Session 2125

Learning How to Identify Customer Requirements: A Key Component of Product Development Courses

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Abstract

A crucial step in the process to develop a new product is the identification of the customer requirements. The outcomes from this step strongly influence both the rest of the development effort and the ultimate success or failure of the product. When students work in teams in product development (PD) projects, they often tend to start generating solution concepts right away without carefully identifying all the stakeholders that must be taken into consideration, determining all the customer needs, and establishing their relative importance. The reason for this may be twofold. First, many engineering students believe that in their professional career they will seldom be actively involved in the identification of the customer needs. Second, it is more appealing for engineering students to embark in the creative and open-ended process of concept generation than to spend time interacting with customers to establish their true expectations. The problem is that, in the "real world," an engineer working in PD needs to be substantially involved in the process of identifying product requirements. In addition, without direct interaction with the customers, it is not possible to have a clear understanding of what they want. This, in turn, usually leads to the selection of a product concept that either fails to satisfy some key customer expectations or sub-optimally trades-off one attribute against another.

To overcome the problems stated above, it is important to emphasize in PD courses a formal process to identify customer needs. Furthermore, students must apply what they learn so that they can really acquire the knowledge and skills required to successfully complete this task. To explore the benefits of this approach, a formal process to actively identify customer requirements was introduced into a sophomore PD course, a senior capstone design course, and a graduate level course in PD. Although the level of interest demonstrated by the teams varied, some of them managed to understand the customer requirements at a level that was above the instructor's expectations. In this paper, the approach followed, the results obtained, and suggestions for future improvement are discussed in the context of projects carried out by the students.

Introduction and Motivation

A typical reaction of students and faculty members that are not familiar with the field of product design and development is that practicing engineers that work in product development projects in the "real world" do not have to be substantially involved in the process of identifying the customer requirements. However, in the current competitive environment in which complete customer satisfaction is the ultimate goal of any product, that is definitely not the case. In order to understand this situation, it is important to take time to consider two different aspects. First, the evolution that has taken place over time in the way in which product design and development is taught at the undergraduate level. Next, how companies have been modifying, adapting and improving their product development processes and design methodologies to be able to remain competitive in a global market place.

In general, the undergraduate curricula of any engineering major must evolve in a way that is consistent with the changing needs and expectations of a very important constituent group: the different companies that usually recruit their students upon the completion of their degree. Since during the past decade product design and development has been the focus of increased attention and evolution in industry, substantial efforts have been made by faculty members of engineering programs across the nation to improve the quality of the undergraduate education in this particular field. This becomes evident if one considers the evolution over time in the number and type of product design and development courses that are typically offered to the students, the changes in the style, content and instructional materials used in those courses, and the attempts to integrate design across the curricula.

As a first step to better prepare the students for the "real-world" practice of engineering, Senior Design Project or Capstone-type courses were incorporated into the engineering curricula. The results of an extensive survey conducted by Todd et al.[1] showed that by the year 1994 many undergraduate engineering programs already included courses of this kind. However, the authors also found at that time that these Capstone programs differed greatly across disciplines and even within each department. A comprehensive review of papers that were published in the Journal of Engineering Education since 1993 (see for example Todd et al.[2], Miller and Olds[3], Dutson et al.[4], Bright and Phillips[5], Farr et al.[6], and Catalano et al.[7]) clearly revealed that, throughout the years, the main focus of these courses has been rapidly changing from "solving a practical open-ended engineering problem requiring a substantial integration of technical knowledge acquired by the students during their previous courses" to "working in multidisciplinary teams to develop new products geared towards satisfying specific customer needs."

The next step in curricular improvements was to include in the curricula freshman or sophomore-level courses aimed at providing a very good introduction to both the process and the methodologies commonly used to design and develop new products (see for example the papers by Dym[8], Starkey et al.[9], Burton and White[10], Little and Cardenas[11], Newman and Amir[12], and Wood et al.[13]). In general, those courses also tried to emphasize the development of the critical skills, attitudes and values that are required to successfully work in teams. Finally, the last step was to explore different strategies to try to incorporate design across the entire curricula (see for example the papers by Wilczynski et al.[14], Lamancusa et al.[15], and Carroll[16]) and the addition of new interdisciplinary elective courses with a strong design component. Typical examples of the latter are Mechatronics courses such as the one described by Yost et al.[17].

The experience gained during the course of the past decade demonstrated that following a project-based learning strategy was, without any doubts, the most effective approach to have the students learn the process, methodologies, and tools, and to develop the crucial skills, attitudes, and values, required for product design and development. As was stated by Frey et al.[18] in the context of a graduate program in product development, "people learn about product development most effectively when they work in teams to build systems that integrate structures, mechanical elements, sensors, electronics, and software."

If we now consider the substantial changes that have taken place in industry in the field of product design and development, we will be able to see that the evolution in the engineering curricula that was described in the previous paragraphs can be considered as a direct response to those changes. In the presence of ever increasing competition and intense business pressures, corporations discovered that a crucial factor to remaining competitive and to having products that are successful in the market place was to substantially improve their PD practices and processes. Something became obvious: companies win or lose, lead or follow, succeed or fail based on the competitive strength of their new product development process.

In the early 1980's most companies employed a functional organization to support all their product development endeavors. Under that framework, a strong emphasis was placed on the technical competence of an individual in his/her particular area of expertise. In the specific case of a product design engineer, what mattered the most was how good he/she was at taking a given set of product specifications and using his/her technical knowledge and abilities to quickly come up with one design that was capable of meeting those specifications in a reasonable way. The product development process (PDP) that was commonly used was what today is commonly known as the "over the fence" approach. In that approach, each function, in turn, performed its product development tasks having minimal interaction with the other functions. The marketing function was the sole responsible for the identification of all of the customer requirements and the passing of them to the design function. The design function then used that input to come up with a design for the product and subsequently passed all the information about the proposed design to the manufacturing function. Finally, the latter decided what changes needed to be made to the proposed product design in order to be able to manufacture it and proceeded to set up the production facility.

Nowadays the situation is completely different. Product development is a concurrent effort in which all the critical functions of the company work together during all the phases of the PDP in order to try to develop an "optimum" design that meets the customer requirements, can be easily manufactured, and is very competitive in the market place. To participate in this new framework, an engineer requires a lot more than good technical knowledge in his/her area of expertise. He/she needs to be able to work effectively in multidisciplinary teams, have very good written and oral communication skills, have an in-depth knowledge about the different tools and methodologies that are used in product development, and the list goes on. If one takes a look at an engineering curricula corresponding to the 1980's and compares it side-by-side with one that is in use today, it will be evident that providing a solid technical knowledge has become only "one part of the equation."

Faculty members teaching product design and development courses often face a difficult task. In many cases, they only have a one-semester course or a two-semester course sequence to provide the students a solid foundation and a meaningful practical experience in product design and development. This implies that, in a very short period of time, the students must learn the process, methodologies and tools while simultaneously dealing with the challenges imposed by working in teams, improving their written and oral communication skills, and solving one or more open-ended, and sometimes interdisciplinary, design problems. Although several very good textbooks are currently available for this type of courses (like the ones by Ulrich and Eppinger[19], Ullman[20], Otto and Wood[21], Dym and Little[22], Dominick et al.[23], and Cagan and Voguel[24], among others) and excellent support materials for working in teams are also available (see for example the Student Guidebook by McGourty and De Meuse[25]), most of the students still need a lot of guidance and support from faculty members in order to successfully complete a product design project, particularly when it is the first one in which they are involved. This, in addition to other factors, usually creates a substantial increase in the workload for faculty members teaching this type of courses in comparison to the typical time commitment required to teach a traditional technical course. Just as an example of this situation, Burton and White[10] reported that faculty demand may be up to four times greater when design based methods are used to teach Freshman Engineering Design courses. To compound the instructional difficulties, although the textbooks cited above are excellent resources regarding PD processes, in many cases the course objectives have numerous technically specific educational goals related to the degree/program, and these cannot be lost as more instructional emphasis is placed on the PD process.

