Integrating Production Aspects of the Product Realization Process into Mechanical Design Courses

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Abstract

This paper describes how the integration of the **P**roduct **R**ealization **P**rocess (PRP) into a mechanical engineering curriculum is incorporated with traditional design courses, and how it has enhanced them by increasing the range of possibilities and realism in design experience. PRP as developed in our current program involves the use of "desk top" scale manufacturing equipment[2]. Without an integrated PRP component in undergraduate design courses, there is usually no requirement for product realization prior to the "Capstone Senior Design" course, if it occurs at all. When students study production techniques using desktop or larger equipment, such as might be utilized in prototype development, they experience product realization and are motivated to return to this equipment for the creation of parts such as are needed to complete the "capstone senior design" project. This is only possible provided the equipment is capable of producing real parts, not just wax models. Even prior to a capstone design course, in a course such as machine component design, product realization equipment allows the students to make and examine actual components which have been vacuum formed, injection molded, blow molded, CNC machined, etc.. This greatly enhances the student's understanding. PRP is of value even when the design need only be verified on paper

I. Overhaul vs. Modification

The total restructuring of courses is a major task full of pitfalls. Such restructuring generally reaches beyond a particular course into the curriculum as a whole. Once PRP equipment and approaches are fully developed, such a restructuring may be desirable or even a naturally occurring evolution; however, a total restructuring of a course to incorporate a concept such as PRP may inadvertently underemphasize key material that has been previously properly emphasized in a course. For these reasons, an evolutionary approach to the implementation of a concept such as desktop execution of PRP is desirable.

Since this author favors an evolutionary approach to modifying existing successful course formats, some examples of deliberate enhancement, indirect or peripheral enhancement, and mandatory inclusion of PRP are presented.

II. Example of a Deliberately Enhanced Course.

The Mechanical Systems Design Course, as configured at The University of Texas at Tyler, has an advantageous configuration for implementing Product Realization components. This course is taught using texts such as Juvinal & Marshek's Fundamentals of Machine Component Design or Shigley & Mischke's Mechanical Engineering Design. Courses taught based on these and similar books are often lecture type courses, but at UT-Tyler the course is taught with a lab component. In the first portion of the semester, the labs are used to study, in depth, into some of the more involved computational techniques such as Castigliano's Theorem and curved beam stresses etc., as executed utilizing general computer computational applications. In the remainder of the semester, the lab is used to pursue team based design projects. It is in the lab in the latter portion of the semester that product realization techniques can be integrated.

A course may be enhanced with elements of PRP without necessarily directly impacting each and every student in the class. If PRP components are a direct part of a project of one or more students in a class, there will be enhancement of learning for others in the class, especially when the students work in teams.

In the ME program at the University of Texas at Tyler, in the Mechanical Systems Design Course, the students have had to perform two "design on paper" projects. The students have always been allowed to actually build a prototype or mockup if they desired, but it was not required and has been by far the exception rather than the rule. It is interesting to note the nature of students who actually did build mockups and prototypes, as they often have a different preferred learning style. Mockups built for this course have generally been crude, but for some student's learning styles, they did serve well. With the inclusion of PRP content in precursor courses, the ability and desire of students to make prototype and mockup parts has been increased.

The term "precursor" courses, rather than prerequisites, is used as some of the PRP content experienced by the students has fallen in courses which far precede the course in question and are at most prerequisites several semesters and intervening courses removed. Examples of such courses are "Introduction to Manufacturing" in the sophomore year, and "Fundamentals of Engineering" in the freshman year.

Students who fall into quadrant D of the Herrmann Brain Dominance Instrument, as discussed by Monika and Edward Lumsdaine [1], that is to say those whose favored way of knowing is dependent on visual and conceptual aspects, are strongly helped by PRP. The key PRP features from which these students benefit are rapid prototyping and the ability to create wax or real parts by "desktop" fabrication facilities[2]. Many of these students, who have been struggling to keep their grades up with their analytically oriented peers, often blossom and make great progress and contributions to their teams because of being able to touch and examine real parts and utilize them in explaining concepts to other students in their team. Because the desktop fabrication facilities make real parts out of real engineering materials, and because the rapid prototyping with paper laminations used at UT-Tyler produces parts of significant strength, students can actually make parts for a real prototype, as well as models and mockups.

III. Example of an Indirectly Enhanced Course.

A key issue in PRP and Desktop Fabrication is the ability to make real parts, not just wax models. The current UT-Tyler Mechanical Engineering program includes an Experimental Analysis course. The students in this course are required to run real engineering type experiments. A recent example of such an experiment was the statistical analysis of tensile properties of a metal alloy. In order to perform such an analysis, a large enough sample size (30+ pieces) of tensile specimens of a particular alloy was required. The presence of a desk top CNC lathe allowed the fabrication of the requisite number of specimens with the appropriate threads, fillet radii, tolerance, and surface finish to meet ASTM standards. Further, the CNC lathe produced greater uniformity than would be expected in manually machined specimens even when produced by a skilled shop technician. The content of the course was enhanced by a portion of the student's time being spent on refining their CNC programming understanding rather than mundane repetitive fabrication of specimens.

IV. Example of a Mandatory Course Enhancement.

The "Capstone Senior Design Course" at UT Tyler effectively requires students who are designing any machine or mechanism short of a large scale system or process to actually produce a working machine or model. A few students who have taken on projects arising from their employment outside academia have had the advantage of being able to purchase or have fabricated expensive and sophisticated one of a kind components. Students working on projects that are not so well backed, have found themselves on highly limited projects, restricted to unsophisticated components, and usually with limited choices of materials that can be machined by manual methods.

Utilizing CNC Desktop lathe and milling operations has increased the complexity of readily produced parts by an order of magnitude. The inclusion of injection molding, vacuum forming, and hot pressing has extended the student's range of materials into engineering and commodity plastics, composites and even ceramics. Most engineering students select projects in which the overwhelming majority of the parts would fit in the proverbial "shoe box". Virtually all such parts are well within the range of desktop machines.

In addition, the PRP desktop approach has put, in the reach and schedule of students, parts formed from materials which require tooling to be manufactured before the actual parts can be manufactured. The impact on their thinking is to free them from "one-of-a-kind" mentality and to begin to conceptualize in terms of "mass-production" components. Most of the students will take jobs in which a major component of their work will be either designing mass production parts or designing the machinery to make mass production parts. The PRP desktop approach has allowed a degree of realism to be introduced to their education which parallels the realism in computer based problem solving vs. "text book problems".

V. Conclusions

This author's experience with integrating the product realization process is primarily with upper division design courses, but the ability to do this is greatly enhanced by the introduction of PRP across the entire curriculum. Not only are the materials and manufacturing courses introduced at the earliest opportunity, but components of PRP are introduced at the freshman level. Consider for example the “Fundamentals of Engineering” course previously mentioned. Rapid prototyping is inherently linked to graphic/drafting skills[3] and logically fits in at the freshman level. Having learned how to draft a part, the students get to see the advantage of having a computer numeric file describing the part as the rapid prototyping software digests that drafting file and turns it into instructions to cut the multiple lamina of a three dimensional laminated paper replica of the part. The motivational and retention value of getting the students hands on the sophisticated PRP equipment should not be overlooked.

The concept behind Product Realization has been dealt with by others without specific recourse to the desktop manufacturing,[4] so one need not link the concepts irrevocably, but having experienced PRP as executed using desktop manufacturing, the efficiency and efficacy of doing the two together is manifest. This author can highly recommend that any one considering either PRP or desktop manufacturing should consider implementing the other simultaneously.

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