design and build a device to satisfy their client, the local Special Olympics.

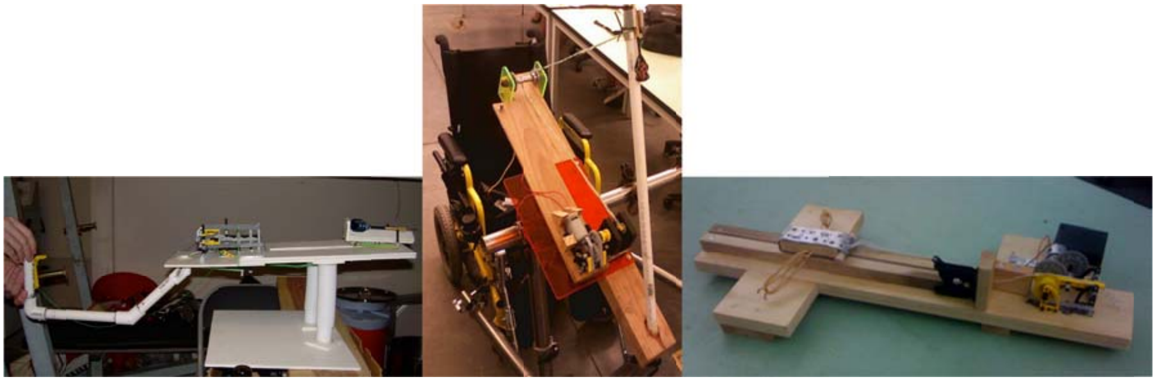

Figure 5: ME329 Adapted Darts Project Examples

ME212: Engineering Dynamics

As part of the engineering fundamentals portion of the curriculum, most engineering students are required to take a course in engineering Dynamics. This is a second year course, lasting one quarter that focuses on the kinematics and kinetics of two dimensional particle and rigid bodies. Historically this is one of the more difficult classes in a mechanical engineering curriculum with a relatively high failure rate. As part of a major restructuring of the course to include many active learning components (see Self and Widmann, 2010 for details),[9] and more “real-world” examples to motivate problem solving (a typical request of the students). Three of the adapted physical activity projects listed in Table 1 are now used as "real-world" examples in the class. These examples are used to motivate the discussion of course concepts and to provide relevant example and homework problems.

The first project, The UPF Frisbee launcher is used in class during the introduction to work-energy methods. A short video clip is shown in class to motivate a discussion of the design of the system and the rigid body dynamics consideration involved in the motion of the Frisbee and the sizing of the spring. The second example is the use of the soccer attachment to illustrate the use of a combination of particle motion kinematics and work energy requirements. This type of example problem shows the students the real-world application of dynamics principals used by their fellow students. Also included in the Dynamics course is an analysis of the Rock-n-Bowler. For this device, students consider the kinematic analysis of the rolling and spinning bowling ball, and the use of work-energy and conservation of angular momentum to analyze how the ball transitions from the ramp to the floor (see Figure 6). Instructor observations indicated increased motivation on the part of the students when they see how their peers (capstone students) have used dynamics principals as part of the engineering design process.

