College of the Arts
Department of Design
California State University, Long Beach
DESN 315: Form and Figures - The Mathematics of Design
Standard Course Outline

I. GENERAL INFORMATION:

A. Course Prefix and Number: DESN 315
B. Title: ***Form and Figures - The Mathematics of Design***
C. Units: 3
D. Prerequisites: Completion of GE Foundation and Exploration Requirements
E. Responsible Faculty: Steve Boyer, Assistant Professor
F. Prepared by: Steve Boyer, Assistant Professor; John Kleinpeter, Professor; and,
Tom Tredway, Assistant Professor
G. Date prepared or revised: Revised November 28, 2018

[*Course Classification:* C-2 (Lecture/Discussion)]
[*GE Classification:* B4 Mathematics/Quantitative Reasoning — EO 1100]
[*Terms Offered:* Fall and/or Spring]

II. CATALOG DESCRIPTION:

Exploration into mathematical foundations of design, architecture, and the arts from the Golden Mean to the latest Artificial Intelligence. Analysis and interpretation of mathematical principles applied to solutions of problems in the design of visual form, environments, and experiences.

Prerequisites: Completion of GE Foundation and Exploration Requirements.

III. CURRICULUM JUSTIFICATION(S):

DESN 315 is intended to develop students' understanding of mathematical concepts and quantitative reasoning used in design and to provide a vocabulary for analyzing and synthesizing the mathematical basis of form, pattern, and structure in the designed environment. This survey course examines mathematically-based design theories and methodologies from different parts of the world in a range of design disciplines through the exploration of their historical and contemporary applications. DESN 315 also develops the quantitative reasoning and problem-solving skills necessary to create and communicate sophisticated arguments about design and society. This course utilizes a combination of lecture and active learning activities, including collaborative small group work, hands-on demonstrations, and mathematically-based design activities.

GE Category: B4 Mathematics/Quantitative Reasoning
The visualization and application of numerical concepts is a critical component of design. This course examines the application of mathematical concepts used in design, with an emphasis on developing competencies and comfort in working with numerical data, using quantitative evidence to support an argument, and interpreting, representing, and applying mathematical data and quantitative reasoning to authentic contexts and situations within design. DESN 315 builds on the fundamental academic skills

of written and oral communication, critical thinking, and mathematics and quantitative reasoning developed in the Foundations as well as the subject knowledge and descriptive and analytical skills acquired in Exploration in the Arts (C1). The complex integration of mathematics/quantitative reasoning skills, design analysis and synthesis skills, and communication and advocacy skills justifies the upper division designation. Students will not only practice computational skills used in design but will also apply mathematical concepts and quantitative reasoning to solve complex design problems and investigate the creative uses of mathematics in design. Concepts explored include number systems, the use of proportion and scale, perspective and other systems of visual composition, and parametric modeling (using formulae to portray data). This course investigates the collection and use of data for design purposes, including anthropometrics, user testing, and data visualization. This course explores the relationship between mathematics, quantitative reasoning, and advanced technologies used in design, including artificial intelligence. Mathematical concepts and quantitative reasoning are integrated into the analysis of design problems and outcomes.

IV. MEASURABLE STUDENT LEARNING OUTCOMES, EVALUATION INSTRUMENTS, AND INSTRUCTIONAL STRATEGIES FOR SKILL DEVELOPMENT:

(*The following student learning outcomes should be listed on all syllabi*)

Upon successful completion of this course, the student will be able to:
SLO 1 – Describe and interpret the numeric basis of visual form in a variety of media and across cultures and historical epochs.

> <u>Student Performance Benchmark(s):</u>
> Students will be able to interpret the form and abstract proportional relationships in works of 2D and 3D design. Students will be able to accurately explain design information presented in mathematical form and mathematical relationships presented through design notation (for example, accurately calculating and explaining the proportional relationships found in a measured floor plan and expressing those relationships using fractions, ratios, and equations).

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Evaluation Instruments:
Specific assignments will vary by instructor but typical assignments may include the production of a diagrammatic analysis (measured plan, section, or elevation) of an object, painting, visual composition or architectural structure including detailed measurements that allow for the parametric representation of the subject (using calculation and formulae to portray data).

Instructional Strategies for Skill Development:
Students will be introduced to the historical and contemporary application of quantitative reasoning to design problems and outcomes through lectures, assigned readings, films, discussions, and demonstrations. The mathematical interpretation of design will be modeled for students in a variety of design fields (i.e., visual communication, interior design, architecture and industrial design) and explained by examples from cultural/historical origins.

