Authentic New Product Development Instruction Made Possible with Low-Fidelity and Lower-Cost Rapid Prototyping

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Abstract

This digest outlines how a new product design and development course can be implemented to provide students with an authentic product design experience in ten weeks. This course incorporates the voice of the customer and the use of low-fidelity prototypes to promote rapid idea generation within multidisciplinary student teams, comprised of marketing and engineering students. Teams create an alpha prototype, an artifact that looks like, and works like, the intended product but is not made with production tooling. Alpha prototypes suitable for realistic customer feedback can be made with the advent of lower-cost fused-deposition modeling prototyping technology.

Introduction

New product development involves an iterative process where information about customer needs (marketing) is converted into workable solutions (design) to meet those needs. A novel cross-disciplinary course has been developed that incorporates both of these important elements. This course was taught in the Spring 2013 and Spring 2014 semesters. In each offering, the class consisted of approximately 15 senior engineering technology students and 6 MBA marketing students. The engineering technology students had taken the Department of Technology advanced computer-aided design class and had some proficiency in manufacturing processes. There were five project teams working on five unique projects. A typical design team consisted of three technology students and one MBA.

There is renewed interest in fostering innovation within larger corporate environments. Clough (2014) has written how General Electric has implemented a corporate-wide training program called FASTWORKS that is focused on speeding product development and increasing customer engagement to improve product quality and lower costs. The format of this class reflects the growing interest in entrepreneurial, or start-up, arrangements in companies to promote more efficient and rapid product development. The cross-disciplinary, engineering-with-marketing, teamwork approach gives students experience working on innovative project work. Drs. Kaufman and Reifschneider were awarded a grant by the Illinois State University Scholarship of Teaching and Learning (SoTL) Small Grant Program to study how to best teach innovation using this new product design course. Although beyond the scope of this digest, which is focused on the role of prototyping in product development, the additional objective of the course was to field test a classroom experience that would enhance a student's skill at being innovative. The findings from this study are being prepared for another peer reviewed journal.

This digest will outline the basic mechanics of this course and illustrate the role of prototyping in the development of the geometric model that becomes an alpha prototype. By incorporating customer needs into the design process and producing a tangible artifact that can be tested by potential customers, students have a more authentic product design experience. The advent of lower-cost prototyping such as fused-deposition modeling from Makerbot (2014) and others enables this type of design cycle to be completed in a ten-week period, or during a single-semester course. Figure 1 shows a Gantt chart of the major milestones taught over a semester-long course. Throughout the body of this digest, one example of a product design that was developed in this course is used to provide a concrete example of the process steps.

New Product Design and Development Gantt Chart

week of term:	1	2	3	4		5	6	7	8	9	10	11	12	13	14	15	16	17
	January			February					March				April				MAY	
Design Project Milestone	**14**	**21**	**28**	**4**	**6**	**11**	**18**	**26**	**5**	**11**	**19**	**26**	**2**	**9**	**16**	**23**	**1**	**8**
COURSE INTRODUCTION	x																	
Ideation Practice & Big Idea	x	X																
1.The PITCH (pdf file)			X															
Big Ideas vetted by instructors										S								
Student pitch Big Ideas to class				X						P								
The VOTE				X						R								
Team Formation					X					I								
2. Team Mission & Plan						X				N								
3. Voice of the Customer								X		G								
4. Concept Generation									X									
In-Class Design Review									Δ									
5. Concept Selection											X							
Preliminary feedback on VOC										B		X						
6. Concept Testing (VOC II)										R			X					
7. Final Prints, Financial Model										E				X				
8. Alpha Prototype DUE										A					X			
9. Prototype Testing										K							X	
10. Final Presentations																		X
EXAMS (Exam 1 and 2)						EXM 1								EXM 2				
Denotes DUE DATE	X																	
Denotes parallel activity																		

Figure 1. Course Gantt chart showing milestones and project schedule.

