A Case Study using 3-D Printing to Improve Innovation and Reduce Waste during the Design Process

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The concepts of lean manufacturing are being incorporated into many organizations. The notion of waste reduction has been proven to be a powerful tool in successful organizations. Cost reduction on the plant floor has been a primary target for these efforts. However, some organizations are beginning to look at nontraditional ways to reduce waste and improve their competitive positions. This is a case study of collaboration between Kent State University's College of Technology and a local business utilizing 3-D printing rapid prototyping (RP) for concept proofing. The project was initiated with the intent to reduce the time and cost normally associated with the design process. However, as the project moved forward, it was discovered that innovation as well as time savings resulted from the use of RP.

1. Introduction

Engineering and technology educators in the 21st century are obligated to provide students with learning experiences that will serve to prepare them for their careers. One way to accomplish this is by using real problems affecting industries in the education process. An effective way to accomplish this is through a mutual alliance between local businesses and the educators through the university's business outreach program. The benefits of this also provide alignment with the university's goals, which are to:

1. Provide a relevant learning experience for the student,
2. Provide a beneficial service to our local businesses, and
3. Further the university's goal of increasing outreach programs.

Another approach is to provide students with lab experiences designed to replicate various components of industrial scenarios.

In 2004, the Applied Science & Technology (AS&T) faculty within the College of Technology (CoT) undertook a review of lab equipment. After the review, it was determined that upgraded and more relevant equipment was needed in order to best serve our students. A three-year plan was developed, and the CoT proceeded to secure funds. It was decided by the faculty to start the upgrade plan at the beginning, the design phase, and proceed through to the final phase of shipping and warehousing. Within the design arena, it was determined that the CAD labs were current, but concept proofing was lacking. The CoT proceeded to purchase a Z Corporation 3-D printer system through Appropriate Technology, the local distributor.

The 3-D printer system has been incorporated into several courses while faculty is still researching the full benefits. The intention is to provide students with the opportunity to use the latest in technology while building confidence and skills.

It should be noted that the CoT is an academic unit within a primarily liberal arts university. Kent State has made as one of its strategic goals the improvement of the outreach programs. In keeping with this goal, the director of the CoT outreach program began contacting local businesses to share various capabilities available within the CoT and to determine if there might be a match between needs and resources.

Some local companies have voiced the concern that many of today's new products often become tomorrow's discounted closeout items. It can be difficult to recuperate development costs in the short time a company may have controlling market share. Yet, companies still must traverse the costly landscape of taking a product from concept to market, or what used to be called "drawing board to store

shelf." However, to be competitive, new methods and techniques that are paramount are needed to reduce cost of this journey.

Today many companies are more than willing to outsource portions of their businesses to organizations that can assist them with new methods and techniques that can improve their time-to-market processes, and therefore, profitability. In addition, off-shoring of design and development services is also becoming more common with many manufacturing companies, in the effort to reduce cost and time.

2. Case Study - Requirements

The following is a case study, based on a real situation, where an alliance was formed and the benefits reaped by both the university and a local manufacturing business in the development of a new and innovative product.

This case study involves a company with extensive expertise in electronics. The company develops and manufactures specialty coils used in Magnetic Resonance Imaging (MRI) Systems for the medical industry. Its products maintain their competitive edge primarily through innovative electronic designs. Its access to mechanical design assistance is somewhat limited and the mechanical components are patterned on previous systems. The engineers had developed a new coil concept with innovative configurations, and they knew this configuration could be even more effective with a new mechanical design. The electronics engineers predicted the properties of the mechanical headrest, but did not have the expertise to detail their ideas or to be able to predict if their mechanical ideas would be good.

3. Case Study - Process

The local company's manager of R&D had heard of the CoT's new RP system through contacts with the Outreach Program and was only slightly familiar with the benefits of rapid prototyping (RP). He had used steriolithography (SLA) for

testing and tooling development, but the company had never used 3-D printing or any of the other RP systems. So this was new territory for the company and a bold move to test a new technology on a high profile product.

After the initial meeting explaining printing strengths and weaknesses, the manager determined that the new electronic configuration for a brain coil would be a good candidate to introduce 3-D printing for concept proofing to the company. The product itself had both an electronic and mechanical component. The company was able to supply drafting support and the electronics engineers were able to convey the mechanical attributes. The drawings were created using the electronics engineer's ideas.

The manager came back to the CoT, requesting assistance with the mechanical portion of the project. At that time, a student was chosen and assigned to the project. This student was assigned liaison duties between the company and the CoT. In addition, the student developed the cost estimations and was responsible for producing the prototypes.

The design team knew that they had a breakthrough idea for a new MRI coil design for imaging the human brain. The new electronics theoretically would produce significantly better images, even using the traditional headrest design. The design team hypothesized that even better images could be obtained by changing the headrest to allow the electronics to be as close as possible to the head. The challenge was finding the configuration for the patient headrest that would best maximize the images from the new coil design while at the same time providing some degree of comfort for the patient.

