

---

# ***Axiomatic Design***

## ***Short Course***

***WPI campus***  
***May 9 and 10, 2006***

---

*A two-day training course composed of lecture, discussion and application practice for engineers and managers intending to learn axiomatic design.*

*Axiomatic design solves design problems, fosters innovation, and shortens design cycles, while improving product and process designs, and promoting collaboration.*

*It goes beyond lean in process and system design, and reduces time to market for product design.*

***Faculty:***

Christopher A. Brown, PhD, PE

*Professor of Mechanical Engineering, WPI*

A leader and pioneer in the application and teaching of axiomatic design, he has over two decades of experience using and teaching axiomatic design in academia and industry.

***Featuring:***

Lectures and discussions on basic and advanced axiomatic design.

Design exercises in applying the principles of axiomatic design to a wide range of design and planning situations.

Participant selected design applications with coaching and design reviews.

Acclaro Software.

May 9 and 10, 2006  
116 Higgins Labs  
WPI  
Worcester, Massachusetts  
[www.axiomaticdesign.org](http://www.axiomaticdesign.org)

---

## BACKGROUND

Axiomatic Design refers to a design system that can significantly improve any type of design activity, including planning, although it is more aptly applied to engineering design problems than to industrial design. It is not about drafting or CAD.

Axiomatic design starts with the premise that good design is governed by axioms, or laws, like physics is governed by physical laws. It was developed initially by Prof. Nam Suh at MIT in the late 1970s. Using a design structure and a design process, intended for the application of these laws, Axiomatic design has been shown to reduce design times, facilitate documentation of design decisions and produce better designs.

The use of Axiomatic Design has facilitated improvements in design by shortening the design process, assisting with collaboration, and aiding in innovations and inventions. Properly applied Axiomatic Design allows for functional modeling that eliminates the need for costly design iterations.

### **COURSE LEADER – Professor Christopher Brown, PhD, PE**

Chris Brown has been teaching axiomatic design at WPI and in industry since 1990. Students in his evening graduate course typically report that they start using axiomatic design at work within the first few hours of the course.

Chris started using axiomatic design when he was a graduate student in the early 1980s at the University of Vermont after meeting Nam Suh. As a senior research engineer, Chris used axiomatic design to design products and processes for Atlas Copco at their research center in Switzerland before coming to WPI. In the past few years Chris has been pleased to have had the opportunity to consult with Nam Suh on design problems.

*"Chris Brown is one of the leading experts in the world on axiomatic design. He is a pioneer in developing effective teaching methods for applying axiomatic design and has developed a keen insight to the design theory and practice. Professor Brown's former students have had great success in industry in improving the productivity and quality of their products."* Prof. Nam P. Suh, MIT, the originator of axiomatic design

## THE APPROACH

This special approach to teaching axiomatic design has been developed and published by Prof. Brown over the past decade and a half. The objective of Brown's special approach is to teach people quickly and effectively how to use axiomatic design.

Brown divides the practice of axiomatic design into three elements: the axioms, the structure, and the process. These elements are presented, applied and practiced over the two days of the course at basic and advanced levels.

---

## **PARTICIPANT PROFILE**

The course is for engineers, managers, directors and vice presidents involved in product, process and system development and design. This would include all the traditional engineering disciplines as well as manufacturing engineers.

Participants will apply axiomatic design to problems that they bring with them, and benefit from coaching during the process and design reviews. Participants will have the opportunity to work on designs in groups.

Specific technical and business functions that could find this course especially beneficial and of particular interest would be:

- Product Development
- Research & Development
- Engineering Design
- Project management
- Process Development
- Manufacturing

## **COURSE OBJECTIVES**

The objective of the course is to supply the participants with enough knowledge and experience to be able to apply axiomatic design to their own tasks immediately after the course. For example, Managers will learn how to evaluate designs through functional modeling, avoiding expensive iterations with prototypes.

The skills that will be acquired include:

- How to go from argument to analysis in evaluating competing designs
- How to apply the two design axioms, and corollaries, qualitatively and quantitatively to a wide variety of design and planning problems
- How to structure the design to facilitate the systematic application of the axioms
- How to formulate a functionally based design with constraints to align with the corresponding physical, process, and tooling elements
- How to develop functional requirements in a hierarchy so that at each level they are collectively exhaustive and mutually exclusive
- How to integrate physical elements and avoid physical coupling
- How to discern functional requirements and constraints
- How to recognize different kinds of coupling and address them
- How to avoid unintended consequences, so that a design remains controllable and adjustable
- How to apply axiomatic design to manufacturing processes and systems and go beyond lean