The critical stages of the product design process are illustrated in Figure 2. This cartoon is a story board format of the product design process outlined by Eppinger and Ulrich (2004) and each panel corresponds to one of the milestones outlined in the Gantt chart of Figure 1. The evolution of the geometric model during new product development begins with a proposition which is The

Pitch in Figure 2. The Pitch is a "big idea" Bruton (2014) that a student presents as a possible design project. Teams are formed based upon which projects proposed by students are accepted by the class to become their semester-long product development project. This is The Vote in Figure 2. Teams consist of at least one marketing student for the required market research, a lead computer-aided designer, and a lead fabricator to assemble a functional alpha prototype. The first critical step in the design process is assessing the voice of the customer in order to determine the customer needs; see panel 3 in Figure 2. Customer needs are a relatively short list of product attributes that potential customers would desire in a new product offering. Using the example of an attachment to a shopping cart called the Dashboard, Figure 3 shows an example of the customer needs that is the result of conducting several surveys of potential customers. The customer needs include new product attributes the customer finds important (focus), how important they are (weighting factor), and how the designer will objectively assess the quality of subsequent designs (metrics). These needs become the blueprint for synthesizing inputs during the next design stage: concept generation.

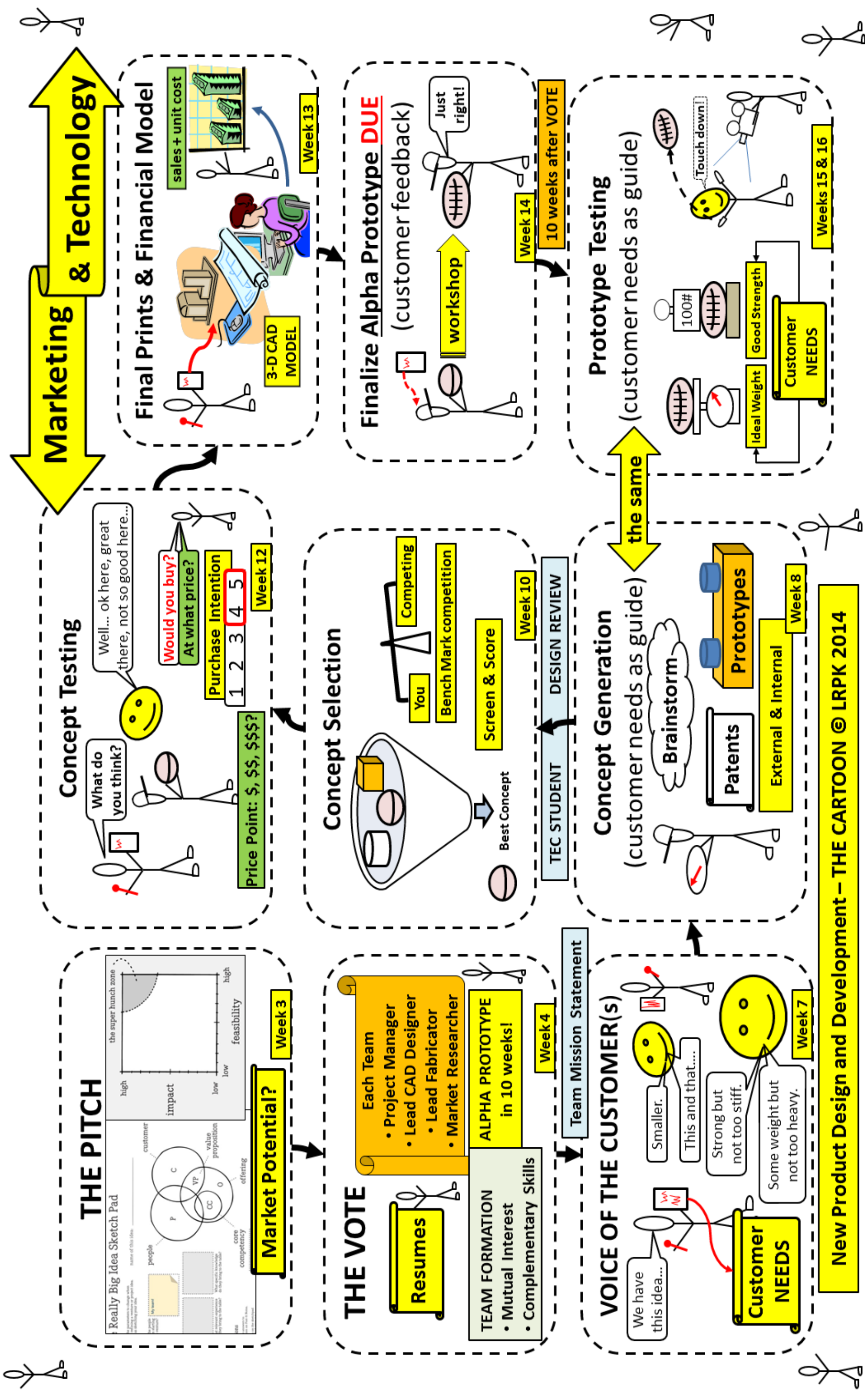
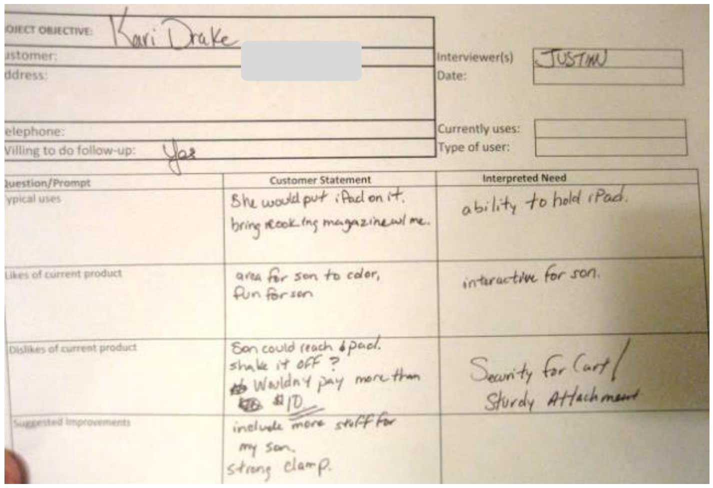


