Teaching Design using a Pharmaceutical Tablet Crusher Case Study

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Abstract - *The University of Waterloo Cases in Design Engineering (WCDE) group developed a case study on the design of a medical device used to crush pharmaceutical tablets. Intended for use in Long Term Care Facilities, the 'tablet crusher' addressed a clear need identified by a consultant pharmacist. The case outlined the design need analysis, the path taken to develop creative alternatives, and the steps to convert this design to a commercial product while highlighting business and technical challenges.*

This case was designed to complement subject matter within several engineering courses on campus and inspire entrepreneurially-inclined students. It has been applied in several academic settings to address several levels of education. In each implementation, the case served to demonstrate the engineering design process, and was specifically tuned for different audiences and delivery formats – ranging from single sessions to weekly expositions.

Case development will be discussed, but the main focus of this paper is the various ways in which this case was implemented, and the corresponding student reaction to this form of teaching.

Keywords: Case Study Implementation; Commercial Product Design; Design Process, Mechanisms.

1. INTRODUCTION

The use of cases for effective learning and teaching has a long history. The Harvard Business School has used cases for many decades and cases are now widely used in a variety of disciplines. In Canada, the Richard Ivey School of Business at the University of Western Ontario has taught and produced cases since the 1920s. [1]

The Waterloo Cases in Design Engineering Group (WCDE) at the University of Waterloo (UWaterloo) was formed in 2005 [2] to write engineering based cases and support the integration of these cases into the Engineering curriculum.

A member of the WCDE group (Baleshta) incorporated a company in 1993, Nordac Design Inc., to

design and commercialize medical products. One Nordac Design product, a pharmaceutical tablet crusher for use in Long Term Care Facilities (LTCFs) was regarded as well suited as a written case study. In practice, engineering design cannot be separated from commercial issues, and the design of this tablet crusher was framed within this actuality. The product was commercialized and these devices are still being used daily in LTCFs. This case [3] has strong potential for application in several engineering courses and for different fields of study.

2. CASE STUDY

The contact person for this case was a consultant pharmacist who worked for a company that supplied medical items to LTCFs [3]. During the initial, exploratory interview she identified the need for an improved tablet crushing device for use in these facilities. Residents in LTCFs receive medication 3-4 times each day but have trouble swallowing their medication in tablet form. Their medication was typically crushed and then mixed with another medium (e.g., applesauce) to ease ingestion.

The prevalent crusher styles at that time were the classic mortar and pestle, twist-style crushers, and lever-based devices. There were considerable problems perceived with these devices, the foremost being noise. Medications were prepared at the resident's bedside or in the cafeteria, where the pounding noise during tablet (pill) crushing could easily be heard by nearby residents and was a significant source of agitation to them. The numerous repetitions required to crush pills was also a source of repetitive strain injury for the LTCF staff administering the medication. Certain "harder" pharmaceutical tablets required a significant amount of force to crush. Studies of crushing force on tablets were performed at UWaterloo [4] and it was discovered that a crushing force as high as 150N was required, with one exceptionally hard tablet requiring 1.3KN (300 lbf).

To assess the commercial demand for this device, the amount of tablet crushing was approximated from the number of resident beds in the Kitchener-Waterloo region and then extrapolated nationally. This resulted in a

staggering 900,000 pills per day. Also, Long Term Care Facility staff was interviewed and they confirmed the need for an improved crusher.

In keeping with the WCDE case format, the tablet crusher case was written in the form of modules. The first module introduced the primary contact, cited the problems with existing pill crushers and the need for an improved design. This initial module was similar in nature to the Ivey Business School Case Study format [1]. Subsequent modules outlined the design progression, including prototype testing, and commercial release of the product. The commercial device is shown in Figure 1 and a module summary is shown in Table 1.