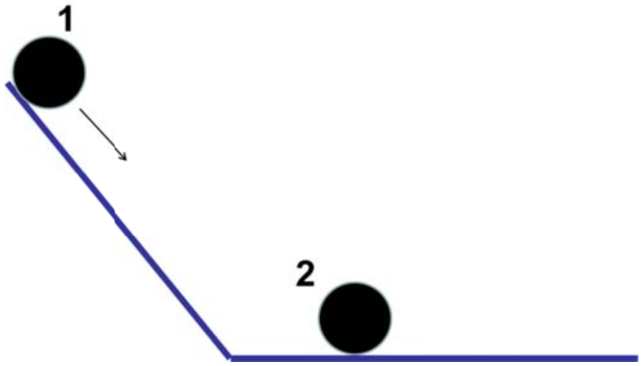

Figure 6: ME212 Dynamics Example Problem for Rock-n-Bowler

ME410 Experimental Methods in Mechanical Design

In this senior technical elective class, students learn experimental measurement techniques for static and dynamic systems including strain gages, accelerometers and photoelastic methods. Adapted physical activity projects are used as motivation for the laboratory portion of this class. In the lab students must design and implement their own measurement systems on a project of their choice. Capstone design students working on their senior projects are required to provide test data to verify their designs. The performance sit ski team (See Table 1) used their adapted physical activity project to measure strains in their frame and pole system to verify their structural design and obtain accurate load measurements (see Figure 4). In addition, they designed a tilt sensor for the pole. Using the synergy between the students senior design project and the experimental measurement class, students could clearly see the connections in their curricular experiences and were highly motivated to obtain good experimental results.

Figure 4: Sit Ski Experimentation in ME410

Assessment of Learning and Attitudes

A variety of tools are being used to assess the student outcomes in terms of the course goals, student motivation and student attitudes about persons with disabilities. The assessment of capstone design learning outcomes is accomplished through traditional means such as the quality of technical reports and presentations. Over the last three years there has been no significant difference noticed in the quality of design reports and/or hardware generated by teams in the class working on adapted physical activity projects and those working on projects not related to assistive technology as measured by the grading of significant course deliverables such as reports and presentations. Although analysis of the projects would indicate that the adapted physical activity projects provide an opportunity for developing project requirements, background research and the conceptual design phase, there is no evidence from these outcomes that this is occurring to a greater or lesser degree than other projects. One can show, however than often industrially sponsored projects come with a more developed set of requirements and therefore the students often neglect to evaluate and question these when they should.

Another measure is the degree to which the students find their projects interesting and motivational. It has been stated by others that students find that service-related projects provide higher levels of motivation[10]. While anecdotally this appears true with adapted physical activity projects, we are attempting the measure students' motivation in their capstone projects through surveys. Results of these situational motivation measures will be available at the end of this academic year. Also we are attempting to measure student design self-efficacy and what impact a adapted physical activity project will have on how the students self-assess their design skills.

The ME329: Intermediate Design classes were surveyed as to whether they found their adapted physical activity projects motivational, whether they helped them learn the design process and whether the projects improved their creativity skills. Tables 2,3 and 4 show the comparison of the student's responses for the two Adapted physical activity projects (Wheelchair Bocce and wheelchair darts) and the two more traditional projects (a wind tower power transmission and a metal forming machine). In general, the students found all four projects as interesting and motivational, and helpful in learning the design process and improving creativity skills. Overall averages indicate that the Adapted Physical Activity projects promotes to the use of Creativity skills to a greater degree than more traditional projects, but more study is necessary to confirm this.

Concerning the use of adapted physical activity examples in the sophomore level dynamics class as motivation to learning to apply Dynamics principles, the authors find that they often generate in-class discussions as to what a senior project looks like and what it means to design physical systems. In this way, they clearly grab the student's interest in a way that other "textbook" Dynamics problems do not. It is possible that the effect of seeing the efforts of fellow students increases the level of interest and the fact that their fellow students applied Dynamics principals in their designs lend added relevance to the topics.

Table 2. Subjective survey responses regarding motivation

	Strongly agree (5)	Agree (4)	Neither agree nor disagree (3)	Disagree (2)	Strongly disagree (1)	Mean
The Wheelchair Bocce Design Project was interesting and motivating.	6	5	2	0	0	4.31
The Wheelchair Darts Design Project was interesting and motivating.	6	16	3	0	1	3.93
The Wind Turbine Power Transmission Project was interesting and motivating.	5	6	2	0	0	4.23
The Stretch Forming Machine Project was interesting and motivating.	4	13	6	4	0	3.62