---

## AGENDA

**Tuesday 9 May 2006**

### **Basic Axiomatic Design**

8:30 registration and coffee and pastries

9:00 class starts

**Introduction to the design axioms – qualitative applications** and exercise

10:30 break and refreshments – review and feedback on the exercise

**Introduction to structuring and decomposing design**

Preliminary exercise in design decomposition

12:00 lunch, review and feedback on the exercise

**Applying axiom one - design matrices**

2:30 break and refreshments – with review and feedback on the exercise

**Applying axiom two** – narrowing alternatives quantitatively

**Integration and Practical design** – self selected problem

5:00 formal finish of day one – certificates distributed

Students are invited to stay later for informal work and review on their designs

**Wednesday 10 May 2006**

### **Advanced Axiomatic Design**

8:00 – 9:00 registration and coffee and pastries

8:30 Review of basics - primarily for those coming second day only

9:00 Advanced Class starts

**Advanced Axiom one** –Application specific coupling – sequence dependence - exercise

10:30 break and refreshments – review and feedback on the exercise

**Advanced Structure – creating domains, comparing themes** – exercise

12:00 lunch, review and feedback on the exercise

**Assigning interactions – quantitative approach and Inheritance in the matrix**

2:30 break and refreshments – with review and feedback on the exercise

**Managing axiomatic design – team work - staying on track**

Advanced full design exercise

**Design reviews**

5:00 design reviews and finish of formal session

**Further design reviews by appointment**

Through the first week in June

---

# COURSE PROGRAM

**Tuesday 9 May 2006**

**Basic Axiomatic Design**

## **1. Introduction to the design axioms – qualitative applications**

The applicability of an axiomatic approach to design is established. The importance of functionally based design is presented in the context of functional and physical design domains. The two axioms, independence and information, are introduced. Independence is discussed in terms of making a design adjustable and controllable, and in avoiding unintended consequences. Correspondence between the design domains is introduced. Information is discussed in terms of maximizing the probability of fulfilling the design functions. The best designs are those that fulfill the functions with the greatest independence and the least information. Qualitative application to design is developed. Examples are presented and discussed.

## **2. Introduction to structuring and decomposing designs**

In axiomatic design the design is structured so that the axioms can be applied. The structure is developed through a process of decomposition into hierarchies from general to specific, across design domains, which are corresponding descriptions of the design. No design can be better than its functional requirements (FRs). The essential elements for developing good FRs will be taught and practiced using several kinds of tests, including CEME (collectively exhaustive and mutually exclusive).

## **3. Applying axiom one - design matrices**

The correspondence between the functional and physical domains is represented in a design matrix. The matrix can be evaluated to determine the level of independence. It can be used to determine if an order of adjustment of the elements of the physical domain is critical, and what orders of adjustment will eliminate inefficient iterations to achieve the desired functions. The design matrix is also used to evaluate competing designs.

## **4. Applying axiom two – calculating information content**

Axiom two is often underutilized. It is used to select between alternatives that have the same level of independence. It can be used to improve yield in manufacturing and robustness in product design. Information is developed quantitatively from the probability of success. Information provides a common basis for comparing design alternatives with components that have different units.

## **5. Integration and Practical design**

The final step is to integrate the elements of the physical domain that were identified and selected in the decomposition. A physical integration matrix will be used to check for unintended coupling between the physical elements. Clear links to the functions elements and identification of the corresponding physical elements are part of the design product.

**0. Review of basics - primarily for those coming second day only**

Ability to use the axioms is assumed. The basics of the structure and process used to support axiomatic design will be reviewed briefly.

**1. Advanced Axiom One – Forms of coupling and how to address them**

Means for identifying several individual kinds of coupling and how to deal with them will be covered. For example, DP-FR coupling is the most commonly encountered and is what the design matrix addresses primarily. FR-FR coupling cannot be addressed by manipulating the design matrix or selecting new DPs. FR-FR coupling results from poor development of the FRs and requires redefining FRs and constraints. The application of CEME to the FR definition process will be addressed. DP-DP coupling can occur during physical integration, and when existing designs are examined. Sequential coupling arises in process design when operations appear to have to be done in sequence. It can obscure other kinds of coupling when using the design matrix.

**2. Advanced Structure – Creating domains, comparing themes**

Based on advanced applications work there are several questions that need to be addressed as designs advance in their complexity and interaction with other designs and objectives and organizations. When do you add siblings or create a new level? How do you know if you are designing the process or the tooling, the mission or the equipment? When does it matter? Would the design process be expedited by creating another domain? Is it time to create a new domain or start another design process with another theme? Techniques for recognizing when the design would be expedited by a change in the structure and how to do it will be reviewed and discussed.

**3. Assigning interactions – Quantitative approach - Inheritance in the design matrix**

When should you write equations to express the DP-FR interactions, and how can you do it? How can you identify the interactions in the equations? What can you do to understand the interactions when the equations are not obvious? How do you assign tolerances through the interactions? When an off-diagonal child interacts, what influence should this have on the parents? How can you check to see if coupling is properly inherited through the design matrix?

**4. Managing axiomatic design – Team work - staying on track**

How do you exploit the potential of teams in design work? Apply the advanced approach to effective collaborative negotiations in addressing design options. Learn how to manage a design review and effectively critique design projects.

**5. Further design reviews by appointment**

Through the first week in June design reviews can be scheduled with Professor Brown by appointment. Appropriate time and additional charges, if any, will be decided based on the individual situations.

