The MINDSET Project

- **Mathematics INstruction using Decision Science and Engineering Tools**
- A collaboration among math educators, engineers, and mathematicians at three universities
- The objective of the project was to create, implement, and evaluate a new HS curriculum that integrates mathematics and engineering concepts
- The project was funded by a NSF DR K-12 grant
- The project is in the sixth year with hope for more

Karen Keene email: Karen_keene@ncsu.edu

 Go to www.mindset.org for sample chapters 7

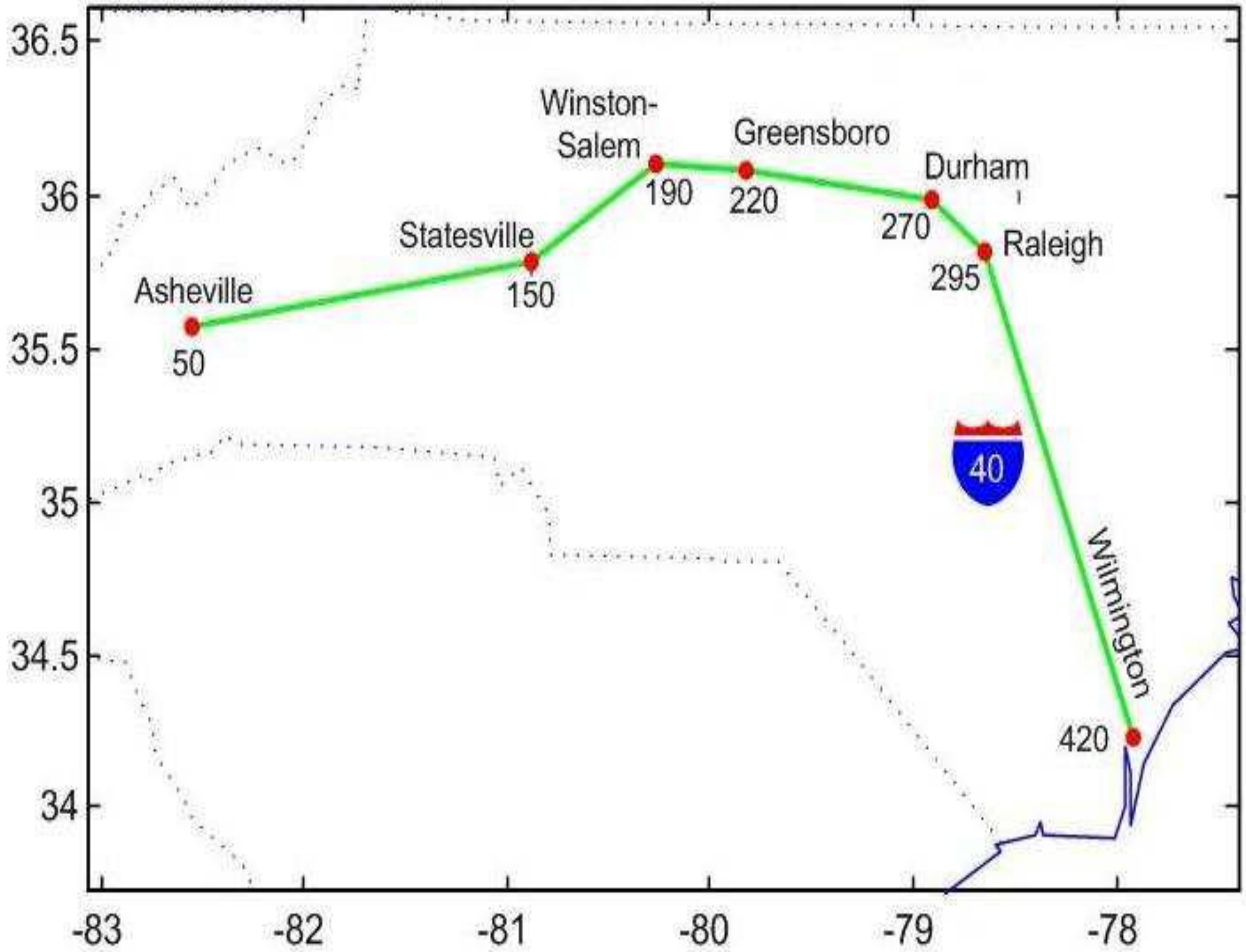
CHAPTER	PROBLEM CONTEXT	PREREQUISITE CHAPTERS	NOTES	AVERAGE TEACHING MINUTES SPENT ON THE CHAPTER (WHERE N = THE NUMBER OF TEACHERS WHO PROVIDED FEEDBACK FOR THIS CHAPTER)	RANGE OF TEACHING MINUTES SPENT ON THE CHAPTER
1 Making Hard Decisions—Multi-Criteria Decision Making	1.1 Choosing a Cell Phone Plan 1.2 Enrique Ramirez Chooses a College 1.3 Judy Purchases a Used Car			553.5 (N = 14)	275 – 990
2 Finding Optimal Solutions—Linear Programming (Maximization)	2.0 An Introductory Problem, Furniture Building 2.1 Computer Flips, a Junior Achievement Company 2.2 SK8MAN, Inc. 2.3 The Pallas Sport Shoe Company			763.9 (N = 22)	324 – 1440
3 Analyzing Optimal Solutions—Sensitivity Analysis	3.1 Computer Flips, a Junior Achievement Company 3.2 SK8MAN, Inc. 3.3 The Pallas Sport Shoe Company	▪ Chapter 2: LP Max	Sensitivity Analysis (Chapter 3) originally was incorporated into LP Max (Chapter 2).	N/A	N/A
4 Finding Optimal Solutions—Linear Programming (Minimization)	4.1 Nutrition in Malawi 4.2 Minimizing Costs to Reduce Phosphorus in Wisconsin Watersheds 4.3 Disk Gasoline Distributors, Inc.	▪ Chapter 2: LP Max ▪ (Possibly Chapter 3: Sensitivity Analysis)	The LP Min Chapter (Chapter 4) can be taught without knowledge of Sensitivity Analysis (Chapter 3). Teacher would avoid questions that refer to Answer and Sensitivity Reports.	337.3 (N = 13)	170 – 540
5 Finding Optimal Solutions—Integer Programming	5.1 Political Advertising 5.2 Opening and Operating the Pizza Palace 5.3 Transporting Oranges to Midwest Markets	▪ Chapter 2: LP Max ▪ (Possibly Chapter 3: Sensitivity Analysis)	The Integer Programming Chapter (Chapter 5) can be taught without knowledge of Sensitivity Analysis (Chapter 3). Teacher would avoid questions that refer to Answer and Sensitivity Reports. Section 5.3 (Transporting Oranges to Midwest Markets) is considered a “transportation problem” rather than an Integer Programming problem. It is included in this chapter because it has integer solutions.	417.3 (N = 12)	216 – 585
6 Finding Optimal Solutions—Binary Programming	6.0 Jarvis selects a Project 6.1 Flipping Houses 6.2 Sam Johnson Makes a Hard Decision 6.3 An Application of Binary Programming—Assignment Problems	▪ Chapter 2: LP Max	Section 6.3 deals with Assignment Problems. This content was a separate chapter and was folded into this Binary Programming Chapter.	336.2 (N = 5)	210 – 480
7 Finding Optimal Locations—Location Problems	7.1 Stadium Hot Dog Stands 7.2 The Smoothie Industry 7.3 Disaster Response Agency	▪ (Possibly Chapter 6: Binary Programming)	The first two sections (which are the bulk of the chapter) have no prerequisites, but the third section requires knowledge of Binary Programming (Chapter 6).	485.8 (N = 6)	215 – 720