Figure 1: Pharmaceutical Tablet Crusher

Table 1: Tablet crusher case modules

#	Module Title	Content
1	Case Study (Introduction)	Consultant Pharmacist Interview; Need for an Improved Crusher; Existing Crushers
2	Needs Analysis	Design Requirements, Criteria, Constraints
3	Conceptual Design	Morphological Box; Design Alternatives; Decision Matrix
4	Final Design	Component Functions; Materials; Operation
5	Prototype & Commercial Manufacture	Prototype Fabrication & Evaluation; Volume Manufacturing
6	Problem Areas and Design Revisions	Use & Abuse in LTCFs; Piston Separation; Side Plate Wear; Ergonomics
7	Business Aspects	Wholesale & Retail Costs; Sales & Advertising; Profit Margin; Final State of Product

Completed in 2011, the case found its first application in MTE380, Mechatronics Engineering Design. It has since been applied and repeated (in some cases) in ME321, ME100, MTE100, and PHARM 321 courses, as well as the Waterloo Unlimited program. Table 2 shows a breakdown of case implementations in these courses.

Table 2: Tablet crusher case study implementation

Course	Class Size	Teaching Objective	Impl .	Case Hours
ME100 Mechanical Engineering Communication & Professionalism	110	Introduction to Engineering Design	4	2x1
MTE 100 Mechatronics Engineering	125	Design Process	2	2.5
ME321 Kinematics & Dynamics of Machines	116	Mechanism Design Example	2	.75
ME380 Mechatronics Engineering Design Workshop	92	Design Process: Alternative Generation	1	2x1.5
PHARM 322 Clinical Application of Pharmaceutical Sciences	110	Trans-disciplinary Design Exposure	2	2
WATERLOO UNLIMITED	15	Introduction to Design	2	1.75

3. RESULTS AND DISCUSSION

The case was implemented in six separate courses. All instructors, course coordinators, and/or program directors involved with the case implementation were interviewed regarding the outcomes using the following questions:

1. Teaching objective: why was this case study an appropriate fit for your course?
2. How was the case presented to students; what concepts were covered?
3. What was the class size?
4. What was the student reaction to this experience?
5. What was your opinion of the strengths and weaknesses of this approach?

The following discussion summarizes and reflects upon the answers to these questions.

3.1 MTE 380 Mechatronics Engineering Design Workshop

MTE 380 was taught to 92 third-year mechatronics engineering students in Winter 2011. A significant part of this course is learning the engineering design process [5]. This process includes a study of needs analysis, problem definition, design criteria, generation of alternative solutions, conceptual design, detailed design, optimization, and implementation. The course includes a major design project set by the instructor. Student groups apply the design process and compete with other student groups within the class to complete the project. Design projects traditionally include construction of an electro-mechanical prototype, and the course grade largely depends on the performance of this prototype during an end of term competition.

Although the pill crusher was not, in its commercial form, an electro-mechanical device, it was seen by the instructor to be “a very suitable mini-project”. Students could apply the design steps to evaluate existing solutions, followed by the generation of new, improved alternatives for an actual engineering system.

The case was implemented over two 1.5 hour tutorial sessions. Students were divided into groups of four and given a quiz at the beginning of the first session. This was to test the groups’ initial understanding of the pill crusher case, titled “Why a pill crusher?” The groups were asked to identify problems with existing solutions (excessive noise, repetitive strain injury and sufficient force). They were also asked to provide an overview of existing pill crushers and prioritize key design requirements (high crushing force output, quiet operation, reduced risk of operator repetitive strain, accommodation of the pill cup medication stack, and economical operation - maximum

retail cost set at \$125). A conceptual sketch of the commercial device was also shown to each group, which included a listing of fundamental component links and joints of the triple pivot mechanism (Fig 2). Students were required to critique this design choice. Following the quiz, the commercial pill crushing device was circulated, and a class discussion ensued for the remainder of the tutorial. The class was challenged to collectively identify possible areas of improvement to the existing mechanical design.

Figure 2: Tablet crusher conceptual sketch & components

The quizzes were graded by the instructor and returned the following week. At the start of the second session, groups reviewed their graded quizzes, considered comments from the previous week’s discussions, and were given time to revise their initial answers accordingly. The second session concluded with group presentations of their proposed design, subjected to instructor and peer review.