Figure 2. The Product Design Cartoon

Customer Needs Matrix

Criteria No.	Focus	Final Customer Need Statement	Weighting Factor	Metric (Measure)	Metric Description
1	Easy to carry	Easy to carry in and out of stores	30%	Dimensions and Weight	Girth (LxWxH) and Weight (lbs) of the unit
2	Size	Support the shopping materials I need	25%	Surface area	Usable surface area for storage (in^2)
3	Easy to attach	Will quickly attach to the cart	25%	Time	Seconds to attach
4	Security	Will stay attached securely during use	10%	Pounds force	Resistance to pulling of the cart (lbf)
5	Price	Will be priced economically	10%	Dollars	Price point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ustomer: Kari Drake
ddress:
elephone:
Villing to do follow-up: Yes
Interviewer(s): JUSTIN
Date:
Currently uses:
Type of user:

Question/Prompt	Customer Statement	Interpreted Need
ypical uses	She would put iPad on it, bring cooking magazine w/ me.	ability to hold iPad.
Likes of current product	area for son to color, fun for son	interactive for son.
Dislikes of current product	Son could reach iPad. shake it off ? Wouldn't pay more than $10	Security for Cart/ Sturdy Attachment
Suggested improvements	include more stuff for my son. strong clamp.	

Figure 3. Voice of the Customer cast as the Customer Needs Matrix for the Dashboard and a sample interview form.

Concept generation, see panel 4 of the Cartoon, involves both internal idea creation, or brainstorming, and external searching of competitive products. Figure 4 illustrates the process inputs of the concept generation stage that result in a refined geometric model. Brainstorming may take the form of either two-dimensional hand renderings or three-dimensional low-fidelity prototypes. Figure 5 shows some examples brainstorming created for the Dashboard project. Low-fidelity prototypes are a low-cost and effective means of generating ideas that can readily be communicated to design team members. Such prototypes used in this course included simple items such as cardboard, foam core, and duct tape. In addition, a hot wire foam cutter, Global Industrial (2014), was used because it can quickly generate three-dimensional shapes without any specialized training, such as CAD modeling. The marketing students on the design teams utilized this prototyping method to rapidly develop and share ideas. In addition, patent searches are conducted to assess what competitive products may offer. After several possible complete solutions for a product were developed, each was scored using the customer needs matrix to determine the best option to go forward. This is the Concept Selection panel in Figure 2. The next critical step involved creating a low-fidelity, but functional, model of the best idea and presenting it to potential customers. Low-fidelity models are used due to the relatively short ten-week time frame. This is the Concept Testing stage in Figure 2, and critical marketing data is obtained at this stage: will customers likely buy a product like this and at what price?