Table 3. Subjective survey responses concerning Design Process

	Strongly agree (5)	Agree (4)	Neither agree nor disagree (3)	Disagree (2)	Strongly disagree (1)	Mean
The Wheelchair Bocce Design project helped me learn to apply the engineering design process.	6	6	1	0	0	4.38
The Wheelchair Darts Design project helped me learn to apply the engineering design process.	7	14	4	1	1	3.93
The Wind Turbine Power Transmission Project helped me learn to apply the engineering design process.	4	9	0	0	0	4.31
The Stretch Forming Machine Project helped me learn to apply the engineering design process.	4	18	5	0	0	3.96

Table 4. Subjective survey responses concerning use of Creativity

	Strongly agree (5)	Agree (4)	Neither agree nor disagree (3)	Disagree (2)	Strongly disagree (1)	Mean
The Wheelchair Bocce Design Project helped me to improve my creativity skills.	7	4	2	0	0	4.38
The Wheelchair Darts Design Project helped me to improve my creativity skills.	6	18	1	2	0	4.04
The Wind Turbine Power Transmission Project helped me improve my creativity skills.	4	7	1	1	0	4.08
The Stretch Forming Machine Project helped me improve my creativity skills.	1	11	10	3	2	3.22

Lastly, we are interested in how the assistive technology context affects student development as conscious citizens. Specifically we are interested in how engineering students view those with disabilities and how the service learning experience might change that. An instrument, the Attitudes Survey on People with Disabilities is being administered to capstone design students before and after their involvement in the projects mentioned above. The students working on industrial based projects provide a control group. It is expected that student attitudes toward people with disabilities will improve more for those who work on the Adapted Physical Activity projects than those who do not. Preliminary results indicate that students identify a positive emotional benefit for working on projects to aid persons with disabilities. More data will be available at the completion of this academic year.

Conclusions and on-Going Work

This paper details the use of Adapted Physical Activity projects in four classes in Mechanical Engineering at Cal Poly. It is evident that service-based design projects that improve the lives of people with disabilities can provide a platform for attainment of the diverse set of learning objectives and student outcomes expected in these classes. It is the author’s intent to compare how students might benefit to a greater or lesser extent based on whether their project is an adapted physical recreation project versus more traditional industrial projects. Preliminary evidence from surveys of junior level students in a machine design class suggests that the students find the projects motivational and a platform on which to exercise their creative skills and learn the design process. On-going efforts for the 2010-2011 academic year include extensive surveys of the capstone class to measure design skill attainments, situational motivation and personal and professional growth (measured through thematic analysis of reflective essays). Lastly we will attempt to measure how working on adapted physical activity projects affects student development as conscious citizens.

Acknowledgements

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Appendix A: ME329 Adapted Darts Project

Adapted Darts

Background

Over one quarter of all Americans do not participate in any leisure time physical activities, and over one half do not meet the recommended 30 minutes of moderate physical activity at least five days per week (CDC, 2005). The World Health Organization estimates that 60% of people worldwide do not meet this exercise requirement. This lack of physical activity has major ramifications on the overall health and mortality rates of the nation and of the world (Warburton, et al 2006, Bauman, 2004, and Hu et al, 2005). Research has shown that increased physical activity leads to reduced risk of numerous health problems, including obesity, cardiovascular disease (Wannamethee, 2001), Type 2 diabetes (Tuomilehto, et al., 2001), hypertension, cancer (Thune and Furberg, 2001), and musculoskeletal disease. There is also evidence that "moderate regular exercise should be considered as a viable means of treating depression and anxiety and improving mental well-being in the general public" (Fox, 1999).

The effects of minimal physical activity are justifiably of concern, but there is an even greater impact on the population of persons with disabilities. Over a decade ago the link between physical activity and disability was seen as an emerging national priority (Rimmer, et al, 1996). Recent reports state that 53% of US adults with disabilities exhibit a lack of "leisure physical activity" as compared to 34% of those without disabilities. Additionally, 42% of adults with disabilities are affected by obesity as compared to 28% of adults without disabilities (CDC, 2005). Factor in the nearly 50 million Americans who have a disability and the numbers become staggering. Of these, over 42% have a physical disability (Waldrop and Stern, 2003). Cleary, there is a need for carefully engineered assistive devices to enhance access to recreation for these individuals. The project outlined here will help educate the community on the issue of engineering greater access to recreation for people with disabilities and will clearly benefit people with disabilities who use the equipment.