Chapter	Problem Context	Prerequisite Chapters	Notes	Average Teaching Minutes Spent on the Chapter (where N = the number of teachers who provided feedback for this chapter)	Range of Teaching Minutes Spent on the Chapter
8 Minimum Spanning Trees & Shortest Path—Graph Theory	8.0 Six Degrees of Separation 8.1 Road Reconstruction 8.2 Medical Supplies 8.3 How Quickly do Rumors Spread?			274.2 (N = 9)	145 – 450
9 Planning Projects—Critical Path Method (CPM)	9.1 Getting Ready for School 9.2 Preparing a Taco Dinner 9.3 Scheduling with CPM for a Flight Propulsion System			482 (N = 10)	360 – 660
10 Making Complex Decisions—Decision Trees	10.1 Planning a Wedding, How many people should be invited? 10.2 Investment in Automation 10.3 Green Tree Energy—Location a New Plant 10.4 Purchasing collision Insurance			561.2 (N = 14)	270 – 850
11 Probabilistic Modeling—The Basics	11.1 The Super Bowl—Conference Dominance? 11.3 Customer Service at Koala Foods 11.4 Getting *The Lancer* to Press 11.5 Worker Absenteeism at BT Auto Industries	▪ (Possibly Chapter 10: Decision Trees)	Knowledge of Decision Trees (Chapter 10) does help tie together basic probability concepts, but this knowledge is not necessary to learn the content of the Basic Probability Chapter (Chapter 11). Expected value is introduced in the Decision Trees Chapter (Chapter 10), but this chapter could also be used to teach expected value.	599.4 (N = 17)	245 – 1350
12 Detecting and Interpreting False Positives and False Negatives	12.1 Spam Email 12.2 Lyme Disease 12.3 Identifying Credit Card Fraud	▪ (Possibly Chapter 10: Decision Trees)	Knowledge of Decision Trees (Chapter 10) does help tie together the concepts in the False Positive/Negative chapter (Chapter 12), but this knowledge is not necessary to learn the content.	360 (N = 2)	180 – 540
13 Using Probability Distributions—Binomial and Geometric	13.1 Customer Service at Koala Foods—Binomial Distribution of Successes 13.3 *The Lancer*—What if We Publish an Incomplete Paper? 13.4 Worker Absenteeism and Spare Workers at BT Auto Industries 13.5 First Time Something Happens: Geometric Distribution—Koala Foods at 8:10am 13.6 Geometric Distribution—NASA Shuttle Catastrophic Failure	▪ Chapter 11: Basic Probability ▪ (Possibly Chapter 10: Decision Trees)	Knowledge of Decision Trees (Chapter 10) does help tie together basic probability concepts, but this knowledge is not necessary to learn the content of the Binomial Distribution (Chapter 13). Expected value is introduced in the Decision Trees Chapter (Chapter 10), but this chapter could be used to teach expected value.	603.3 (N = 9)	380 – 850