Specific student feedback was not collected but the instructor did receive general feedback that was “very positive”. Class participation was 100% in both tutorial sessions, which was seen by the instructor as a positive indication of student engagement. Due to this “overwhelming participation” the plan was revised to present the design revisions in the second session.

Student quiz responses, such as “hospitals do not like exposed surfaces because they are difficult to clean” exhibits insight that does not typically stem from textbook

style problems. When shared with the class, an appreciation was gained by all for the less obvious, but often very important, aspects that must be considered in design.

The instructor reported that the case was a “very effective and compact exercise to train students on the generation of alternatives and improving an existing design.” He felt that this case could have been of more use if it had been integrated into the weekly lecture content of the course. The case modules (needs analysis, conceptual design, design limitations, design alternatives, dynamic modeling and simulations) could be introduced as a weekly lab exercise after the related design topic was covered in the classroom.

3.2 ME321 Kinematics and Dynamics of Machines

ME321 is taught to third year mechatronics engineering students. Students are introduced to the synthesis and analysis of mechanisms and machines to provide desired motions and complete intended tasks. The instructor indicated that these topics are critical to the subject of machine design. The course also includes computer-aided mechanism design and analysis processes [6].

The pill crusher case was implemented during the winter terms of 2012 and 2013 to help teach students the engineering design process as it relates to machine mechanisms. The use of this case was deemed appropriate by the instructor as it included many of these design elements and was mechanism based. (The triple pivot mechanism used for this medical apparatus was inspired by sheet metal piercing tools.) It was seen as an interesting example for student study. “It was actually students (familiar with the device) who suggested that the pill crusher be used as a teaching tool in this class.”

The case was implemented as a teaching demonstration. The sessions began by describing the various steps of a typical design process, including type and dimensional synthesis, for mechanisms/machine applications. The commercial tablet crusher was presented to demonstrate its operation. It served as an example of a “practical system which takes advantage of a simple mechanism to provide an efficient solution to a real-world engineering design problem.” The tablet crusher was then circulated among the students so they could closely study the relative motion between parts and see how the device worked. A class discussion of this design followed. The sessions ended by introducing an applied design project for a specific application.

This experience aligned well with the topics covered in the course, especially kinematics of machines and type synthesis. The pill crusher case motivated students to consider simplicity and desired functionality in design. Student feedback was not formally obtained but the

instructor noted that students wanted to know about real-life design problems and see practical examples.

The large class size and physical layout of the classroom were cited as obstacles by the instructor. Space constraints prevented separation into groups. The instructor felt that introducing a laboratory component to the course would allow the measurement of the angles and linkages of the commercial crusher. Its motion could be analyzed based on the techniques and simulation tools discussed in class. This would improve the use of the tablet crusher case and challenge the students with a higher level of analysis.

3.3 ME100 Mechanical Engineering Communication and Professionalism

This course contains a myriad of subjects, intended to provide new mechanical engineering students with the basic skills/tools needed to succeed in their courses and in their work term jobs. Topics include ethics and professionalism, workplace safety, oral, written and graphical communication, error analysis, and engineering design [7].

The tablet crusher case study was implemented in ME100 during the Fall terms of 2011 and 2012. The exercise was presented to two separate classes of 100-120 students each term. The teaching topic was the engineering design method. The instructor (Collins) decided that an effective teaching approach would be for students to progress through the design steps for this product and at the same time reinforce their learning by showing an example of how this was actually conducted.

The learning objective in using a case-study was for new engineering students to learn and then directly apply the basic steps of the engineering design process. The instructor opted to use the tablet crusher for a number of reasons. To begin with, the case developer (Baleshta) was also an instructor for this class and was known to the students. This personal connection to the project seemed to foster greater interest from students. The subject matter did not require a deep engineering background in order for students to participate. It was simple enough in concept that first year students had the skills to devise design alternatives. At the same time, it was a product that students had likely never seen before, so they had no preconceived ideas of how such a device would work. Since the resulting tablet crusher is real commercial product, the instructor was able to show the class the final implemented design. At the end of the exercise, the real product was revealed.