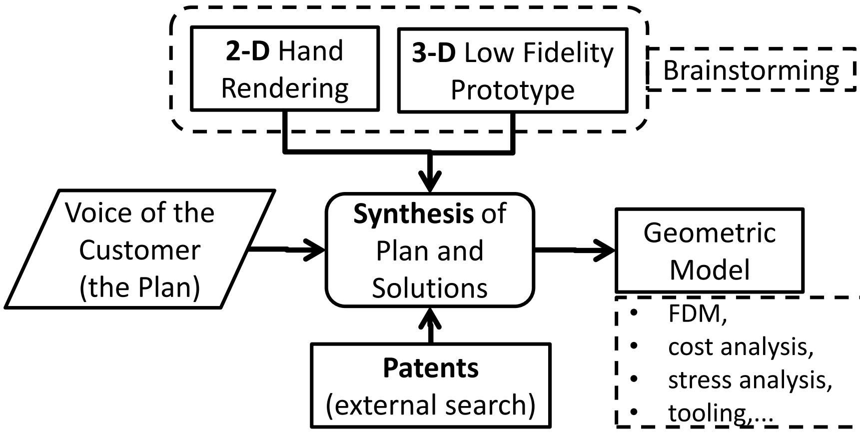

Figure 4. The Geometric Model is the result of an informed synthesis of internal searching with 2-D & 3-D concepts as well as external searches of patents.

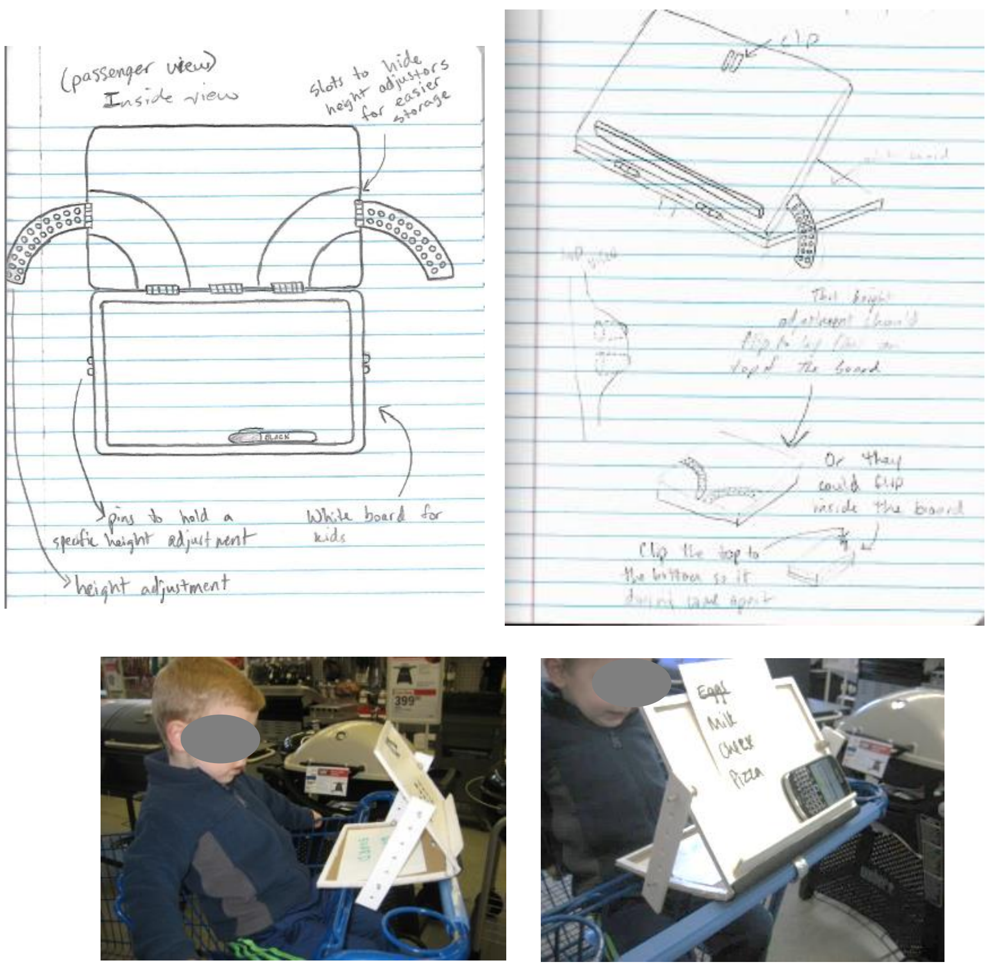

Figure 5. Brainstorming: concept sketches and low-fidelity prototype (foam core).