Given all the challenges stated above, in many cases little time is devoted in PD courses to two very important activities of the PDP: the process of identifying the customer needs and the process of translating those needs into target specifications for the product. In some instances, a fairly comprehensive list containing a mixture of both customer needs and target specifications is provided to the students as the starting point for their product design effort. Furthermore, in some occasions, the information that is given the students at the beginning of the design project even prescribes specific components that they must use by force in their product. Examples of this type of situation can be found in "competition type" product development projects such as the Society of Automotive Engineers (SAE) Mini Baja competition or the American Society of Mechanical Engineers (ASME) Human Powered Vehicle competition.

It is extremely important to keep in mind at all times that the final word about the degree of success or failure of a product is determined by the customers, not by the team that developed it. No matter how technically sound a product may be, if it fails to satisfactorily meet some of the customer expectations, or if it does not perform well in comparison to other similar products offered by the competition, it is almost certain that it will not be successful in the market place. Nowadays many companies understand this situation very well and one can find in the literature numerous papers and case studies that emphasize how important it is to adequately identify all the customer requirements. For example, Solo[26] provides a good description of how Whirlpool obeys consumer dictates when developing appliances. She also points out how General Motors now regrets hurrying its slow-selling 1992 Caprice to market, even though consumers had indicated in prior tests that, among other things, the rear wheels looked too small.

As Pottruck and Pearce[27] remind us, customers actually drive innovation and new product development. Any company that can discover what the customer really needs, create it quickly, and then let customers know about it is going to be successful. Although at the present time the internet is facilitating increased customer contact, unfortunately the customer's message is not always clear, and a true understanding of the emotional core of the customer is required to be able to develop creative products that satisfy indirectly-voiced customer needs (i.e., latent needs). One good example of this is the minivan. According to Pottruck and Pearce[27], Ford opted not to develop it because no one ever said directly "I want a van that drives like a car." Through direct contact with customers the designer was able to hear first-hand the frustration of many "soccer moms" who complained about the dirt in their sedans, who needed more room, and who didn't want to drive van that felt like a truck. Chrysler listened to the designer and was first to market with the now popular minivan. Interestingly enough, Ford made a similar mistake later, opting not to pursue a driver's-side sliding door on their minivans until well after the competition introduced that hugely popular feature.

There are also examples of "technology-push" products which reflect that, even in those cases, satisfying existing needs is a key factor for success. For example, when Percy Spencer, a Raytheon engineer working on radar systems, noticed that a candy bar melted during a radar system test, that ultimately led to the development of the microwave oven, which in today's society has essentially become a requirement of every kitchen. While no customer ever said "please give me an oven which uses microwave energy to quickly cook my food," there was a deep underlying need (desire) for faster food preparation techniques.

Without any doubts, the marketing function is indispensable in any large corporation and it plays a leading role during the process of identifying the customer needs. However, to achieve success, the engineers that are involved in the design and manufacturing of the product must have an excellent understanding of what the customers want (including their latent needs) and this is impossible to achieve without having a close interaction with the customers. In general, customers express their requirements in non-technical terms and their need statements have to be translated into target specifications that can be used to guide the rest of the development effort. Since the marketing function does not have the technical expertise to do that translation process, the engineers have to take the leading role in that crucial activity. Also, unless an engineer truly internalizes what the customers want and how important each one of the desired product attributes is to them, how can we expect that he/she will actually have a customer-centered mindset while performing other product development tasks? Consequently, it is very important for engineers to learn how to participate in the process of identifying customer requirements and how to keep the "voice of the customer" in mind while making decisions about the product. What is the point in spending many hours performing technical calculations in a design that at the end is not going to be well received by the customers? The authors feel that no one should know more about what the customer expects from a certain component, sub-assembly, assembly or product than the engineers that are designing it. It is for this reason that they chose to integrate customer needs gathering tools and processes into their engineering design courses.

The authors have instructed many PD related courses at the undergraduate and graduate level. In general, those courses involved a one or a two-term product design project in which the students had to work in small teams to carry out all the key activities of the concept development phase of the PDP. A close interaction with the teams revealed that three activities are particularly difficult for the students: identifying customer needs, setting target specifications for the product, and generating product concepts. In this paper, we will only consider specific aspects of those courses that are related to the process of identifying customer needs and we will address the other two in future publications.

The remainder of this paper is divided in six sections. In *Identifying Customer Needs*, a generic PDP for products of low to moderate complexity that the authors teach to is presented. This section clarifies where in the PD process the task of identifying customer needs is typically done. In *Description of the Courses Considered,* a brief summary of the some of the PD related courses the authors have instructed is given. *Instructional Approach* summarizes the pedagogy used to teach the process of establishing customer needs. Two examples taken from student project work are given in *Sample Student* projects. The final two sections correspond to a discussion of the *Results* of our experiences in this regard and *Conclusions and Future Work.*

Identifying Customer Needs

The product development process (PDP) that the authors teach to in their courses is the generic PDP for "market-pull" products of low to moderate complexity presented by Ulrich and Eppinger[19] in their book "Product Design and Development," with some minor modifications and adaptations. Figure 1 provides a schematic representation of the different phases of that PDP. There are, of course, many other PDP models, such as the "Waterfall Model,"[28] the "Spiral to Circle Model"[28] (commonly used for software development), the "System Acquisition Process" used by the Department of Defense (DoD), or any company's detailed PDP. However, it is the authors' experience that, with the exception of the "Spiral to Circle Model" that has some very unique characteristics, all the fundamental phases and steps of other PDP models for "market-pull" products can be mapped very easily to the one presented by Ulrich and Eppinger[19] by just changing a few names and modifying the level of decomposition. Although the generic PDP proposed by Ulrich and Eppinger[19] may be perceived as a relatively simple representation of a PDP, it has been our experience that it elegantly captures all the key activities that must take place in order to translate a perceived market opportunity into a product. There are, of course, numerous activities of the product life-cycle after the product launch (sales, service, recycling, buybacks, etc.), but for purposes of a first product design and development course, we feel the model shown is at the appropriate level.

Referring to Figure 1, the main goal of the *Product Planning* activity that precedes the beginning of the actual product development effort is to identify the portfolio of products to be developed by the organization and the timing of their introduction to the market. In general, the output of the product planning phase includes the *Mission Statement* (sometimes also referred to as a charter, a design brief, or a product direction letter) for each one of the PD projects that a company plans to purse in the near future. The main purpose of the mission statement is to define the general scope of the product development effort. It is used by the firm to specify a particular market opportunity and to lay out the broad constraints and objectives for the project. Although the mission statement specifies in which direction to go, it generally does not provide a precise destination or a particular way to proceed regarding the product design.

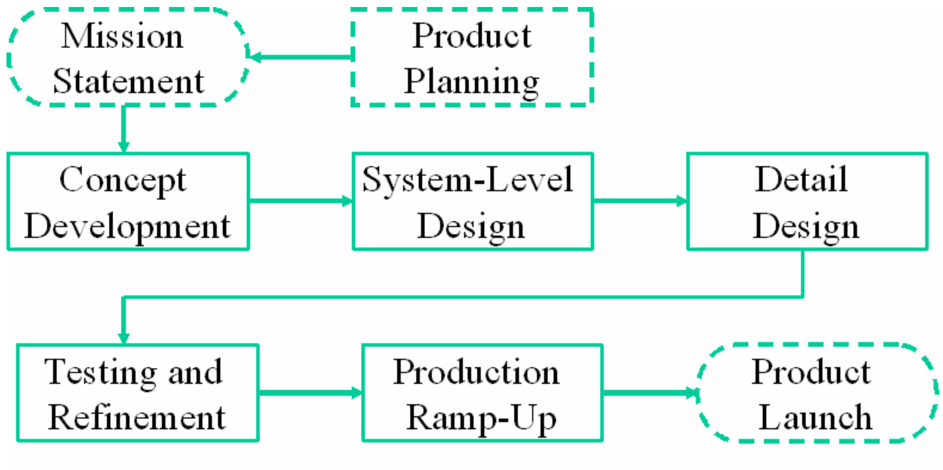

Figure 1. Phases of the Generic PDP proposed by Ulrich and Eppinger[19]