Our initial discussions concluded with an agreement to proceed. Expectations were detailed, including production of several versions of a 3-D printed headrest based on the company's designs. The company emailed the drawing files, and

within a few days, the first design was produced on the Z Corporation 3-D printer. It was a simple design based on the current headrest design.

The drawings were used to create the part using 3-D printing. The completed part was sent to the company, and the electronics were applied and tested. The Z Corporation plaster material proved to be radio-translucent and excellent for testing the electronics. The images were improved over older electronic configurations, but the designers were convinced that even better images were possible. This headrest established a benchmark for imaging quality from which modifications and design adjustments could be made to the mechanical design.

From this point, the design team brainstormed and developed several versions of the headrest, using what was determined to be the best characteristics. Four distinctly different mechanical configurations were developed. Each version was "printed" and evaluated. The headrests used a variety of shapes, from non-adjustable and fitted to mechanically flexible but rigid. In total, five versions were developed and produced.

It should be noted that this design team had only CAD support for this project. The design engineers understood the electronic innovations and the design process well enough to comprehend the direction that the headrest design needed to take. It should also be noted that there was no question regarding the final production material, since it was a fixed variable in the design process due limitations set by regulations and previous submissions made to and approved by the FDA. So only the configuration was in flux.

The design question that needed to be answered was which shape would produce the best images while still providing comfort for the patient. Each design was fitted with the electronics and tested. The project team reviewed the results and recommended to management the one that optimized the images and patient

comfort. Management agreed with the recommendation, and the new product has now advanced to the human testing phase.

4. Case Study - Benefits

The design team was energized to have multiple configurations in their hands. This was also the first time the team was able to perform side-by-side comparisons and complete a thorough examination of the prototypes prior to finalizing the specifications.

This case study demonstrates how the relatively low-cost, plaster 3-D printing process can be used for a quick assessment of the concept for mechanical devices. This company had previously used SLA for validation testing and tooling development. This was its first use of 3-D printing in plaster. The company's design team was also stunned at the reduction in the time needed to come to a decision. This project was so successful that the company now includes the possibility of using 3-D printing on all projects. The company estimates it saved 12 weeks in the design phase of this project.

In addition, the cost of testing the various configurations of the 3-D printed headrests was significantly less than the company had originally estimated based on SLA pricing. If SLA were the only method available, the team would not have had the budget to produce the five new versions for evaluation. In this case, the cost of producing five headrests with 3-D printing technology was about the same as one SLA model. Three-dimensional printing offers a cost- and often, time-saving advantage when a company is working on developing new products.

The team was satisfied that the best design choice was made, and a more expensive SLA version was ordered to complete the manufacturing and tooling process.

The outcome was a complete, innovative system developed by electronic engineers who had a thorough understanding of the electronics and the outcomes that were needed, but only basic understanding of mechanical design. The final system performs better than originally predicted. This is due to the breakthrough in the electronics and, in part, to the better headrest design.

Another benefit of this project was that a student was able to participate in the project. he meetings with the company were used as an experiential learning opportunity for the student to observe the discussions and negotiations as they occur in the normal course of business. These meetings also allowed the student to demonstrate his understanding of mechanical design and to contribute to the discussion about alternate configurations. The student was also assigned the tasks of estimating the cost of the part, estimating the time required to complete the task, and performing an evaluation of the mechanical specification.

The university also experienced success in this project by furthering its established strategic initiatives. These include to:

- Encourage innovation in learning
- Focus on those we serve
- Engage with the world beyond our campuses
- Build and sustain relationships that foster success

This case study represents a model both for future collaborations and to further the strategic initiatives by incorporating a process that considered all of the strategic initiatives. This project provided an opportunity for applications-based learning outside the traditional classroom, involved a student, worked with a local company, and provided a successful completion of the project that has led to additional collaborations.

The CoT has also experienced a win with this project, in that it has been identified as a contributor to the successful launch of an innovative product by a local

business. This was accomplished through the use of on-campus talents and capabilities.

4. Summary

This project was successful due to several factors that came together to produce an environment that was ready with people who had an idea of how to appropriately apply a new technology.

This project provided a collaborative effort for a local company to address a need utilizing a local resource that proved beneficial to everyone. This case study represents a positive experiential learning opportunity for everyone involved. The electronic engineers discovered a mechanism to overcome the shortage of mechanical support to realize their own design outcomes quickly and without going over budget. The company has now provided its customers with a new and innovative product that provides superior results over earlier models. This success will indirectly benefit the financial state in Northeast Ohio.

The university realized the benefit of the modern equipment in the labs for the overall performance and future of its students. Because of its foresight in requesting the technology, the CoT had the opportunity to work with this local business to produce this result. This is a stellar example of how the university's investment in modern equipment has gone far beyond the university's walls. The CoT's reputation has been advanced by this positive experience, and this success story will prove a platform to establish design collaborations with other companies.

This project provided a significant experience for the student in his formal education process. The student learned about the complexities of product design and innovation as demonstrated by this global competitor.

Engagement of faculty during this entire project provided experiences that have enhanced professional development. In addition, information and lessons learned will be transferred to the classroom. Future students will benefit from this experience.