After customers have provided feedback on design improvements, a refined geometric model is completed. It is important to emphasize the role of parametric associative geometric modeling in this case. Many design changes are relatively small adjustments to the existing geometry so updates should be relatively straight forward. In addition to helping create a finalized design, the Concept Testing provided critical marketing data about the potential sales volume and sales price. This information along with the expected unit cost to produce the finalized design allows a realistic financial model to be developed. This stage is the Final Print and Financial Model in Figure 2. Figure 6 shows some prints of the finalized Dashboard product. It is important to note that, if at this stage it is shown the product cannot yield a positive return, there will need to be a major adjustment in the design or, in actual practice, the project is stopped. All design teams had ten weeks after the initial product pitch until they were to submit their alpha prototype for inspection by the instructors. Another important factor of alpha prototype creation is shown in Figure 7, the Dashboard project. An alpha prototype may consist of more than simply parts made on a fused-deposition modeler. In this case, alternate materials are used to make certain components, because either they are much cheaper than making them with the FDM (use sheet stock for large flat surfaces) or they are much stronger (metal screws). Design teams had two weeks to conduct testing with potential customers and summarize their findings. Figure 8 shows the Dashboard alpha prototype being tested by a potential customer in a grocery store. The measure of how successfully their products were assessed is based upon the metrics they established during the initial voice of the customer stage when the customer needs were drafted.

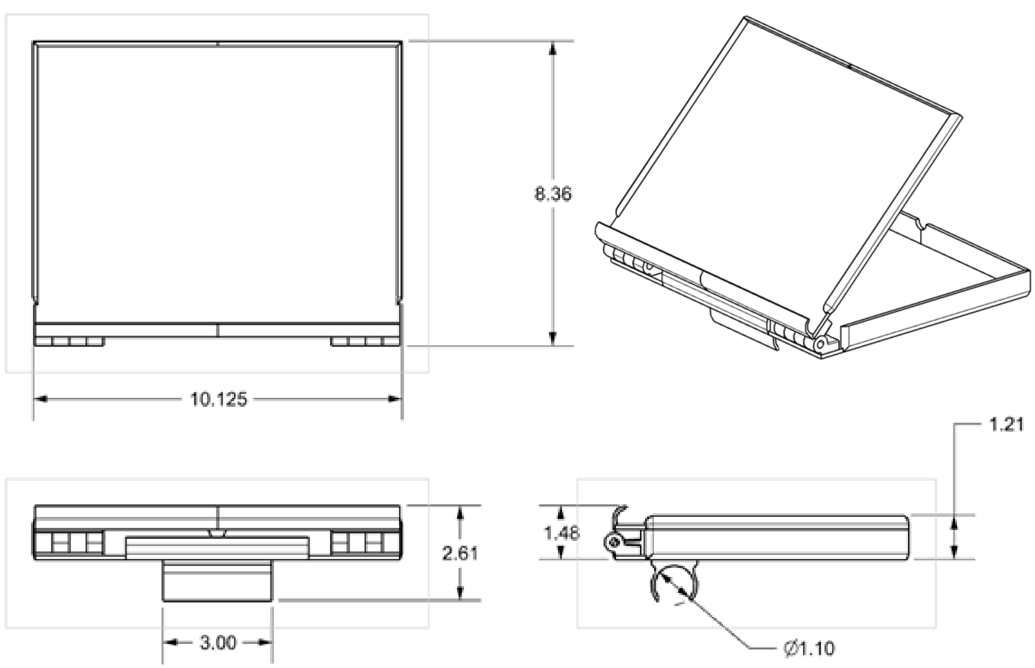

Figure 6. Final computer-aided design model used to create the FDM components.

Figure 7. Alpha prototype: a high-fidelity prototype made primarily from FDM. Note the alpha prototype consists of FDM parts (red) and other plastics (clear panels of 1/8 inch thick acrylic sheet) and metal screws (self-tightening hinge). Acrylic is glued to the FDM plastic.

Figure 8. Testing of the Dashboard alpha prototype with potential customers.

Conclusions

The important points from this presentation are three-fold. First, products exist to solve customer needs. Combining the interests of marketing and technology students allows both disciplines to better realize the role of the voice of the customer during the creation of new products. The geometric model of any design ultimately begins with the customer in mind. Second, the synthesis of an initial three-dimensional model is a feedback process that is driven by the customer needs and has inputs that can be either two-dimensional drawings or three-dimensional low-fidelity prototypes. Low-fidelity prototyping allows all members of a design team to communicate more effectively, because such methods do not require specialized training, such as CAD, to create geometry. Finally, with the advent of lower-cost fused-deposition modeling, a more authentic product design experience is possible for students within a single semester. The FDM platform allows creation of functional product designs that can be rigorously tested by potential customers. Product testing, and the feedback it provides, brings the product design process full circle for the students.

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