The details of all the activities involved and the deliverables corresponding to each phase of the PDP shown in Figure 1 can be found in Ulrich and Eppinger[19]. It must be pointed out that we always use a project-based learning strategy in all the PD related courses that we teach. The phases of the PDP that we actually include as part of the product design projects that the students carry out vary depending on the level of the course and on its duration. For very obvious reasons, the *Production Ramp-Up* phase and the *Product Launch* activity are never included in the scope of the projects. Invariably, in all the courses we require the teams to complete all the major tasks corresponding to the *Concept Development* phase of the PDP. In the case of a one-term, 4-credit, sophomore-level course, we always try to select a relatively simple product and we don't ask the students to work in the remaining four phases of the PDP. However, as part of the requested deliverables for the project, at the end of the term all the teams are required to present a "proof-of-concept" physical prototype of their product. For a two-term, 5-credit, senior design course sequence, the students are also required to work in the *System Level Design* and *Detail Design* phases of the PDP. In addition, all the teams are also requested to do some basic testing and refinement of their proposed product. Finally, for a one-semester, 3-credit, graduate course in Product Planning and Development, we usually include as part of the scope of the projects the completion of the *Product Planning*, *Concept Development*, and *System Level Design* phases of the PDP. The teams are also requested to present at the end of the term, among others, a "proof-of-concept" physical prototype of their product.

Figure 2, adapted from the book by Ulrich and Eppinger[19], schematically shows the different tasks corresponding to the *Concept Development* phase of the PDP. As can be seen from the figure, the *Mission Statement* for the product constitutes the input for the process of identifying customer needs. Once all the customer requirements have been determined, the next step corresponds to the process of establishing the target specifications for the product. In the remainder of this paper, we will focus our attention in the process of identifying the customer needs. At this point it is important to clarify that we are going to use the word *need* and the word *requirement* interchangeably to denote any attribute of a potential product that is desired by the customers. Also, we are not going to make a distinction between a *want* and a *need*.

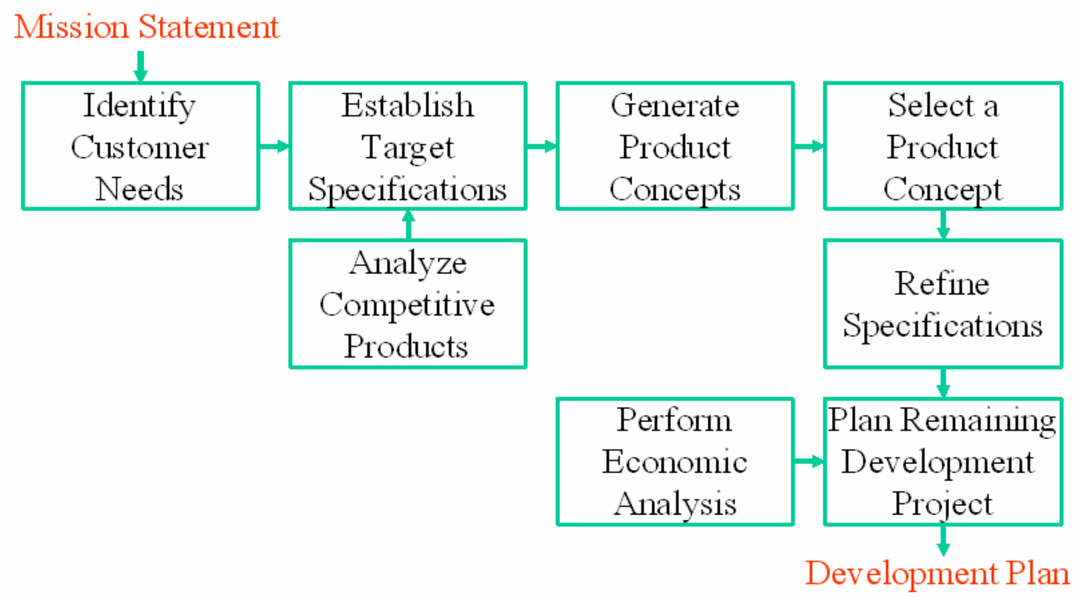

Figure 2. Main Tasks of the Concept Development Phase[19]

Customer needs answer the question: What is it that the customers want? They represent the "voice of the customer" and, consequently, are expressed in the "language of the customer" (i.e., they are usually expressed in non-technical terms). The customer needs are independent of any particular product that the development team might decide to pursue. Thus, they are solution neutral because they are not specific to any particular product concept that the team eventually chooses to pursue. The development team should be able to identify the customer needs without knowing if or how it will eventually address all those needs. It should be fairly obvious that it is very risky business and a very bad idea to proceed with any downstream PD activities without having a complete and thorough understanding of customer needs.

To identify the customer needs, the team developing the product must first determine exactly who the customers are. In most design situations there is more than one customer. For market-pull products the most important customers are obviously the consumers (i.e., the people that may eventually decide to buy the product). Although some highly specialized products (like a nuclear submarine or a jet engine) are not consumer products, they still have a broad customer base (i.e., numerous stakeholders). Standards organizations and regulatory authorities should also be viewed as customers as they too may set requirements for the product. Thus, it is important to identify all stakeholders in the product development effort to make sure all their needs are taken into consideration.

A very useful tool to think about the customer needs is the "Kano Model" of customer satisfaction schematically presented in Figure 3. This model classifies the customer needs into three different categories: basic, performance, and exciting. The basic needs are all the product requirements that are usually not verbalized by the customers since they correspond to assumed functions of the product. The standard expectations of the customers that one can usually guess at constitute the basic needs (e.g., the car will start). The only time a customer will mention a basic need is if it is not satisfied. If all the basic needs are not fully implemented in the product, the customers will be disgusted with it. Thus, poor implementation of any basic needs results in disastrous customer satisfaction, while fully meeting all the basic needs merely results in neutral customer satisfaction.

Figure 3. Kano Model (Diagram adapted from that of Noriako Kano, Yoko University)

In the case of market-pull products, it is easy to infer some of the basic needs of several of the stakeholders. Consumers typically want a product that works as it should, lasts a long time, is easy to maintain, looks attractive, incorporates the latest technology, and has many features. The production customer wants a product that is easy to produce (both manufacture and assemble), uses available resources (human skills, equipment, and raw material), uses standard parts and methods, uses existing facilities, and produces a minimum of scrap and rejected parts. Meanwhile, the sales customer wants a product that meets consumers' requirements, is easy to package, store and transport, is attractive, and is suitable for display.

As can be seen in Figure 3, the performance-related needs correspond to all the customer requirements for which the degree of customer satisfaction is roughly proportional to the degree of their implementation in the final product. That is why these needs are also referred to as *linear satisfiers.* This category corresponds to all the customer requirements that are verbalized in the form "the better the performance, the better the product." Examples of performance related needs for the case of an SUV include cargo capacity and fuel economy.

Exciting needs are often unspoken because customers do not expect them. They include innovative and distinctive items, features, and/or services that put you ahead of the competition. As can be seen in Figure 3, if they are absent, the customers are neutral. However, if they are present, the customers' reaction to the final product is surprise and delight. At the present time one good example is the stow-and-go third row seats in a minivan, such as those pioneered by the Honda Odyssey. Honda engineers were very observant of minivan owners, and correctly deduced from observing drivers' behaviors and how they used their vehicles that this feature would surprise and delight the consumers. They were correct, leaving the competition to lose market share and play catch-up while subverting all of Honda's related patents. Now Daimler-

Chrysler is responding with an attempt at leap-frogging the competition by planning to be the first-to-market with stow-and-go seats in both the second and third rows of a minivan.