Chapter	Problem Context	Prerequisite Chapters	Notes	Average Teaching Minutes Spent on the Chapter (where N = the number of teachers who provided feedback for this chapter)	Range of Teaching Minutes Spent on the Chapter
14 Using Probability Distributions—Poisson	14.1 The CSI Team 14.2 Scheduled and Urgent Patients at a Health Care Clinic	▪ Chapter 11: Basic Probability ▪ (Possibly Chapter 10: Decision Trees)	Expected value is introduced in the Decision Tree Chapter (Chapter 10), but this chapter could be used to teach expected value. This chapter also includes two sections on Exponential Distribution, but this content will be removed from the chapter and made available in a supplemental appendix.	386.7 (*N* = 3)	285 – 450
15 Using Probability Distributions—Normal	15.1 Cutting Fabric for Parachutes 15.2 Automobile Battery Warranties 15.3 *Rappin' Skoop Dogg*—Seasonal Demand	▪ Chapter 11: Basic Probability ▪ (Possibly Chapter 10: Decision Trees)	Expected value is introduced in the Decision Trees Chapter (Chapter 10), but this chapter could be used to teach expected value.	575.6 (*N* = 15)	160 – 1170
16 Managing Randomness—Quality Control	16.1 Assembly of the Fuselage of a Boeing 787 16.2 Monitoring the Quality of Boeing 787 Fuselage Assembly 16.3 Compiling data to Create Quality Control Charts for the Assembly of Boeing 787 Fuselages	▪ Chapter 15: Normal Distribution		408 (*N* = 4)	282 – 630
17 Waiting in Line—Queuing Theory	17.1 Post Office in Britton, MI—Single Server 17.2 Airport Security Screening 17.3 Customer Complaints about the Front and Center Ticket Sales	▪ (Possibly Chapter 14: Poisson Distribution)	Knowledge of the Poisson Distribution (Chapter 14) does help tie together concepts in this chapter, but this knowledge is not necessary to learn the content of the Queuing Theory Chapter (Chapter 17).	No Data	No Data
18 Project Planning—Program Evaluation Review Technique (PERT)	18.1 Preparing a Taco Dinner 18.2 Relocating CHEM-PACK Containers for the Super Bowl 18.3 Construction of a TV Tower	▪ Chapter 15: Normal Distribution ▪ (Possibly Chapter 9: CPM)	The CPM Chapter (Chapter 9) provides detailed descriptions of how to go through the project planning algorithm. The PERT Chapter (Chapter 18) provides a brief description of the same process without Gantt Charts.	401.8 (*N* = 9)	180 – 564
19 Making Predictions—Markov Chains	19.1 Using Markov Chains to Make Predictions about Total Cholesterol Levels 19.2 Using Markov Chains to Predict about Medication Adherence 19.3 Video Game			343.8 (*N* = 8)	180 – 540

ONE – DIMENSIONAL LOCATION: NORTH CAROLINA INTERSTATE 40

Ellie and Fran receive shipments of strawberries from a supplier whose farm is located in Greenville, South Carolina. The supplier would like to expand his operations and has decided to purchase one plot of farmland along Interstate-40 in North Carolina to better serve his customers in the following cities: Asheville, Statesville, Winston-Salem, Greensboro, Durham, Raleigh (e.g., Ellie and Fran), and Wilmington. In order to have access to a large labor pool to staff the farm, the supplier has decided to purchase the land in or just outside of one of the aforementioned cities. The figure below gives a map of North Carolina showing the potential cities along I-40 where the supplier will purchase the plot of farmland. It also shows the number of highway miles from the beginning of I-40 at the state's western border to each city. The farm should be located to minimize the distance the supplier needs to travel to serve his customers; assuming that I-40 will be used for all travel. The weekly demand in truckloads to each city is in parentheses: Asheville (10), Statesville (8), Winston-Salem (10), Greensboro (14), Durham (12), Raleigh (20), and Wilmington (6). Determine where the supplier should purchase farmland and locate his new strawberry farm.