SLO 2 – Represent and apply principles of scale, proportion, repetition and transposition to calculate and convert between quantitative representations of visual form, and to create procedural design methodologies.

Student Performance Benchmark(s):
Students will convert design information into an appropriate mathematical portrayal in order to generate images or structures by applying generative procedures (algorithms).

Evaluation Instruments:
Specific assignments will vary by instructor but typical assignments may include the creation of a visual composition, object or experience based upon a detailed set of calculations and mathematical procedures developed by the student. Students will document the algorithm symbolically and give it to another student, who will then follow the procedures and compare their results with the original student's intent.

Instructional Strategies for Skill Development:
Generative procedural design methodologies will be explored through lectures, assigned readings, and discussion that examine the historical and contemporary application of scale, repetition and transposition to the design of patterns and structures in different design cultures. Discussions and activities will examine the ways these strategies can be applied to contemporary design problems.

SLO 3 – Design and develop a process to collect numerical data relevant to design.

Student Performance Benchmark(s):
Students will be able to design a data collection process that utilizes appropriate methodologies or theoretical frameworks from relevant disciplines.

Evaluation Instruments:
Specific assignments will vary by instructor but typical assignments may include the creation of a research proposal outlining the design and development an appropriate process to collect data relevant to design.

Instructional Strategies for Skill Development:
Examples of appropriate and ethical processes to collect various types of data used in design will be discussed, including anthropometric data, user testing data, and survey data.

SLO 4 – Analyze and interpret numerical data through the organization and synthesis of evidence to reveal insightful patterns related to design.

Student Performance Benchmark(s):
Students will use quantitative data analysis calculations to organize and synthesize evidence and reveal insightful patterns, differences, or similarities in order to form deep and thoughtful judgments, drawing insightful, carefully qualified conclusions from their research.

Evaluation Instruments:
Specific assignments will vary by instructor but typical assignments may include the creation of a single datum graphic based on the analysis of design data collected by the student.

Instructional Strategies for Skill Development:
Examples of appropriate methods to analyze various types of data used in design will be discussed, including the difference between quantitative and qualitative data, the role of inductive analysis and deductive analysis, and the ways analysis of demographic data, user data, and survey data informs design. Special emphasis will be placed on the role of data visualization as an analytical tool.

SLO 5 – Communicate numerical data and quantitative information through the design of an effective visual form for the purposes of inquiry and advocacy.

Student Performance Benchmark(s):
Students will communicate quantitative information in connection with an argument, presenting their data in an effective visual format that represents themes and relationships using a mathematical portrayal that contributes to a further or deeper understanding of the subject.

Evaluation Instruments:
Specific assignments will vary by instructor but typical assignments may include the production of an infographic that advocates a position based upon an analysis and interpretation of data collected by the student. Students must be able to support their position based upon the data as well as the method for collecting and analyzing the data.

Instructional Strategies for Skill Development:
Examples of appropriate and ethical processes to collect, calculate, and analyze various types of data used in design will be discussed. The generation and use of infographics for analytical and persuasive purposes will be explored through the discussion of data analytics and visual rhetoric.

V. OUTLINE OF SUBJECT MATTER:

Mathematics is a discipline of abstraction and design is a discipline of instantiation. The relationships between these two activities is intertwined as moving fluidly between Idea and Instance requires the use of systems of symbolic notation. We extend the concept of calculation when we accept visual metaphor as a tool for solving problems that runs parallel to the tools of symbolic notation provided by mathematics. The overarching subject of the course shall be to explore the parallels between numeric and visual problem solving.

This is a broad outline of topics to be covered. Subject matter and sequence of topics may vary by instructor.

UNIT 1 - Methods of Abstraction (Weeks 1-4) (SLO 1)
The study of symbolic notation systems that facilitate the abstract representation of our physical environment.
Potential topics could include:

- Number Systems and Symbolic Notation (such as: integers, natural numbers, binary and hexadecimal, computer code, musical notation, etc.)
  Descriptive languages are constrained by the symbolic notation systems they employ.
- Pattern Languages and Formulae
  Formulae represent relationships. Pattern Languages are formulae for solving common design problems.
- Spatial Analogy (such as: drawings, models, sketches)
  Systems that represent the world as seen.
- Parametric representation (using formulae to portray data)
  Systems that represent the world as abstract relationships.

• Mapping and Measuring (converting form into figure)
Methods for converting physical phenomena into data.