Assuming that all basic customer needs are met and that the degree of achievement on the performance needs is also competitive compared to other similar products, a product with some exciting features has a much higher probability of success in the market place than one without any. Finally, it is worth noting that features tend to move from the exciting category to the basic category over time. Returning to the minivan example presented in the previous paragraph, ultimately when everyone has caught up and has similarly functional stow-and-go third row seats, that feature will have moved from an exciting feature to a basic one.

In essence, the methodology that the authors teach in their PD related courses for the process of identifying customer needs is the one proposed Ulrich and Eppinger[19]. However, the authors also make extensive use of their own academic and industrial experiences and the ideas corresponding to the Kano Model. The specific details of the methodology together with the instructional approach used by the authors will be presented in detail in a subsequent section of the paper.

Description of the Courses Considered

In what follows, the interested reader will be able to find general information about two specific courses of the many in which the authors have implemented the instructional approach regarding determining customer needs that will be discussed in the next section. Both courses are taught using a project-based learning strategy in which the students work in small teams in a design project aimed at developing a product.

It must be pointed out that, in the case of senior design projects, the authors also request the student teams to follow a structured PDP. If as part of their program of study the students did not have a previous course in product development, lectures are incorporated as needed to cover all the fundamental concepts and methodologies that the students need to complete the different product development tasks that are included as part of the scope of their project.

Product Development

This is a one-semester, four-credit, sophomore-level course at South Dakota School of Mines and Technology (SDSM&T). It is a mandatory course for all the undergraduate students in Mechanical Engineering and it is an elective course for Industrial Engineering undergraduate students. The course description provided in the SDSM&T catalog is as follows:

"The course presents in a detailed fashion useful tools and structured methodologies that support the product development practice. Also, it attempts to develop in the students the necessary skills and attitudes required for successful product development in today's competitive marketplace. The cornerstone is a semester-long project in which small teams of students plan, conceive, design, and prototype a simple physical product. Each student brings his/her own background to the team effort, and must learn to synthesize his/her perspective with those of the other students in the group to develop a marketable product. An introduction to manufacturing aspects that must be taken into consideration during product development is provided in the context of a mini-project."

As can be seen in Figure 4, this course is considered a prerequisite for most of the mandatory and elective advanced solid mechanics courses that the Mechanical Engineering undergraduate students can take during their junior and senior year, including of course the senior design course sequence (Mechanical Engineering Design I & II).

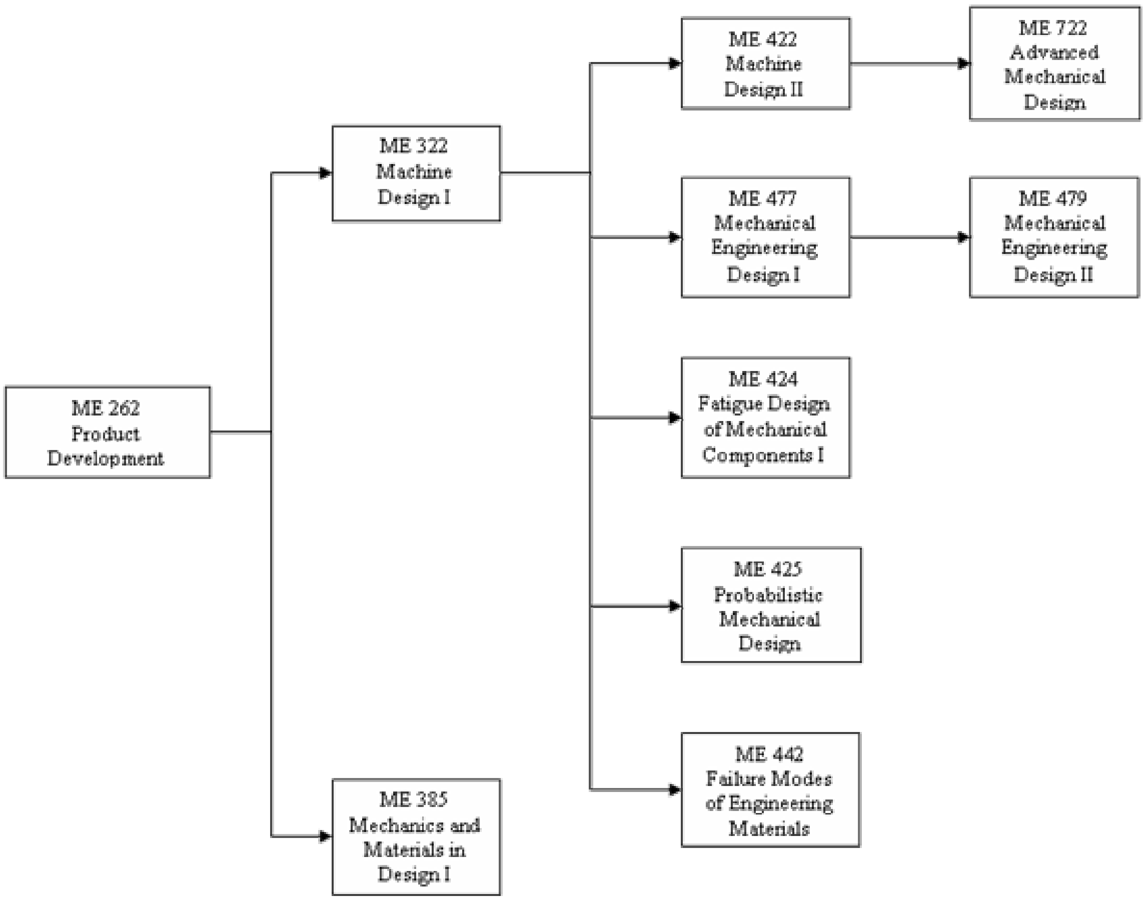

Figure 4. Course sequence analysis for the sophomore level product development course at SDSM&T

After taking this course, it is expected that the students should be able to:

- Develop a set team rules and an assessment strategy to be used during a structured product development process.
- Apply the basic elements of the Quality Function Deployment (QFD) methodology to identify the customer needs, carry out a competitive benchmarking, and set the target specifications for a product.
- Classify the customer needs according to the Kano Model of customer satisfaction.

- Decompose a problem into simpler sub-problems using a functional decomposition, a decomposition based on the sequence of user actions, a decomposition based on key customer needs, or a decomposition using a combination of these three alternatives.
- Carry out an effective external search for product concept ideas using resources such as consulting experts, searching patent databases, analyzing competitive products, etc.
- Use their own creativity to generate original product concept ideas.
- Apply the basic elements of the TRIZ methodology to generate product concepts.
- Effectively use concept classification trees and concept combination tables during the concept generation process.
- Apply decision matrices to select product concepts.
- Develop and carry out a prototyping plan.
- Create different types of prototypes for a given product concept.
- Prepare and execute a simple concept testing plan.

Product Planning and Development

This is a one-term, three-credit, mandatory course in the Master in Product Development Program (MPD) at the University of Detroit Mercy (UDM). The main goal of the course is to provide a fundamental understanding of all the key steps that are necessary in end-to-end product development and to gain the knowledge of and the ability to use various tools during each phase of the PDP. The topics covered in the course include both generic product development and automotive specific processes. In general terms, it is expected that after taking this course the students be able to:

- Describe the steps in a generic PD process.
- Describe automotive specific PD processes and the similarities/differences to the generic process.
- Identify the different functions in a product development organization and what they do.
- Apply PD processes to development of products.
- Be able to apply appropriate tools to each of the phases in a PD process.
- Be innovators within their company when it comes to improving PD processes.

We typically guide the student teams of five or six students per team through the project selection phase while allowing nearly full latitude as to the actual product they will develop. This course ultimately requires that they develop working proof-of-concept prototypes by the end of the term. Some examples of past projects taken on by students in the Product Planning and Development course include, among others, improved bicycle storage systems, a bicycle carrier for a motor vehicle, a tool for conveniently cleaning gutters from the ground level, a vehicle trunk/cargo area grocery organizer, an improved aftermarket in-car entertainment systems, an automatic fish feeder, and a doggie washer.