1. Label each cities "weight" on the map (i.e. their contribution in truckload trips to the overall system).

2. Determine the total weight of the system.

3. Identify the median location by cutting the total weight in half.

To find the optimal solution, we need to find the cumulative sum of the weights of the system.
Cumulative sum: ____
____

Example: Cumulative sum for Winston – Salem is:

The optimal solution is found where the cumulative sum just surpasses the median location.

4. Starting at Asheville, create a cumulative sum of the weights for all the cities along I – 40.

5. Locate the strawberry farm at the city where the sum exceeds 40 for the first time.

HOW CAN YOU CHECK YOUR WORK?

DOES THE CUMULATIVE SUM ON BOTH THE RIGHT AND LEFT HAVE TO BE THE SAME NUMBER?

________________ ________________ is the sum of each of the distances from the farm multiplied by the respective weights of each city.

NOTES: Distance is measured in absolute value and they are measured in reference to the city where the farm is located.

Find the cost for each city:
Asheville:

Statesville:

Winston – Salem:

Greensboro:

Durham:

Raleigh:

Wilmington:

Total Cost:

Section 13.4: Geometric Distribution—NASA Shuttle Catastrophic Failure

NASA and the astronauts all recognize and accept the fact that all manned space flight is inherently dangerous. In addition, unlike automotive testing, it is not possible to actually test all of the systems under real-world conditions. Instead, they develop policies and procedures for trying to make the vehicles as safe as possible while being able to meet the space mission needs. Typically, they use engineering judgment to estimate the risks associated with space flight.

As work began on development of the space shuttle, the NASA team of engineers and managers collectively estimated that there was a 1-in-80 chance of a catastrophic failure. They anticipated flying the shuttle only 50 times. They were, therefore, optimistic that there would be no catastrophes.

Sinky Lee is doing a school project on the shuttle missions. She wants to use this estimate of 1-in-80 to explore a number of related probabilities. She also wants to compare the initial estimates to the actual record of catastrophes to see if the experience to date is in line with their original estimates.

Sinky learns that between 1980 and 2011, there were 135 shuttle missions. The final space shuttle mission ended on July 21, 2011.

Sinky will use the Binomial and Geometric Distributions to summarize the catastrophic risk probabilities. She will use the actual total of 135 missions instead of the originally planned 50.

She begins her exploration by calculating the probability that the first failure occurs on any specific flight. Sinky realizes these probabilities are very small. A 1-in-80 chance equals a probability of 0.0125.

Q1. Given the estimated probability of a catastrophic failure is ${}^{1}\!/_{80}$, does it seem reasonable that there were 2 catastrophic failures in 135 shuttle missions?

Q2. Using the 1-in-80 estimation, what is the probability that there will be a catastrophe on the first flight?

Q3. What is the probability that the first five flights are safe and there is a catastrophe on the sixth flight (i.e., the first catastrophe was on the sixth flight)?

Q4. What is the probability that the first catastrophe occurs on the 25th flight?

Q5. What is the probability that the first catastrophe occurs on the 50^{th} flight?

Q6. What is the probability that there is a safe flight the first $n - 1$ flights and catastrophe on the nth flight?

The first catastrophic failure occurred 73 seconds after liftoff and involved the Challenger on January 28, 1986. It was the 25^{th} flight in the Shuttle series.

Q7. What is the probability that the first catastrophe occurs on or before the 25^{th} flight?

Q8. Is it surprising that the first catastrophe occurred by the 25^{th} flight?

The Shuttle managers thought that 50 flights posed a limited risk when the odds were 1-in-80.

Q9. What is the likelihood that the first failure would occur on or before the 50 flights completed. Should they be concerned?

Sinky Lee learns the second catastrophe was the Columbia disaster, which occurred on February 1, 2003 upon attempted reentry into the atmosphere. This shuttle launch was the 113^{th} NASA shuttle.

Q10. Is it surprising that the second catastrophe occurred by the 88 flights after the first?

Q11. Now that Sinky has further investigated the NASA shuttle missions, does it seem reasonable that there were 2 catastrophic failures in 135 shuttle missions given the estimated probability of a catastrophic failure is ${}^{1}\!/_{80}$?