UNIT 2 - Symmetry, Balance, Proportion, and Perspective (Weeks 5-7) (SLO 2)
The study of the mathematical relationships among and between component parts and the whole.
Potential topics could include:
- Perspective, Perception and Distortion systems (such as: Brunelleschi's perspective and Mercator's cartographic projection from the Renaissance)
- Geometry and ratios (such as: Golden Ratio from the Parthenon and Fibonacci's number sequence)
- Form and aesthetics (human perception of spatial ratios)

UNIT 3 – Generative Processes (Weeks 8-10) (SLOs 2, 3)
The study of the use of mathematics to generate form.
Potential topics could include:
- Tiling Systems (such as: tessellation in Islamic pattern design)
- Design Processes and Algorithms (such as: pattern weaving, transposition, translation, scaling)
- Parametric and Generative Form (procedural design methodologies including software generated design)
- Artificial Intelligence in design (new tools for solving complex problems)
- Biomimicry and Biomorphogenesis (understanding and incorporating the fundamental numerical relationships of nature in form)

UNIT 4 – Data Analysis and Visualization (Weeks 11-15) (SLOs 3, 4, 5)
The study of methods of data collection, calculation, analysis, and representation in design.
Potential topics could include:
- Data collection methods and statistics (such as: anthropometrics and user testing)
- Visualization of data (such as: charts, graphs and infographics)
- Strategies of representation (visual rhetoric)
- Communication and Advocacy (using data to express an opinion)

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VI. METHODS OF INSTRUCTION:
This survey course utilizes a combination of lecture, discussion, assigned readings, and active learning activities, including collaborative small group work, hands-on demonstrations, and mathematically-based design activities, as the primary methods of instruction. The lecture component of this course is intended to introduce and develop concepts, reinforce content and concepts from assigned readings, demonstrate techniques, and model problem solving approaches. The active learning portion includes hands on, collaborative, guided practice applying the concepts, techniques, and approaches covered in lecture and readings to the interpretation, analysis, and application of mathematical principles in design. This course can be taught using face-to-face, hybrid, or online modes of instruction.

VII. INFORMATION ABOUT TEXTBOOKS/READINGS
Due to the dynamic nature of the subject matter, it is expected that the instructor will create a reader for this course. If in the future, a comprehensive textbook is created, it may be selected and supplemented with materials typically outside the range of textbooks. Key texts may include:

Broug, Eric. (2008). *Islamic Geometric Patterns*. Thames & Hudson. New York.

Harlizius-Klück, Ellen. (2017). "Weaving as Binary Art in the Algebra of Pattern," *Textile: Cloth and Culture* 15:2.

Huff, Darrell. (1993). *How to Lie with Statistics*. W.W. Norton and Company. New York.

Shiffman, Daniel. (2012). *The Nature of Code*. The Magic Book Projekt.

Tufte, Edward R. (2001). *The Visual Display of Quantitative Information.* Graphics Press. Cheshire, CN.

Wolfram, Stephen. (2002). *A New Kind of Science*. Wolfram Publishing. https://www.wolframscience.com/.

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VIII. BIBLIOGRAPHY:

This is a foundational bibliography that suggests a broad sampling of diverse writing on mathematics, written for the layperson, offering a different perspective than standard college mathematics texts. Traditional college level courses in mathematics focus upon calculative procedures and use standard notations for expressing numerical relationships. Material in this course should emphasize different modes of numerical expression. These texts can be viewed as a representative sample of the kind of material that could be adopted for the course.

Mathematics Texts:

Ballast, David Kent. (1988). *Architect's Handbook of Formulas, Tables and Mathematical Calculations*. Prentice Hall. Upper Saddle River, New Jersey.

Berlinkski, David. (1997). *A Tour of the Calculus.* Random House. New York.

Elam, Kimberly. (2011). *Geometry of Design. Studies in Proportion and Composition. 2nd Edition.* Princeton Architectural Press. New York.

Kaplan, Robert and Kaplan, Ellen. (2014). *The Art of the Infinite - The Pleasures of Mathematics.* Oxford, New York.

Shiffman, Daniel. (2012). *The Nature of Code*. The Magic Book Projekt.

Thompson, Silvanus P. and Gardner, Martin. (1998). *Calculus Made Easy*. St. Martin's Press. New York.

Other Texts:

Alexander, Christopher. (1964). *Notes on the Synthesis of Form*. Harvard University Press. Cambridge, MA.

Abbott, Edwin A. (1992). *Flatland - A Romance of Many Dimensions*. Dover. New York.