The pill crusher was presented to the students over two 50 minute lectures. The first session commenced with a lecture on the engineering design process, and the class was made aware that engineers use many approaches to develop solutions to engineering problems. Basic engineering design steps were presented. During step one,

Needs Assessment, the problem was defined and the class was told that there was a real product need, and the tablet crusher case was introduced. The class was told that a LCTF has approached them with a request for a better way to crush pills. The needs of the LCTFs were outlined, along with a review of current approaches, and their deficiencies. It was emphasized that this was a real situation.

The class was then introduced to the idea of a Problem Statement. They were asked to work in pairs to write up their own problem statement based on what they were taught. Then one statement (volunteered by a student pair) was displayed to the class. The students compared it to their statements, made suggestions, and the instructor revised the displayed statement. Once the instructor was satisfied with the results they were shown the problem statement from the case study.

Requirements, Constraints and Criteria were next defined, and students developed case-specific examples of each. These were also discussed as a class. When the instructor was satisfied, the actual case study requirements, criteria and constraints were presented. In the words of the instructor "it's a good exercise; students see what they have missed, and they even come up with specification that they feel were missing from the case study."

The Conceptual Design stage of the design process followed, beginning with Synthesis. The "think-pair-share" method was employed as a teaching tool. The class was given 5 minutes to conceive an idea on their own. They then "paired up" and shared their idea with a classmate (2 minutes). Finally, they were arranged in groups of 4-5 and asked to brainstorm. Each group was asked to select one concept, and complete a quick sketch and description. The instructor circulated around the room, offering advice and encouragement. Instructor feedback was that engagement was very high at this point: the students "just seem to really get into it." Their concept sketches were submitted at the end of the first lecture.

Between the first and second lectures, the instructor sorted the concept sketches into groups based on common design aspects (6 to 7). The best 3 examples were scanned for subsequent presentation.

At the start of the second lecture, a brief review of the previous week's work was presented. This was followed by introducing the concept of using a morphological box for component selection. The instructor developed the morphological box with the class (on the board) using their designs. As usual, this was followed up with discussion of case study design concepts.

The Conceptual Design process continued with a Design Evaluation. The classes were introduced to weighting and evaluation schemes with an emphasis on their relationship to the chosen design criteria. The evaluation scheme was then applied to the morphological

box, and the students were required to select a winning design concept. The winning group was asked to stand and take a bow.

The remaining steps in the design process cannot be done by the class, so at this point the instructor switched to presenting the case study design. The instructor worked through implementation, testing and validation, and the class was shown the final recommendations. The iterative nature of the design process was reinforced.

The instructor felt that students responded well to this case-based exercise. They became very much involved in the process. Very high participation rates and high levels of class excitement were evident. Students had a lot of fun, especially when they saw their ideas presented to the class. The instructor further noted that students mentioned this exercise during later terms, which reflects upon its impact.

When reporting on the perceived weakness of this approach, the instructor noted that large class sizes were an issue. The rooms were crowded and more space for groups to spread out and work comfortably would be useful. The case implementation was covered over two lectures but "three sessions would have been better if we had the time."

When receiving class input (problem statement, constraints and criteria, etc.), the instructor had to be careful not to lose control of the class. This was seen to be particularly challenging during the weighting of the design criteria. It could degenerate into a (good natured) shouting match as students would heckle one another over the relative weightings and scores used in the evaluation. The instructor used this to point out the subjectivity of weighting schemes to personal opinion, and the variability inherent in the approach.

Direct student feedback was solicited (April 2013) from a small group of students who had experienced this exercise in ME100 during the Fall 2012 term. They reported that the case study was a good fit for the course as it covered what they would be doing professionally in the future i.e., "solving problems restricted by criteria and constraints." They saw it as an example that was "100% practical" as this case study stemmed from a real problem. It was a good fit as students "really enjoy and want more practical examples." They found the instructor engaging and saw humour in the more creative and comical designs. The students were quite proud when their designs were presented to the class.