Instructional Approach

This section describes the approach the authors take with regard to teaching the process of identifying customer needs. The content of this section will be presented essentially as a discussion of the related key instructional content of our courses as well as some discussion of the associated student assignments and project requirements.

Instructionally, we lecture on each topic using PowerPoint slides that are made available to the students for download on our course web site, require some small assignments intended to reinforce the key concepts presented in class, and have the students actually apply the tools and processes described during the lecture to their product design project. We use assignments at various stages of the development process as both a means to keep the projects progressing at a rate that should ensure their completion by the end of the course, and as a means to provide feedback at numerous points during the students' projects.

The students are constantly reminded that one must thoroughly know his/her customers and how they plan to use the product to fully identify all of the customer requirements. Using a slight modification to the methodology recommended by Ulrich and Eppinger[19], we request the teams to follow a six step process to identify the customer needs:

Step 1. Gather raw data from customers.
Step 2. Interpret the raw data in terms of customer needs.
Step 3. Organize the needs into primary and secondary needs.
Step 4. Establish the relative importance of each need.
Step 5. Categorize each need according to the Kano model.
Step 6. Reflect on the results and the process.

In the paragraphs that follow, we discuss in some detail relevant information about each of these steps.

Step 1. Gather raw data from customers.

We recommend the students consider three methods of obtaining information from customers: interviews, observing similar or related products in use, and focus groups. We tell the students to place an emphasis on the first two strategies due to two main reasons. First, Griffin, Abbie, and Houser[29] have shown that typically two one hour interviews generate more knowledge about the customer needs than a single two hour focus group. Second, a successful focus group generally requires a professional level of skill, detailed marketing knowledge, and involves other logistical and timing difficulties. Although some companies also rely on written surveys or make use of the internet to try to gather customer data, we generally recommend students begin with interviews and observation. Time permitting, we show during a lecture some video clips of focus groups to better familiarize the students with that tool since it is very likely that the marketing organizations of the company they will be (or are) working for will routinely use them. We also use illustrative examples of customer surveys and assist them with the design of their own survey if they choose to develop one.

The question always arises as to how many interviews are necessary to be sure that virtually all needs are identified. This is a difficult question to answer rigorously when one does not have prior experience with a similar product. Thus, we usually ask the students simply to continue the process until further interviews generate no new useful information.

Step 2. Interpret the raw data in terms of customer needs.

Customer needs are expressed as written statements and are the result of interpreting the need underlying the raw data gathered from the customers. Each statement or observation made in the previous step may be translated into any number of customer needs. Multiple analysts may translate the same raw data gathered from the customers into different needs. Thus, we strongly encourage all the team members to participate this translation process.

In many cases, some customers actually try to prescribe specific design solutions (and often not the best ones). We ask the students to be very careful to understand the underlying need in a customer's statement and to be sure to capture it in solution neutral terms (i.e., as a need and not as a solution). For example, an automotive customer may say "having a handle here [gesture] would be great." The underlying customer need is not a handle, but rather ease of ingress/egress. The engineer must be sure to understand the real need. Otherwise, it is extremely unlikely that the development team will come up with truly innovative solutions. As an example, one of the concept cars recently presented by Toyota tilts the passenger compartment to ease the ingress and egress problem rather than providing assistive handles.

Consistent with Ulrich & Eppinger[19], five guidelines are given for writing the needs statements:

- Express the need in terms of what the product has to do, not in terms of how it may do it.
- Express the need as specifically as the raw data.
- Use positive, not negative, phrasing.
- If possible, express the need as an attribute of the product.
- Avoid using the words must and should.

Step 3. Organize the needs into primary and secondary needs.

In general, the output from the previous step is a list with a large number of detailed need statements. To be able to communicate in an effective fashion with persons outside of the core product development team, and for some of the subsequent PD activities, working with such a large number of need statements can be awkward and difficult. Thus, it becomes necessary to find a practical and convenient way to summarize them.

The goal of this step is to organize all the need statements into a two-level classification or hierarchy. The detailed need statements are grouped into different categories that become the primary needs. Each primary need is characterized by a set of secondary needs that correspond to detailed need statements obtained in Step 2.

Although many product development teams can successfully complete this task without detailed instructions, we recommend to the students to use the following methodology proposed by Ulrich and Eppinger[19]:

1. Print or write each need statement on a separate card or self-stick note.
2. Eliminate redundant statements.
3. Group the cards according to the similarity of the needs they express.
4. For each group, choose a label.
5. Review and edit the organized needs statements.

In lecture, we illustrate the above methodology with an example.

Step 4. Establish the relative importance of each need

The hierarchical list of customer needs generated in the previous step does not provide any information about the relative importance that customers place on each one of them. Having a sense of the relative importance of the needs is crucial since the development team will have to rely on that information to make trade-offs and allocate resources during subsequent tasks of the PDP.

The objective of this step is to assign a numerical importance weighting to each one of the secondary needs. For that purpose, we suggest to the students to use the following scale to specify the relative importance of each need:

1. Feature is undesirable to most customers.
2. Feature is not important.
3. Feature would be nice to have, but is not necessary.
4. Feature is highly desirable.
5. Feature is critical.

There are two basic approaches that can be used to establish the relative importance of the secondary needs: relying on the consensus of the team members based on their previous experience with the customers, or basing the importance assessment on additional interaction with the customers and customer surveys. Although the second approach is more reliable, due to time constraints we recommend to the students to use only the first one. We also find it useful to ask the students to tabularize all their results up to this point and we provide them templates for that purpose.

Step 5. Categorize each need according to the Kano model.

Since the Kano model of customer satisfaction can help the development team to gain a better understanding of the customers' expectations, we ask the teams to classify each one of the secondary need as basic, performance, or exciting. Based on the feedback that we have received from the students, this step has proven to be very useful since it has served as a "sanity check" for the results of the previous step of the process and for the way in which the team performed the process as a whole.

As background for this task, we like to involve the students in a class discussion intended to identify many of the basic, performance, and exciting needs of an automobile corresponding to a specific market segment that most of the students are familiar with.

Step 6. Reflect on the results and the process

The process of identifying customer needs is not an exact science. The development team must rigorously challenge its results to verify that they are consistent with all the knowledge and intuition the team has developed through many hours of interaction with customers.

From an instructional perspective, we use examples based on previous projects or case studies to illustrate each one of the six steps mentioned above.

At this point it is important to mention that in our courses we introduce, at an awareness level, all the key ideas corresponding to Quality Function Development[30] (QFD), but we do not ask the students to conduct a full QFD for their design project. Reference materials are suggested for the students wishing to pursue this topic in further detail.

Sample Student Projects

In this section we summarize and discuss two specific examples related to the process of identifying customer needs. These examples correspond to product development projects that were carried out by undergraduate students in past course offerings. Although the authors have instructed many product design projects using the approach that was described in the preceding section, they decided to select two projects that satisfied the following criteria:

- All the teams were working on the same product development project and there were more than five teams in the class.
- The teams were not allowed to share information about the project since they were competing against each other to conceive the most successful product.
- The product to be developed was a "market-pull" product with a potential consumer base that was relatively large.
- If they wanted to, all the teams had the possibility to interact with the most important stakeholders.

In 2001, the Mechanical Engineering senior design project at the University of Detroit Mercy involved the development of a hard, preferably self-storing, tonneau cover for the new Ford Thunderbird. Five teams of five students each and one team of six students worked on this design project over a period of two consecutive academic terms under the close supervision of the first author. Ford Motor Company supported this project both financially as well as through access to technical experts, CAD data, vehicle prototypes, and six "bodies-in white." As will be seen in this discussion, this project will illustrate an example where initially the teams had some difficulties identifying all the customer needs.

The faculty member teaching the capstone senior design course sequence and two Ford engineers worked together to prepare the mission statement for the project. Table 1 summarizes all the elements of the mission statement that was given to the teams as the starting point for their product development effort.

Table 1. Mission Statement for the "Ford Thunderbird Hard Tonneau Cover (HTC) Project"

Product Description	Hard, preferably self-storing, tonneau cover for the Ford Thunderbird that matches the current style of the vehicle, is highly reliable and durable, requires minimum maintenance, and perfectly seals the covered area.
Key Business Goals	• For a painted, self-storing, hard tonneau cover, the production cost of each cover must be less than or equal to "C1" and the required investment must be less than or equal to "I1". • For a painted, manual storing, hard tonneau cover, the production cost of each cover must be less than or equal to "C2" and the required investment must be less than or equal to "I2". • Production volume of "P1" to "P2" units per year. • The hard tonneau cover will be introduced in the "Y1" model year. The "job 1" date for this model year is month "M" of year "Y2". • At this point it has not been decided if the hard tonneau cover will only be an option or if it will be standard in all vehicles.
Primary Market	Market segment corresponding to the Ford Thunderbird: All the relevant details of this market segment were provided to the students.
Secondary Markets	None.
Assumptions	• Self-storing. • Perfectly seals the covered area. • The design perfectly blends with the styling of the vehicle. • Requires minimum design changes to the vehicle. • Highly reliable and durable. • Requires minimum maintenance. • Easy to use. • Easy to manufacture, assemble and install in the vehicle. • The control to operate the cover must be located within easy reach of the driver. • The convertible top cannot be modified.
Constraints	• Must satisfy all the applicable government regulations currently in force. • Cannot make any changes to the structural elements of the vehicle. • It is possible to attach components to the key structural elements of the vehicle as long as they are not weakened. • The only source of energy to provide power to any component is the electrical energy available in the vehicle. • The space available to store the cover is, in order of preference: - The space in the trunk below the convertible top stowage area. - The storage space behind the seats. • If the space behind the seats is used, the range of motion of the seats must not be affected. Also, the operation of the cover must not create discomfort to the passengers. • The only element of the body of the vehicle that can be modified is the panel behind the convertible top stowage area.
Internal Stakeholders	• Marketing. • Design Studio. • Engineering. • Manufacturing. • Customer Service. • Purchasing.
External Stakeholders	• Consumers. • Ford Dealers.

It must be pointed out that all the numerical values that were given in the original mission statement for the product were intentionally masked in Table 1 due to obvious reasons.

So that the reader can have a better understanding of the scope of the design project and of some of the assumptions and constraints given in the mission statement, Figure 5 shows a top view of the convertible top stowage area of a Ford Thunderbird prototype.

Figure 5. Thunderbird Prototype Vehicle Showing Stowed Convertible Top

The teams were asked to follow the structured methodologies outlined in the previous section to identify the customer needs. Because the authors know from experience that, in most cases, the majority of the teams are not very effective during their first attempt to identify the customer requirements, they ask the students to perform this task and to immediately submit their results for feedback and grading. At this stage, the authors usually proceed to compile a comprehensive list summarizing the different customer needs that were identified by the teams and use that list as one of the tools to provide guidance to the class as a whole and to each team in particular regarding any deficiencies detected. Then, if needed, a team can proceed to repeat the process in order to obtain an improved list of customer needs. For the Thunderbird project, Table 2 summarizes the results obtained after the teams' initial pass at identifying customer needs. It is obvious that this list is incomplete. For example, notice that only one team stated the need for the mechanism to use the electrical energy available on the vehicle although this is an important constraint (need from Ford) that is given in the mission statement. Numerous other arguably important needs went unidentified by most of the teams during this first attempt. For example, just two teams considered regulatory requirements. Although all the students knew the target market for the product right from the first day of the project, a couple of teams decided to try to identify customer needs by also interviewing some friends and/or relatives that did not fit the description of the type of person that may consider buying a Thunderbird. Given these and other problems, the authors feel that the practice of compiling the needs and providing feedback to the teams based on that information constitutes an important step for not letting success "slip away" from some teams at this early stage in the course.

Table 2. Customer Needs for the "Ford Thunderbird Hard Tonneau Cover (HTC) Project"

Category	Need	# of Teams	Imp.
Styling	The HTC preserves the "retro" look of the vehicle	6	5
	The HTC color blends with the rest of the vehicle		5
	The HTC has few visible seams		4
Ease of Operation	The HTC operation is automatic	6	5
	The HTC control switch is positioned ergonomically		4
	The HTC is self storing		5
	If manual, the HTC operation requires a single person		4
Safety	The HTC cannot be operated at high speeds	2	5
	The HTC is well secured to the vehicle		5
	The HTC operation has no pinch and contact points with passengers		5
	The HTC does not infringe into the passenger compartment in a crash		5
	The HTC does not affect the structural strength of the vehicle		5
Sealing	The HTC perfectly seals the convertible top stowage area from dust and water	5	5
	The HTC channels water to existing drainage system		5
Functionality	The HTC preserves the open experience	5	5
	The HTC supports moderate weight		4
	The HTC does not hinder visibility		4
	The HTC operation is fast		4
Energy	The HTC mechanism uses electrical energy available on board	1	5
Serviceability	The HTC is easy to remove and reinstall	3	4
	The HTC is light weight		4
	The HTC mechanism is simple		4
	The HTC can be repaired using common tools		4
	The HTC parts are easily accessible		4
Durability	The HTC lasts the life of the vehicle	6	5
	The color of the HTC does not fade		4
Reliability	The operation of the HTC has good reliability	6	5
	The HTC is designed for frequent use		5
	If automatic operation of the HTC fails it has a manual override		4
Cost	The HTC does not add substantially to the vehicle price	2	5
	The HTC causes minimum design changes to the vehicle		5
Exciting Features	The HTC detects precipitation and operates cover and CT automatically	1	3
	Operation of the HTC is possible at low speeds		3
	The HTC operation can be remotely activated from the key pad		3
	The HTC has illumination when it is in operation		3
Legal Requirement	The HTC mechanism satisfies federal regulations	2	5
	The HTC design does not violate existing patents		5
DFMA	The HTC mechanism has few total parts	2	4
	The HTC mechanism parts are symmetric		4
	The HTC has good accessibility for assembly		4
	The assembly of the HTC only requires common tools		4
	The HTC uses standard parts		4
	Manufacturing of the HTC uses current processes, materials and equipment		5
	Manufacturing of the HTC requires minimum tooling changes		5
NVH	The HTC does not give rise to noise during vehicle motion	2	5
Packaging	The HTC mechanism is compact	3	4
	The HTC not interfere with convertible top operating mechanism		5
	The HTC mechanism maintains trunk space		5
	The HTC mechanism allows normal movement of the seats		4

In the case of the Thunderbird project, after the students made a second attempt to correct the initial deficiencies that were detected, in general the list of customer needs that was presented by each team was more complete and the teams based all their subsequent development steps on their improved lists of customer needs. Obviously the method of compiling needs across teams to help ensure completeness only works when all teams are working on the same project.

Ultimately, the students continued the product development process and each team built a working physical prototype of the product concept that they selected. There was naturally some variation in the perceived effectiveness of the concept proposed by each team. As an example, Figure 6 shows the physical prototype that was presented by one of the teams at the end of the project. This particular cover is actuated using two motorized four-bar linkages (one on each side) and it is very nicely packaged to fit existing geometry and constraints. Something that perhaps can be perceived as a disadvantage of this particular design is that requires the modification of the convertible top. However, during one of the early stages of the PDP, this team negotiated with Ford personnel the approval of this deviation from the original assumptions that were given in the mission statement for the product. It is interesting to note that two of the teams diverged in the design path from the other four when they proposed manually operated rather than automatic covers. This decision was most likely driven by the difficult trade-offs between cost, complexity, and convenience, and we cannot say with certainty how good that decision was. In the "real world," the customers would ultimately speak to that.

Figure 6. One Team's Prototype HTC

The second example that we will consider here corresponds to a product design project that was carried out during the fall semester of 2002 as an integral part of a sophomore-level product development course that first author taught at SDSM&T. A total of 73 undergraduate students whose major was either Mechanical or Industrial Engineering were enrolled in this course. The design project selected by the instructor involved developing a flying toy that was capable to transport a crew of at least two GI Joe® toy soldiers whose individual heights were approximately four inches. Table 3 presents all the information corresponding to the mission statement that was given to the students at the beginning of the semester.

Table 3. Mission Statement for the "GI Joe® Super Flyer Project"

Product Description	Safe, resistant, and attractive flying toy capable to transport a crew of at least two GI Joe toy soldiers whose individual heights do not exceed approximately four inches.
Key Business Goals	Short Term: • Comprehensive physical prototype ready by Monday December 9, 2002. • Make the most effective and efficient use of the material and facilities available on campus to build the comprehensive physical prototype. • Keep any out of pocket expenses to a minimum. • The selling price of the product should be at the most 80 dollars. Long Term: • Introduce the product to the US market in April 2004. • Start exporting the product to other countries in October 2004. • Capture 15% of the US market for flying toys by the end of 2004. • Have a profit margin of at least 25% of the product cost.
Primary Market	Middle class boys who are 7 to 12 years old.
Secondary Markets	Upper class boys who are 7 to 12 years old.
Assumptions	• The toy is safe. • The toy gets the attention of the children in the target market. • The toy can be used with GI Joe toy soldiers whose individual heights do not exceed approximately four inches. • The toy can fly both in open and in closed areas, indoors or outdoors. • The toy is strong enough to resist impacts due to landing without being damaged. • The toy can transport during its flight a crew of two or more GI Joe toy soldiers.
Constraints	• If some assembly is needed, it must be simple enough so that a single child can assemble the product without any help. • A single child must be capable of launching the toy. • Once the toy starts to fly, it must not be controlled by any external means. • Besides any energy provided by the child, the only source of energy that the toy can have must come from standard batteries.
Stakeholders	• Children in the target market. • Parents of the children in the target market. • Toy stores. • Department stores. • Distribution Centers. • Customer Service Department. • Sales Department. • Legal Department. • Production.

The 73 students taking the course were divided into nine teams as follows: four teams of ten students each, two teams of nine students each, one team of eight students, and one team of seven students. At this point it is very important to clarify that having such a large section was definitely not the idea of the instructor teaching the course. It became necessary to form teams with such a large number of students because it was extremely difficult for a single instructor without adequate TA support to manage more than eight or nine teams working in a product development project. It has been the authors' experience that, in an academic setting, design teams of more than five students are usually at a high risk of experiencing relatively serious teaming problems, starting from the basic aspect of trying to find common meeting times that can fit around the busy schedules of so many students. Furthermore, when a large number of students are involved in a product design team, decision making usually becomes difficult. Also, any lack of coordination among the students can result in a dramatic decrease in the efficiency of the team. In an effort to try to minimize as much as possible teaming problems, during the first two lectures of the semester the tools and techniques for working in teams given by McGourty and De Meuse[25] were covered in the course.

As the first step in the process of identifying customer needs, the students are asked to reflect about who the customers are. Something particularly interesting about developing a toy like the one considered here is that, in general, the person making the decision to purchase the product is not the same as the person that will actually use it. Due to the limitations in time and resources, the teams are requested to decide which ones are the most relevant customer groups that, as a minimum, they should consider for the purposes of identifying customer needs. Then, the teams are asked to document their decision using both the first row and the first column of a customer selection matrix like the one shown in Table 4, which was taken from the final report submitted by one of the teams. In the cells of the matrix, which represent the different customer groups, the students are asked to record the number of one-on-one interviews and the number of focus groups, if any, that they conducted for each customer group.

Table 4. Sample Customer Selection Matrix for the "GI Joe® Super Flyer Project"

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="7">Stakeholders</th></tr>
<tr><th>Lead Children</th><th>Children</th><th>Lead Parents</th><th>Parents</th><th>Grandparents</th><th>Toy Stores</th><th>Department Stores</th></tr>
<tr><td rowspan="3">Target Market</td><td>Middle Class Boys</td><td>0</td><td>18</td><td rowspan="3">0</td><td rowspan="3">18</td><td rowspan="3">5</td><td rowspan="3">2</td><td rowspan="3">3</td></tr>
<tr><td>Upper Class Boys</td><td>0</td><td>1</td></tr>
<tr><td>Girls</td><td>0</td><td>2</td></tr>
</table>

In the case of the customer selection matrix given in Table 4, the team did a very god job at selecting the target markets and the relevant stakeholders taking into account that SDSM&T is located in a small city. The only problem is that the students considered the parents/grandparents of different target markets as a single customer group. There are two interesting aspects about the information contained in the table that are worth mentioning. First, the team was unable to find any lead children or lead parents during their interactions with the customers. In general terms, lead users are an excellent source of information for identifying customer needs since they can verbalize new needs (i.e., latent needs) months or years ahead of most customers[19]. Second, the team decided to include girls as a secondary market after they conducted a small focus group at a local elementary school.

Once the teams identified the different customer groups that they were going to take into consideration, they were asked to gather raw data by using one-on-one interviews, by observing similar products in use and by taking a careful look at the different environments where a child may try to use a flying toy. Also, the teams were requested to check all the regulations applicable to their product and to pay particular attention to safety issues. As can be seen in Figure 7, some of the teams also decided to conduct focus groups at local elementary schools.

Figure 7. Visit to an Elementary School Class to Gather Customer Needs

Before conducting the interviews, the teams were asked to create a template like the one shown in Table 5, which was taken from the final report submitted by one of the teams, for each one of the different customer groups that the team decided to consider. Since the team members usually split into sub-groups of either two or three students to carry out the interviews, it is very important for all the sub-groups to follow a similar format. Also, the students need to carefully think in advance the specific questions/prompts they are going to start a conversation with the customers. This is particularly important because, in general, the questions/prompts will change for each customer group. Also, the team must make sure that the questions/prompts used will truly promote a conversation with the customer rather than give rise to "yes/no" or very short answers. The team cannot expect to be able to actually "listen the voice of the customer" unless it manages to get the customer to talk and express his/her needs.

Table 5. Sample Form to Record Interviews with 7-12 Years Old Middle Class Boys

Customer Name	"Optional"	Date
Approx. Age		Place
Phone	"Optional"	Start Time
E-mail	"Optional"	End Time
Address	"Optional"	Team Members

Is the customer willing to do follow up: Yes ☐ No ☐

Introduction / Product Description Safe, resistant, and attractive flying toy capable of transporting a crew of at least 2 GI Joe toy soldiers whose individual heights do not exceed approximately four inches.		
Question/Prompt	***Customer Statements / Observations***	***Interpreted Needs***
Do you play with GI Joes?		
Do you have a toy that flies? **YES** What would make it better? What do you not like about your flying toy? Where do you usually play with your flying toy? **NO** Would you like to have a flying toy? What kind of flying toy would you like to have? If you had a flying toy, where would you play with it?		
If you had a flying toy that carried GI Joes, where would you want to put them?		
If you could make your own flying toy what shape would you give it? **(Use Visual Aide)**		
Write a paragraph/journal entry describing the ultimate flying toy you would like to build to transport small action figures.		
Draw a picture and describe a flying toy that you would like to build to transport small action figures.		
Latent needs identified during the interview / Comments		

It is interesting to note that some teams developed and used during the interviews visual aides like the one shown in Figure 8. As can be seen from Table 5, those teams clearly defined at which particular point during the interview they were going to use each visual aide. Also, in the case of the interviews with children, some of the teams asked them to draw a flying toy and to write a story about it. This helped the students to identify themes, color schemes, shapes, and specific features (like lights, sounds, armament, etc.) that the children liked. As expected, the teams found that there were differences among the information gathered from the children. For example, some of the kids wanted a "red, white, and blue" patriotic color scheme for their toy, others preferred a "camouflage type" of color scheme, etc. To help the students cope with this situation, they were reminded that for the project they wanted to come up with a single product that had the greatest sales potential possible and that in the "real world" most toy manufacturers usually offered several options and not a single design.