---

## BREAKOUT DESIGN EXERCISES

**Tuesday 9 May 2006**

**Basic Axiomatic Design**

### **1a. Qualitative applications of axiom one, independence**

- recognize DP-FR coupling

### **1b. Qualitative applications of axiom two**

- differentiate designs with different levels of information

### **2. Introduction to structuring and decomposing design**

- use Acclaro to decompose a design of your choosing by developing corresponding FR-DP hierarchies, working in groups or individually. Where the designs may involve proprietary information the design review will be done privately. Other designs will be reviewed by the entire group.

### **3. Applying axiom one - design matrices**

- use Acclaro to develop design matrices for a design of your choosing, building on exercise 2, working in groups or individually, with private or public design reviews.

### **4. Applying axiom two**

- narrowing alternatives quantitatively by calculating the information content, applications in product and process design and in selection.

### **5. Integration and Practical design**

- this is the culmination of the design exercises from the first day. Some of the portions of the design will be completed and reviewed

Students are invited to stay later for informal work and review on their designs

**Wednesday 10 May 2006**

**Advanced Axiomatic Design**

### **1. Advanced Axiom one**

- case studies, using Acclaro review existing designs and sort out different kinds of coupling, then develop and discuss strategies for dealing with them, develop further examples from design problems of selected by participants

### **2. Advanced Structure – creating domains, comparing themes**

- case studies, using Acclaro address evaluate design objectives in a complex context, decide where the process and means to accomplish need to be developed separately. Develop strategies to address the creation of new designs, new decompositions along new themes, or new domains.

---

### **3. Assigning interactions – quantitative approach and Inheritance in the matrix**

- case studies, using Acclaro trace inheritance through the matrix.
- evaluate DP-FR coupling thorough the development of equations on self selected design problems.

### **5. Managing axiomatic design – team work - staying on track**

Using Acclaro, working in teams and working on participant selected projects, create a design decomposition and review it. The design and the review process will be reviewed.

### **6. Additional design reviews**

Using Acclaro, a design started in the class, or others, can be reviewed by email and phone or in person depending on the situation.

## **MORE ON THE PROFESSOR**

Chris Brown is the author or co-author of over one hundred technical and scientific several articles, including several on how to teach Axiomatic Design. He has worked as a consultant applying axiomatic design to space travel and ski bindings. He teaches a regular grad course that applies axiomatic design to manufacturing processes. He also teaches a course on the Technology of Alpine Skiing, and is a former All-American ski racer and Swiss certified ski coach. His oldest son is a graduate of Dartmouth's Thayer School of Engineering and is currently on the US Ski Team, his youngest son is currently studying chemistry at St. Lawrence University and on their ski team. Chris is founder and director of the WPI's Haas Technical Education Center for Computer-controlled Machining and of the WPI's Surface Metrology Lab. He is also the former director of the Manufacturing Engineering Program at WPI. He was previously with Atlas Copco at their European Research Center and with the Swiss Federal Institute of Technology's Materials Department in Lausanne, Switzerland. He got his PhD in Mechanical Engineering at the University of Vermont in 1983 working under Branimir von Turkovich studying machining and materials.

---

## PROGRAM INFORMATION

[www.axiomaticdesign.org](http://www.axiomaticdesign.org)

**Date/Location:** May 9&10, 2005, WPI, 116 Higgins Labs, Worcester, MA 01609

**Schedule:** Registration and continental breakfast from 8:00 to 9:00 am Tuesday May 9, reception Tuesday at 5, second day registration and continental breakfast from 8:00 to 9:00am on Wednesday May 10 with the finish of the formal session at 5. Informal design reviews individually scheduled through 8 June.

**Course fee:** \$725 per day, or \$1350 for both days

- groups of 3 or more from the same company get a 15% discount.

- SME members \$25 discount for the total of both days

**Hotel Accommodations:** Rooms are being held at Courtyard by Marriott on 72 Grove Street Worcester, a block or so and a walk through the park to the campus . Price is \$129 per night. Reservations must be received on or before April 21. The rooms are being held for May 8 and May 9. Reservations can be made by calling 1-800-321-2211 or 1-508-363-0300 and referencing Axiomatic Design at WPI.

### Registration Application

(fax: 508 831-5627, email: brown@wpi.edu)

First Name: \_\_\_\_\_ Last Name: \_\_\_\_\_

Email \_\_\_\_\_

Phone \_\_\_\_\_ Fax \_\_\_\_\_

Job function: \_\_\_\_\_

If this is part of a group registration - company name:

SME member? yes no member number \_\_\_\_\_

**Checks** – payable to Worcester Polytechnic Institute

**Credit card** Mastercard Visa Discover American Express

Name: \_\_\_\_\_

Card number: \_\_\_\_\_ Expiration date: \_\_\_\_\_

**PO#:** Company Name: \_\_\_\_\_

Address: \_\_\_\_\_

Phone: \_\_\_\_\_ Fax \_\_\_\_\_: