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Attitudes Toward Failure in Capstone Design Projects

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Abstract:
While working in industry during the 1980s and 1990s, project failures were to be avoided at all costs. For engineers in the medical device industry, these failures could be in the form of: 1) an idea for a new product or feature that eventually failed due to technical infeasibility, regulatory hurdles, lack of market interest, or difficulty in manufacturing; 2) a prototype that did not function as required; or 3) an animal or human clinical study that yielded poor results. They typically resulted in significant project delays, wasted time and money, and lost revenues, and often led to lower raises, fewer promotion opportunities, and damaged reputations.

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In an industry setting, experienced project managers quickly learn that almost no project is completed exactly as originally planned when the original project and schedule were established. Every project presents challenges that threaten the completion and market introduction date of the project, and the challenge for a project manager is to find ways to either prevent these delays or minimize their impact on the project schedule if and when they do occur. They also learn that breakthroughs and inventions cannot be predicted or planned. The creative process needs time to incubate and cannot be rushed or scheduled. Companies that attempt to do so by including these milestones in a project schedule will inevitably experience delays in their new product introductions.

Technical managers understand that a company's attitudes and policies toward failure can impact the quality and number of innovative ideas generated by the company's technical personnel (engineers, scientists, and others). If engineers are penalized if they pursue a design concept that is truly new and innovative, and it results in failure, then to avoid being penalized in the future, many of them will choose to work on more predictable, less risky new products that have a greater probability of success. They will prefer to work on projects over which they can exert more control, are more predictable, and more familiar with to increase the probability that the project can be completed as scheduled. They will not be willing to take a risk and try something new. This will have a significant impact on innovation, new product development, and revenue from new products.

Today, many books on innovation encourage people to "fail fast." This does not mean that companies are pleased if a project fails. It means that companies should encourage people to take risks and experiment with new ideas and accept that risk taking often results in failure. It acknowledges that failures will occur when developing truly innovative products, and that the sooner these failures occur and are dealt with, the sooner a new innovative product can reach the market.

Projects involving innovative new products tend to be riskier and cost more to develop, and may require new, unproven production processes. They may also present more regulatory and market acceptance risk. However, the typical risk/return relationship suggests that truly innovative new products, with their inherent higher risk, may have the highest potential return. Experienced engineering managers, product development consultants, and the innovation management literature recommend that companies focus not on the failure itself, but on what was learned from the failure. This information can help companies determine a new direction for the project (pivot) and prevent similar failures from occurring in other projects.

Studies of successful new product development teams indicates that when senior management implements policies that encourage teams to take risks and experiment with new ideas, teams tend to be more highly collaborative [1]. 3M has been known as a highly innovative company for many years. The company has policies that encourage experimentation with new ideas. Engineers and scientists at 3M can spend up to 15% of their time on "pirate" projects that are not approved or part of an assigned project [2]. They can use company facilities to experiment with new ideas and if these ideas do not result in a new product or solution to a problem, there are no consequences to the employee. There have been instances where this extracurricular experimentation led to new products for the company. Senior management has seen the payoff from this policy, which creates a culture of innovation and encourages creative thinking and experimentation. Policies that encourage risk taking and experimentation with new ideas, attitudes that acknowledge that failures will occur, and practices that focus on learning from failures all help create an environment that is conducive to creativity and innovation.

To prepare our students to work in and contribute to an innovation nurturing environment, and to enhance their learning experience in capstone design courses, an environment that encourages risk taking and experimentation is needed. However, in academia, students are not typically encouraged to fail and certainly not rewarded for failure. The focus on grades treats failure as the worst-case scenario. This makes sense for exams and research papers where students are expected to demonstrate mastery of the course material. Engineering students must be able to correctly apply what they learn in the classroom to calculate forces, stresses, pressures, flow rates, current, voltages, and other values. They must also be able to properly use analytical tools such as finite element or failure modes and effects analyses. The inability to do so could result in injury or other harm to patients, medical personnel, and caregivers. These types of calculations and analyses are straightforward and do not involve risk taking or innovation, justifying a low tolerance for failure in these applications. While appropriate for many engineering courses, this low tolerance for failure may not be appropriate for a design course.

To encourage and nurture innovation among our students, we need to create a culture within capstone design courses that is more tolerant of failure. In many of these courses, a prototype that does not function properly is considered a failure and often earns a lower grade than one that is fully functional. Grades for capstone design courses should not be based solely on how well the prototype functions; instructors should consider the cause of the failure. Lower grades are appropriate if the team did not spend adequate time on the project due to laziness, lack of interest in or dedication to the project, and other similar reasons. However, if the team was committed to the project, demonstrated persistence in trying to get the prototype to work, and built and tested more than one prototype iteration, then the grade should reflect this. If a student team could explain to me in their final report why the failure occurred and how they would revise the design if they had more time and resources to solve the problem, it would demonstrate to me a solid understanding of the design and how to improve it, and I would consider this when assigning the final grade. I feel that the final grade should focus on what the team learned from the project. If the team tried a truly innovative approach or developed an innovative concept, they should not be penalized, but rewarded for trying, as long as they made a serious attempt to test the concept and understand as much as they could about how to modify the prototype to get it to work better.

This approach may be difficult to implement in design courses that include projects that are heavily funded by industry sponsors. If it is expected that in exchange for significant project funding, the team will provide a fully functional prototype, then to keep industry sponsors happy, there may be less tolerance for failure. Industry sponsors should understand that if they want the team to develop a truly innovative new design concept, then they need to accept that the team may experience failures and not deliver a fully functional prototype at the end of the course. If the team is expected to provide a fully functional prototype at the end of the course, then students may feel that there is less tolerance for failure. This could result in more straightforward, conservative design concepts than more innovative, risker design concepts proposed and investigated by the students.

In my opinion, the focus of a capstone design course should be on learning about design (process), not only on delivering a functional prototype to a client (product). In a 2015 survey of 208 capstone design instructors, respondents were asked: "How do you balance product versus process in your capstone design projects?" Survey results indicated that although there were courses that focused only on product or only on process, most respondents either weighed the two equally or emphasized process [3].

In summary, if we want our students to design innovative new medical devices during their careers, then we need to encourage them to take risks and experiment with new ideas, and make them comfortable taking risks, before they enter the medical device industry. We can learn from companies that provide environments that are conducive to creativity and innovation and find ways to reward risk taking and new ideas in capstone design courses.

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