1.2 Benefits of Adapted Physical Activity

Physical activity is beneficial in a myriad of ways, but for people with disabilities the benefits are potentially even more profound. In addition to the obvious cardio-respiratory endurance and weight control benefits, physical activity has a number of other social-psychological benefits. Many of these widely acknowledged benefits of physical activity directly counter the impact of disability. For example, people with disabilities are predisposed to having low self-concept, poor self-image and low self-esteem, all of which may be countered through physical activity (Sherrill & Tripp, 2004).

Many people with disabilities live in some degree of social isolation and develop strong feelings of isolation and exclusion, which can be reduced by facilitating their inclusion in physical recreation (Klapwijk, 1987). Participation in physical recreation has the potential to reduce isolation and foster new friendships, which in turn can help maintain the individual's participation. Extending an individual's social support network of friends and family is critical to promoting long-term inclusion in adapted physical activity settings (CDC, 1999). This is echoed in the multi-year Project Shake-It-Up program focusing on health promotion and capacity building through adapted physical activities (Block, et al, 2005).

Adapted physical activity offers many psycho-social benefits for both persons with and without disabilities. Participants in adapted physical activity report feeling that they are no longer viewed as being disabled (Goodwin, Thurmeler, and Gustafson, 2004). Adapted physical activity also affords persons with disabilities the opportunity to increase self-awareness, to gain pride in their accomplishments and to self-explore through exercise. Moreover, individuals without disabilities tend to view persons with disabilities differently when they are seen participating in physical activity. They are viewed as actively engaged "outside of the illness metaphor" (Goodwin, Thurmeler, and Gustafson, 2004 p. 392).

Adapted physical activities also offer significant health benefits. People with disabilities are at a greater risk of being obese than the broader population of the United States (Rimmer, 1999; Rimmer and Wang, 2005; Liou, Pi-Sunyer, and Laferrere, 2005). Finding ways to encourage and facilitate increased physical activity is clearly an essential component of combating this tendency. People with disabilities can also realize health benefits to a more profound degree than the population without disabilities. If a disability impacts an individual's muscular endurance or coordination, exercises designed to increase muscle strength or improve coordination are potentially even more beneficial (Klapwijk, 1987).

1.3 Goal of this Project

In 2007 a group of xxx xxx professors received a Research to Aid Persons with Disabilities (RAPD) grant from the National Science Foundation to work with undergraduates students to design and build devices to allow persons with various physical disabilities engage in physical activities. The basic goal of this project is to product a prototype of a dart playing machine to be used by a person with very limited physical ability. It is anticipated that the user will be in a wheelchair and that they will have only the ability to activate one or two switches and move a single hand with a range equal to a 6 inch sphere. This prototype will be useful background information for a group of Xxx xxxx students who will design a complete working system for their senior project starting in Fall 2010.

There are many difficult aspects to a project like this that require research and development. You will be placed in design teams of three (**3**) members to design and build a functional prototype of the "throwing" part of the concept. The intent is to present this design to the Senior Project team for further development. Since the RAPD grant team will be interested in further development of the "best" systems, each design will be rated for performance on a standard scale which combines cost, weight, energy consumption, accuracy and overall aesthetics (a.k.a, a "coolness" factor).

Your conceptual prototypes will be built using LEGO® Technics gears – a solution not infrequently used in industry for concept prototyping of machinery, mechanisms and manufacturing systems along with the motors that we tested in lab #2. LEGO® gears and pulleys are of high quality (tolerances to a few ten-thousands of an inch), relatively inexpensive and obviously easy to assemble. You will augment these kits with the motor(s), batteries and other inexpensive items of your choosing. You may not use other gears or other motors in your design as we are trying to design a build and low-cost prototype using materials on hand.