Group work was stated to be a highlight experience as they received different points of view and very interesting ideas from the other group members which allowed them to build stronger class relationships. They felt that this approach was very effective. Other comments: "it efficiently showed the design process and tools," "the knowledge is very practical to engineering of any kind" and "there was general excitement when we designed our own pill crushers." A perceived weakness was that some

group members were more vocal and had more input than the shy members of the group, and that time constraints coupled with group size rushed the selection of the best designs.

3.4 MTE100 Mechatronics Engineering

MTE 100 is an introduction to the mechatronics engineering profession, taught to a class of from 120-140 first year mechatronics students at UWaterloo. Topics include the design process, project planning, data presentation, measurements and error, control logic, sensors and actuators, intellectual property and engineering graphics. A mechatronic design project/competition with small groups supplements the lecture material [8].

The pill crusher case was used in a single 2.5 hour session during the Fall Terms of 2011 and 2012. The teaching objective was to reinforce the design process introduced early in the course, as well as the design topics (design simplicity, lateral thinking, technical sketching, computer aided design and aesthetics) covered in the graphics component of the course throughout the term. As with ME100, this case was deemed by the instructor (Baleshta) to be simple enough for the students to understand and make contributions in response to teaching the design path. It was also seen as an enjoyable and creative means for students to conclude the term by reviewing the development of an actual commercial design and devising their own solutions.

The MTE100 sessions commenced with an introduction to the WCDE group and their case-based teaching goals. Next, lead-in topics included the difference between a “basement inventor” and a professional design engineer, the need for innovative design in Canada (Canada’s Innovation Decline) [9] and the unique position of engineers to see and act on opportunities for innovation. A question was asked of the students: “Who in this class has an idea for a product or service that they may like to commercialize at some future date?” The intent was to heighten student engagement and to foster entrepreneurial interest using the case study.

Following this introduction, the engineering design process was presented. This process was based on the text by Voland [10]; the same design process forms the basis for the capstone design project course required for mechatronic engineering students in their final year of study. A five stage design path was shown: Needs Analysis, Problem Formulation, Abstraction and Synthesis, Analysis, and Verification. Due to time limitations and the level of student engineering knowledge at this stage in their education, only the first three steps of the design path were covered during this session.

The implementation of the case was similar to ME100. Both course instructors shared information and presentation materials. There were, however, some differences. Instead of the think-pair-share approach, students were immediately set into groups of four. Groups worked on the progressive steps of the design cycle and were shown (as in ME100) the actual results from the case following their efforts. The MTE100 case study implementation included the market feasibility analysis quantifying the amount of pill crushing, and the need to consider both technical and non-technical aspects of a design. Urinals are used as a light-hearted ancillary example, where the plumbing works well but the poor human interface can lead to other problems. Also explained were basic business concepts of margin vs. markup and its effect on the product’s commercial viability, and a rule of thumb for wholesale vs. retail pricing. These are of fundamental importance when designing for commercial applications, based on the experience of the instructor.

The MTE100 rollout did not have students develop a morphological box, but an example was shown and the concept explained. The student groups used a decision matrix to choose a design from the two design alternatives that they were challenged to generate during the session. This differed from the “best designs” chosen by the instructor and class in ME100. A representative from each student group was invited to present their chosen alternative at the instructor podium, while displaying a sketch of this result to the class at large, Figure 3.

Feedback following the MTE sessions was not formally solicited, but the instructor observations paralleled ME100 in that student engagement was generally high and students were proud to display their serious (and humorous) results.

Figure 3: Students Presenting Selected Design Solutions

Students were very interested in the hands-on trial of the existing commercial device. The instructor also found

this to be an opportunity to communicate accrued practical design experiences and knowledge within the context of this case-based session.

3.5 PHARM 322 Clinical Applications of Pharmaceutical Sciences

This course presents leading edge discoveries in the pharmaceutical sciences. Students are required to define the clinical application of these discoveries and integrate information from multiple disciplines to develop strategies to solve fundamental health care problems [11].