Figure 8. Visual Aide Used by One of the Teams During the Interviews

Table 6 presents a comprehensive summary of all the customer needs that were identified by the teams. This list was compiled by combining the information contained in the final report that was submitted by each one of the nine teams. It is important to mention that there were three teams that did an excellent job and had in their list most of these needs.

Table 6. Customer Needs for the "GI Joe® Super Flyer Project"

Primary Need	#	Secondary Need	Imp.	Kano Model
The SF has good flight characteristics.	1	The SF flies indoors.	5	Basic
	2	The SF flies outdoors.	5	Basic
	3	The SF can perform stunts.	4	Exciting
	4	The SF is easy to launch (a single child).	5	Basic
	5	The SF flies fast.	3	Performance
	6	The SF flies an appropriate amount of time.	4	Performance
	7	The SF flies an appropriate distance.	4	Performance
	8	The SF can land on a solid or liquid surface.	2	Exciting
	9	The SF allows the user to control flight height.	3	Exciting
	10	The SF allows the user to control flight time.	3	Exciting
	11	The SF allows the user to control flight distance.	4	Exciting
	12	The SF allows the user to control flight direction.	2	Exciting
	13	The SF lands near its launch point.	4	Performance
The SF is attractive.	14	The SF has an attractive color scheme.	4	Performance
	15	The SF has an attractive shape.	4	Performance
	16	The SF has an attractive size.	5	Performance
	17	The SF can be customized by the user.	1	Exciting
	18	The SF has symmetric decoration.	2	Performance
	19	The SF can be painted.	2	Exciting
	20	The SF looks realistic.	4	Performance
	21	The SF looks futuristic.	3	Performance
	22	The SF is educational.	2	Exciting
	23	The SF has attractive packaging.	4	Performance
The SF is durable.	24	The SF does not break upon landing.	5	Basic
	25	The SF does not break during launch.	5	Basic
	26	The SF has a warranty.	5	Performance
	27	The SF does not have parts that break off easily.	5	Basic
	28	The SF is easily maintained.	5	Basic
	29	The SF is made from durable material.	5	Basic
The SF is safe and meets Government Regulations.	30	The SF is free of parts that could pinch a child.	5	Basic
	31	The SF is nontoxic.	5	Basic
	32	The SF is not corrosive.	5	Basic
	33	The SF is not flammable.	5	Basic
	34	The SF is not explosive.	5	Basic
	35	The SF is not radioactive.	5	Basic
	36	The SF contains no lead paint.	5	Basic
	37	The SF has no electrical, mechanical or thermal hazards.	5	Basic
	38	The SF has no sharp edges.	5	Basic
	39	The SF contains no parts for a child to choke on.	5	Basic
	40	The SF operates at a reasonable noise level.	5	Basic
	41	The SF has slow descent.	5	Basic
	42	The SF does not damage the walls.	5	Basic
	43	The SF has controlled flight.	5	Basic
The SF is entertaining.	44	The SF is realistic.	4	Performance
	45	The SF is interactive.	4	Performance
	46	The SF is imaginative.	4	Performance
	47	The SF has moving parts.	4	Performance

Primary Need	#	Secondary Need	Imp.	Kano Model
	48	The SF has detachable parts.	4	Performance
	49	The SF has interchangeable parts.	4	Exciting
	50	The SF has a landing mechanism.	2	Exciting
	51	The SF has storage area(s).	4	Performance
	52	The SF glows in the dark.	2	Exciting
	53	The SF is capable of land as well as air travel.	3	Exciting
	54	The SF has radar to detect enemies.	2	Exciting
	55	The SF throws smoke during takeoff.	1	Exciting
	56	The SF ejects the GI Joes® when it looses control.	3	Exciting
	57	The SF holds the child's interest.	5	Basic
The SF has accessories.	58	The SF is transformable.	2	Exciting
	59	The SF has lights.	4	Performance
	60	The SF has decals.	4	Performance
	61	The SF has sounds.	4	Performance
	62	The SF is remote controlled.	3	Exciting
	63	The SF has guns/missiles.	4	Performance
The SF is simple.	64	The SF is easily assembled.	5	Basic
	65	The SF is compact/easily transported.	4	Performance
	66	The SF has a small number of parts.	3	Performance
	67	The SF is easy to use.	5	Basic
	68	The SF needs no batteries.	2	Performance
	69	The SF is lightweight.	3	Performance
The SF is cost efficient.	70	The SF is economically priced.	4	Basic
The SF meets the company constraints.	71	The SF can use standard batteries.	5	Basic
	72	The SF is capable of carrying two GI Joes®.	5	Basic
	73	The SF flies independently once launched.	5	Basic
	74	The SF is appropriate for 7-12 year olds.	5	Basic

Once the process of identifying the customer needs was completed, the teams carried out all the remaining activities of the concept development phase of the PDP. Also, the teams built physical prototypes of their proposed product concepts and demonstrated them during the final presentations. Just as an example, Figure 9 shows an initial prototype that was made by one of the teams for the purposes of refining its product concept and obtaining feedback from some of the customers.

Results

In this section, we will summarize some of our experiences and some of the results that we have obtained when we have used the instructional approach presented in this paper to guide teams of student through the process of identifying customer needs. Although we only included two specific examples in the previous section, the information contained here is based in all the project-centered product design classes that we have taught over the course of several years.

In general, the authors have observed that approximately 20% of the teams tend to really become customer advocates and continue the rest of the product development process wearing a "customer headset." These teams are the ones that ultimately tend to conceive the products that appear to best satisfy the customer needs and, consequently, are the ones likely to be successful if they were to be commercialized.

Figure 9. Early Prototype of the Product Concept Proposed by one of the Teams

About 20% of the teams do a very good job at identifying the customer needs when they are performing that particular task of the development process. They also use that information effectively to establish the target specifications for the product. However, later in the process they seem to lose focus of some important customer expectations when they are making some critical design decisions or are faced with difficult trade-offs.

Approximately 40% of the teams perform the process of identifying customer needs in a way that could be described as barely acceptable. Some of these teams try to keep the customer in mind during the rest of the PDP. However, since they were unable to recognize a relatively large number of customer requirements, their products seldom become the ones preferred by most customers. Other teams in this category tend to drift further away from the customers' perspectives as the development effort continues.

Finally, the remaining 20% of the teams seem to be somewhat ineffective at truly identifying all the stakeholders that must be taken in consideration and at implementing the methodologies used in the process to identify and prioritize the customer requirements. These teams often select product concepts that try to satisfy most of the needs that they identified but, because the list is fairly incomplete and there are additional deficiencies in the information corresponding to the relative importance of the needs, these teams almost always propose products that most likely would fail if introduced in the market place.

Something that must be kept in mind is that several crucial factors for the success of any product development effort are the interest, commitment, enthusiasm, and technical competence of the members of the development team. If these factors are missing, any methodology that one decides to use will be ineffective. This finding is consistent of our observation in industry that teams without a strong passion for the product they are developing seldom produce winning products.

Conclusions and Future Work

In conclusion, the process of identifying the customer requirements is a vital part of any product development effort. Hence, the authors consider that it is extremely important to include in any comprehensive product design course an effective instructional approach that can help the students learn the process, methodologies, and tools that are commonly used for that purpose. At the end, the ultimate success or failure of any product depends upon how thoroughly and how accurately this initial phase of the PDP has been done.

In this paper, we emphasized the relevance of identifying all the customer needs during the concept development phase of the PDP and we discussed in detail our instructional approach regarding incorporating aspects of needs identification and prioritization into our PD related courses. Two examples of past student work were summarized, one illustrating a case where the students were not particularly effective in their first attempt at identifying all the customer needs, and another where some of the teams did a superb job in this regard.

In the near future the authors plan to prepare two additional papers similar to this one. One devoted to the process of translating the customer needs into target specifications for the product and the other dealing with the important step of concept generation.

It is expected that as other competitive advantages across companies continue to decline from a technological standpoint, companies will begin competing essentially on the strength of their product development processes. Consequently, it is important that engineering education be poised to meet the changing needs of technical employers over time.

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