Detailed Project Description

Teams of three students will design test and document small, lightweight machines that when given a standard electrical switch input or a low force mechanical switch will throw a dart at a dart board target. The board will be located according to standard rules of darts which means it will be mounted 5' 8" from the floor and the oche (that is the name of the line the thrower must be behind) will be 7' 9" from the wall. The user should be able to aim the mechanism (two angles) and activate the "throwing" of the dart. The use should not have to hold up the weight of the device.

The location of final testing will be in room 192-120. Performance scoring will be based on (i) total points for 3 dart "throws", ii) its cost, iii) how much energy it consumes during a throw and iv) the "coolness" or elegance of its design. Note that the design should be appealing to the user (the person with a disability) and promote inclusiveness. This means that the user while using the device should feel, as much as possible, like they are an equal participant in a dart game as an able-bodied player. More information and videos about the game of darts can be found at:
http://www.tradgames.org.uk/games/Darts.htm
http://www.youtube.com/watch?v=EWO73_tfY30
http://www.youtube.com/watch?v=9P6OuWk4uQg&feature=related

Teams

Students are pre-assigned to teams as noted near the end of this document Teams were formed based on the students' problem solving preferences indicated by their MBTI numbers.

Materials for prototype

Each team will be given a motor of their choice from those tested in the lab. LEGO gears and other parts can be "purchased" from the lab and will be included in the total project "cost". No "purchases" during week #1. Note that cost totals will be generated from the final prototype's bill of materials and self reported by the team. **All parts from the lab are considered "borrowed" and must be returned at the end of the project in good condition for future ME329 students.** Each gear has an estimated "cost" of $0.05/tooth and other Lego parts cost $0.10 each. You may also purchase and use other low-cost items (e.g. springs, rubber bands, tape, batteries, switches, other Lego parts, Rapid Prototyped parts, etc…) provided you do not exceed a limit of $25. Any additions must be described and cost accounted for in your design documentation. You are required to use Lego gears and the provided motors. In other words you cannot use a different motor or other gearing system.

Power Supplies

Each machine must be only receive input through an electrical switch or switches and must therefore have its own battery pack. This is a major design consideration and should be taken into account from the outset of the design. As with the motor, you must select your electrical power storage medium to the match the machine requirements. The choice of batteries and any accessories such as a battery case and on-off switch is up to you. You are responsible for obtaining them and wiring them up. (Radio Shack is a good place to look as well as internet sources).

Testing Your Design

I will bring a soldering iron and multi-meter to the lab for your use.

UPF – Universal Play Frame

Your design must attach to the UPF. This device will be brought to lab. It was designed by Xxx xxxx students and is used by the local Special Olympics to attach various adapted recreation devices. Already we have golf (shown above), T-ball, a Frisbee Launcher, a Soccer kicker and a Bowling attachment. The dart thrower will be the next attachment.

The Design Process

It is up to your team to set up and follow a schedule based on the following design methodology.

1) Customer Requirements, Specification Development and Project Planning
2) Research and Conceptualization
3) Conceptual Model Building
3) Preliminary Analysis and Layout
4) Prototyping
5) Design Refinement and Final Assembly.

Team members will share the same score for this project so be sure to check each other's work.

Deadlines

April 15th in lab: Meet your team, Develop Project Plan, List Customer Requirements and generate engineering specifications. Review with me. Begin Conceptualizing
April 22nd in lab: , Continue concept work and build a foam-core concept model. Start preparing your Conceptual design descriptions (see instructions below).
April 29th in lab: Furlough Day: Continue working on project.
May 6th: Turn in Design Documentation, Short Presentation and Prototype testing: Times TBD

Conceptual Design Document (Due April 26th in class, 15% of Project Grade)

Turn in a brief, formatted document with:

1) The detailed project schedule and your current status.

2) An annotated sketch of your proposed approach and an explanation of how it will work. Also a discussion of any major design issues or concerns that may affect the performance of your design should be included.

3) A list of major components that you expect to use (motor, gears, pulleys, batteries, linkages, etc…).