In the spring terms of 2011 and 2012 the case author (Baleshta) was invited, due to his experience with medical device design, to give guest lectures at the Waterloo School of Pharmacy, and share these experiences with the students. This interdisciplinary involvement was initiated by the PHARM 322 instructor, who felt that the exploration of atypical aspects of their field was of particular benefit to the development of healthcare professionals. It would compel pharmacy students to step outside of their comfort zone and challenge them with questions that are dissimilar to their conventional courses. Students would gain exposure to different ways of thinking about and approaching a problem.

The sessions were two hours in length. This was presented in a smart classroom with video conferencing to an adjacent classroom for a combined class of 110 students.

The pharmaceutical tablet crusher fit well with the scope of the course (as the initial need was identified by a consultant pharmacist). While designing medical devices, the case author had appreciated the valuable input received from pharmacists. Pharmacy students would be exposed to many medical devices (well or poorly designed) during their subsequent practice and might gain from learning the basics of the engineering design process.

Case implementation began with a discussion of the benefits of exposure to the “engineering perspective” as it is applied to medical device design. The potential for pharmacists to identify needs and see opportunities for innovation was highlighted. As pharmacists deal with both the public and medical professionals they are in an excellent position to confirm the need for a product and make recommendations regarding design functions. The five-step design process was introduced and, as per ME100 and MTE100, only the first three steps were covered in-depth (needs assessment, problem formulation, and abstraction and synthesis). Similar to the MTE100 sessions, groups were formed to work through the design steps then compare their thoughts to what transpired in the real-life case example. At the conclusion, the groups were invited to present their proposed design solutions to the class.

The second (2012) PHARM lecture included changes based on instructor reflection of the sessions in MTE100 and the first Pharmacy session. A small selection of mortars and pestles were distributed amongst the groups and they were able to crush calcium tablets. This hands-on activity was intended to show how arduous this task would be for the LCTF staff, especially when repeated for many residents. Design process templates were also developed and distributed to each group. These were formulated for efficient and effective reporting of group activity. Templates were established for needs assessment, defining criteria and constraints, identifying problems with existing crushers, generating design alternatives and a decision matrix chart. These proved to be very useful, an example template is shown in Fig. 4.

Figure 4: Decision Matrix Design Process Template

The instructor observed that pharmacy students (in these classes) were initially more hesitant to participate than engineering students. However it was possible to build enthusiasm with the majority of the students, especially during the creative design alternative stage. Again a sense of humour was displayed as well as some commendable attempts at devising design solutions.

The course instructor reflected that there was great value in what was taught during these sessions even if it was “outside the box.” The case presenter (Baleshta) concurred that the design process for problem solving does indirectly affect pharmacists. It opened students’ eyes to the role they can play with medical product innovation and advancement. It confirmed the usefulness of an interdisciplinary approach, so the lecture was well aligned with the course’s main objectives. It is hoped that these pharmacists might now think differently when dealing with the medical devices they use. They developed an appreciation for the difficulty and complexity of device development and the number of stakeholders in the process. The case-based style was seen as a change of pace and its relaxed interactive nature compelled students to brainstorm, express their ideas on

paper and to become fully engaged in the content. The opportunity to discuss ideas and work in a team setting with peers was also enjoyed. The weakness as perceived by the course instructor was that it was difficult to present to the large class, and the group size (4-5) made it hard for all members to participate. Time constraints once again were mentioned as a factor in covering the material with sufficient time, to adequately discuss the issues, and explain concepts in detail. Also, students were not experienced with the case study format.

Student reaction to the case implementation was relayed by the course instructor. Some enjoyed this different experience and were happy to show their “engineering flare.” The experience spurred some to think more about how they could contribute to society. Other students failed to see the relationship of design to their positions as pharmacists.

3.6 Waterloo Unlimited

Waterloo Unlimited, an outreach program at the University of Waterloo, gathers students nationally from grades 10-12 for a pre-university enrichment experience. The program typically incorporates a trans-disciplinary theme, such as change and design. Students explore and integrate knowledge from all UWaterloo faculties. The emphasis is to nurture students to develop “higher-order” skills such as “communication, analysis, synthesis, initiative, curiosity, responsibility, leadership, teamwork and creativity” [12].