Broug, Eric. (2008). *Islamic Geometric Patterns*. Thames & Hudson. New York.

Doczi, György. (2005). *The Power of Limits: Proportional Harmonies in Nature, Art and Architecture.* Shambhala. Boston and London.

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Harlizius-Klück, Ellen. (2017). "Weaving as Binary Art in the Algebra of Pattern," *Textile: Cloth and Culture* 15:2.

Hofstadter, Douglas R. (1999). *Gödel, Escher, Bach - An Eternal Golden Braid*. Vintage. New York.

Huff, Darrell. (1993). *How to Lie with Statistics*. W.W. Norton and Company. New York.

Johnson, Steven. (2002). *Emergence: The Connected Lives of Ants, Brains, Cities, and Software*. Scribner. New York.

Paulos, John Allen. (2001). *Innumeracy - Mathematical Illiteracy and its* Consequences. Vintage Books. New York.

Petersen, Ivars. (1998). *The Mathematical Tourist - Snapshots of Modern Mathematics.* W.H. Freeman and Company, New York.

Resnick, Michael. (1997). *Turtles, Termites and Traffic Jams - Explorations in Massively Parallel Microworlds*. MIT Press. Cambridge, MA.

Sibbald, Tim. (2018). *Teaching Interdisciplinary Mathematics*. Common Ground Research Networks, Champaign, IL.

Sorkin, Michael. (1997). *Local Code*. Princeton Architectural Press. New York.

Sutton, David. (2002). *Platonic and Archimedean Solids*. Walker and Company. New York.

Thompson, Darcy Wentworth. (1992). *On Growth and Form.* Cambridge University Press, Cambridge UK.

Tufte, Edward R. (2001). *The Visual Display of Quantitative Information.* Graphics Press. Cheshire, CN.

Wolfram, Stephen. (2002). *A New Kind of Science*. Wolfram Publishing. https://www.wolframscience.com/.

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IX. INSTRUCTIONAL POLICIES REQUIREMENTS:

Instructors may specify their own policies with regard to plagiarism, withdrawal, absences, etc., as long as the policies are consistent with the University policies published in the CSULB Catalog. It is expected that every course will follow University policies on Attendance (PS 01-01), Course Syllabi (PS 04-05), Final Course Grades, Grading Procedures, and Final Assessments (PS 05-07), and Withdrawals (PS 02-02 rev). All sections of the course will have a syllabus that includes the information required by the syllabus policy adopted by the Academic Senate. Instructors will include information on how students may make up work for excused absences. When class participation is a required part of the course, syllabi will include information on how participation is assessed. When improvement in oral communication is an objective of the course, syllabi will include a rubric for how oral communication is to be evaluated.

X. SPECIAL NEEDS STATEMENT:

Students with a disability or medical restriction who are requesting a classroom accommodation should contact the Disabled Student Services. Disabled Student Services will work with the student to identify a reasonable accommodation in partnership with appropriate academic offices and medical providers. We encourage students to reach out to DSS as soon as possible.

XI. COURSE ASSESSMENT:

The exact set of course assignments will vary depending on the instructor. University policy requires that no single evaluation of student achievement may count for more than one-third of the final grade. Final grades will be based on at least three, and preferably four or more, demonstrations of competence. Appropriate assignments may include…

Week	Assessment	SLO	Percent of Final Grade
2	Exercise 1: Vector or Raster*	1	5%
3	Project 1: Binary Textile Design	1	10%
4	Quiz 1*	1	5%
6	Exercise 2: Determining Proportional Relationships	1, 2	5%
7	Project 2: Symmetry, Balance and Proportion in Architecture	2	15%
7	Quiz 2*	2	5%
8	Exercise 3: From Descriptive to Prescriptive Symbolic Languages	2	5%
9	Project 3: Nature and Form*	2, 3	15%
10	Quiz 3*	2, 3	5%
12	Project 4: Research Proposal – Data Collection Process	3	5%
14	Exercise 4: Single Datum Graphic*	4	5%
15	Quiz 4*	3, 4	5%
16	Project 5: Advocacy Infographic (final assessment)*	4, 5	15%

*Requires calculation

XII. CONSISTENCY OF SCO STANDARDS ACROSS SECTIONS:

Each instructor is responsible for creating a syllabus for the course that conforms to this document in order to ensure consistency across different sections and semesters. Instructors should be free to select topics appropriate to their interests, expertise and appropriateness for aiding the student in achieving the SLOs.