4) Description of any transmission that you anticipate on using including the number of stages on the transmission ratio for each stage. Each gear or pulley pair is a stage, also describe any linkages and their function.

Design Presentation (In lab, May 6th, 25% of Project Grade)

Assume that you have been asked to present your prototype to your management at a small startup company that is vying to become the producer of these machines. You need to convince them that it is worth investing the money to continue with product development. You will have 15 minutes for your presentation and demonstration. You will probably want to use PowerPoint with drawings or sketches to get the main points across. Your presentation should be well organized (each person is required to speak approximately 1/3 of the time). Your presentation should answer the following questions.

1) What is the main design principle or approach behind your machine? How does it work? Why and how did you pick this approach? What is your design rationale?

2) What motor and power source did you pick and why?
3) How much do you anticipate your machine will weigh?, cost?
4) How accurate do you think your dart throws will be?
5) How much power will it consume for one throw?

Performance Run-off (Immediately after or as part of your presentation' 25% of Project Grade. Times to be announced)
The performance testing will be organized as follows:

1) Each machine will do three tosses and the points will be recorded.
2) After the three tosses, each team will move their project to the power measurement station. There the terminal voltage from your battery pack and the current will be measured while preparing for a dart toss. The power (Volts x Amps) will be multiplied by the elapsed running time of the motor as discussed under **Performance Scoring.**

Performance Scoring (the following percentages relate to the performance)

1) Successful tossing of a dart > 2 ft (5%)
2) Total Dart Score (10% normalized to highest score in all lab sections)
3) 1/(Total Energy Consumption*Cost) for a throw. (10%)
This score is based on your ranking within all lab sections.

Check with me before you attempt a "loophole" design. Remember that the purpose of this performance test is to compare legitimate solutions for the future dart throwing senior project. Anything inconsistent with that goal is likely to be discouraged.

Final Design Document (Due on May 6th, 35% of Project Grade)
This should be a brief report that describes the overall design with the help of clearly labeled drawings and notes. Among other things, it should address the following kinds of questions:

- Why did you adopt the design, motor choice, and transmission choice that you did? For example: if you used a 2-stage belt drive or a single stage worm gear drive, why did you do it.
- Also, in what ways, if any, did you modify your design from the conceptual design document?
- What is the overall input/output ratio of your machine's drive system? Also, for each stage of your transmission, what is the type (worm gear, spur gear, bevel gear, belt and pulley, friction drive, etc.) and transmission ratio?
- How much does your machine weigh?
- How much electrical power does your machine consume for a dart throw?
- Based on your above answer + the given data regarding the motors + your own intuition, where do you think the main sources of power loss are?
- If you had to design a second version that what kinds of design changes would you consider? (Assume that you would not be restricted to LEGO components and the DC motors)
- What is the major factor that I should consider in determining the coolness" factor of your design (what are you most proud of)?

The final design documents should be self-explanatory and sufficiently complete for somebody else to re-create your design. Engineers often think that their documentation is more "self-explanatory" than it really is. Usually it takes much more explanation that you think!

Grading

As with any real engineering project, the overall grade will reflect a combination of design, performance and presentation quality. Also don't forget that the real purpose of this exercise is to gain experience in using mechanical elements in design and to have fun. Remember, failure often teaches more than success, so don't hesitate to be creative!

Appendix A

Teaming for DP #1

The project is to be completed in teams of 3 (except team #9) as shown below

Lab Section -03 8-11 am (Note that one team will have two members)

	Team Member #1	Team Member #2	Team Member #3
1			
2			
3			
4			
5		Names Removed for ASEE	
6			
7			
8			
9			

Lab Section -04 12-3 pm

	Team Member #1	Team Member #2	Team Member #3
1			
2			
3			
4			
5		Names Removed for ASEE	
6			
7			
8			
9			

Lab Section -05 3-6 pm

	Team Member #1	Team Member #2	Team Member #3
1			
2			
3			
4			
5		Names Removed for ASEE	
6			
7			
8			