The Waterloo Unlimited program values open-ended experiences beyond classroom learning. The tablet crusher case study was seen as in “ideal” fit within this framework. Prior to the case-based presentation, the students were introduced to design in a broad context multi-disciplinary basis. The students then choose from a variety of workshops across campus to gain exposure to applied design. The pill crusher represented design in an engineering context and the case-based workshop was considered an appropriate means to “thoroughly involve students in the design process and to challenge them to develop their skills.” Fifteen students selected this 1.75 hour session.

The format of the presentation was similar to the pharmacy directed talk, and the workshop instructor (Baleshta) leveraged prior experience from the MTE 100 and PHARM 321 presentations. Groups were arranged and they worked through the initial design steps of needs analysis, problem generation, generation of alternatives and selection of an optimal design. Due to the smaller group size, all students could experience pill crushing using a mortar and pestle. The smaller class (and classroom) also exposed one of the key problems with existing crushers, the unpleasant noise generated while crushing tablets.

The workshop instructor noticed that the responses from this enthusiastic group of Grade 11 students matched that of the first year engineering students, especially during the needs analysis and problem formulation stages. A significant limitation was the classroom projection system where it was not possible to display the design sketches from the students.

The Program Director shared direct student feedback with the instructor. The positive comments included “best part of the week,” “relevant to the real world,” “amazing, loved the session,” “loved the design challenges,” and “it showed design from an engineering and business perspective.” The less positive comments included the lack of time, the lack of opportunity to build a device, more direct injection of instructor experience, more time for questions about the field of engineering, and to include an exploration of other medical devices.

The Waterloo Unlimited Program Director stated that the strengths of this workshop included the fit with the design theme, hands-on experience, teamwork, communication, and the engaging speaker. They would be interested in expanding the pill crusher workshop to include the entire group of students at the program “because it so effectively demonstrates the design process and so thoroughly involves the students in a valuable learning experience.”

4. CONCLUSIONS

The simple, but interdisciplinary nature of the tablet crusher design made it appropriate to use the tablet crusher case study for a wide range of courses and academic levels both within and outside mechanical engineering.

Although the case has been used in several different courses, its implementation has largely been directed towards teaching the design process. It would be interesting to see the case re-introduced at higher levels in engineering for more analytical study. It could conceivably be integrated into statics, kinematics, stress analysis, materials (fatigue), manufacturing processes, and mechanical design courses. The case should, of course, not be “repeated” if the students have previously experienced it for design process teaching but might do well with these other applications of engineering.

In the presented implementations, the commercial solution had been shown either at the onset of the session or following each step of the students design process efforts. According to Leenders & Erskine (1) this is not the most interesting way to present a case and their ranking system would place it at a lower level of case difficulty. Implementation might be modified for higher levels of engineering, where the case results would not be presented to students until all the intended design steps were completed.

Interdisciplinary exposure to this case occurred largely by serendipity, but its impact in other faculties and programs was positive, and will continue. The design-business interface could be studied. As mentioned, design and business aspects of product design cannot be separated in actuality, but usually are in courses. An ergonomist proposed that this case could be used in ergonomics courses as it deals with “optimization of physical effort, injury prevention, reduction of noise annoyance, and operational behaviour related to use and maintenance of a product.” Figure 5 shows a wireframe depiction of the crusher that could be introduced as a lead-in to kinematic or ergonomic analysis.

Figure 5: Wireframe Depiction of Crusher for Kinematic and/or Ergonomic Analysis

One theme found in all the case-based session feedback was that students found this process engaging. The impact of time constraints was also prevalently noted. Ongoing improvements such as the use of physical teaching aids (the mortar and pestle method, and commercial device demonstration) also enhanced student experience. Design step templates quickened the process and improved the quality of student input. A means of projecting the design case solutions to the class are essential, as this allows the students to proudly (or humorously) present their work (Figure 6). Regular instructor and student feedback also provides input for continuous improvement.

Figure 6: Example of Student Design Alternatives

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