Is it All Just Random?

A Focus on Cross-Curricular Activities

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Introduction

There has been a steady increase in the focus on science, technology, engineering and math (STEM) concepts within the realm of education. Despite increased awareness and programs in STEM, student interest in science continues to drop amongst high school aged students. In Canada, for example, while students generally perform well in national science tests, student enrollment in science courses drops "dramatically" once the mandated amount of coursework has been met (Toronto Sun, 2012). One factor that may be involved in this drop in enrollment may be general interest levels. According to one survey, a 20% drop in interest in science seems to occur between the ages of 12 to 18 (Toronto Sun, 2012). In the UK, similar findings are seen in education, with a purported 12% drop in interest in science between the ages of 12 to 14. This finding is combined with that of general lack of science understanding and relatedness to their desired fields of employ (The Telegraph, 2008). For students in the US, a 60% drop in STEM interest has been reported to occur in students by the end of their high school careers (STEM School, 2013). Considering these findings, there seems to be a need for education to relate science to the general student in order to maintain student engagement in STEM related concepts throughout their education.

One way to increase or maintain student engagement in STEM may be to relate concepts across the curriculum. Evidence exists in support of an increased focus in cross-curricular activities increases science interest and success (Chris S. Hulleman, 2009). However, finding a general context within which to address science content that works for every student is difficult. Not every student will maintain an interest in science, regardless of a connection to his/her community. Not every student is interested in sports or robots. Furthermore, relevancy alone does not address the increased interest in developing common practices or skills involved in STEM learning, or learning in general. With that said, implementing a cross-curriculum in schools has been shown to increase the perception of relevancy amongst students. Likewise, student engagement in the process of learning seems to increase, along with content knowledge and literacy skill – important goals in the Common Core and Next Generation Science Standards (Peterson & Rochwerger, 2006).

Developing a cross-curriculum can create internal relevancy. A student who enjoys English class but detests math can learn math concepts through relating to the book he/she is currently studying. A student who feels uncomfortable with English class can use the scientific method and standards in reporting data and analysis to develop a successful argumentative essay. Calls for increased use of cross-curriculum in schools highlight the ability to align content to standards, increase student engagement in learning, and increase focus on cooperation used in real-world activities (Johnson, 2013).

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A successful implementation of cross-curricular teams can increase the engagement of the faculty in the learning process, as well. This was demonstrated in one study where teacher engagement in the process was evaluated throughout one school year (Reed & Cori, 2009). What is interesting to note is that while both teachers and students found the process beneficial to learning, the co-curricular process was initially difficult to implement amongst the faculty and was heavily dependent upon the use of a facilitator (Reed & Cori, 2009). While intense to initially set up, finding and/or creating a streamlined cross-curriculum that can be ubiquitously utilized across the state may be extremely beneficial for both the students and the faculty involved.

The following lessons were developed with this goal in mind: to create a cross-curricular, science-driven curriculum based on popular and/or classic literature in order to increase interest or relevancy in science topics and show commonality across disciplines in attitudes and skills considered "science practices".

In developing these lessons, the following student goals were considered:

Students will learn to:

- Analyze the literature, science content and attitudes in the context of the history surrounding the literature
- Explore and apply appropriate mathematical knowledge to the content
- Develop and represent strong argumentative and/or persuasive writing skills in the context of science through identifying key concepts and supporting ideas with data or evidence

The example lessons provided in this booklet are adapted from a summer camp held at the ***Illinois Mathematics and Science Academy*** in the summer of 2014. This camp utilized the book, *Wonder*, by R.J. Palacio, to introduce science and math concepts to students entering 5th and 6th grades. This curriculum begins with a focus on the literary component. Campers were required to read the book prior to attending camp. The first lessons focused on summarizing the story and identifying the main concepts. Science and math components were introduced in relation to the story itself. Real-world connections were made throughout, allowing for a comparison between fictional events and what is historically known in science.

The specific lessons offered here deal with genetics and probability, topics that are advanced for the average 5th and 6th grade student. However, difficult concepts often can be better understood by younger students when they are given a chance to discover the concepts through inquiry-based lessons and discussion, allowing them to scaffold information to previously understood concepts. To help engage the students in these difficult concepts, it is important to find a source of fiction that is relatable to the specific age being taught. The target age of readers for the book, Wonder, is 9-12 years, making this book a good choice of focus for late Elementary to Middle

School aged students. Through the use of one piece of fictional literature, the curriculum can address the four core subject matters: English, Science, Math, Social Studies. In doing so, students learn to identify, analyze and properly use evidence to support arguments they develop. This promotes the understanding that the skills used in one discipline can be used in all disciplines and enables student interest in the one core subject to be "generalized" over all.

References:

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Lesson Plan: About A Gene

Logistics

Class age/size: 20 Students, working in pairs
Materials:

- Student Sheets (20 sets)
- 10 sets of 4 color and 4 clear cellophane squares
- Pencils (20)

Time: 50 minutes
Location: Classroom
Safety: N/A

Objectives/Standards

Students will:

- Discuss hereditary and genetic concepts and relate these scientific subjects to the book, ***Wonder***, by R.J. Palacio
- Demonstrate the understanding of how alleles of genes are potentially distributed amongst offspring of two parents using a graphical representation: Punnett Square
- Analyze the results of a Punnett Square to determine differences between what the genetic makeup is and what is the outward (physical) expression of these genes
- Critical thinking and determination of facts versus fiction in relation to genetics and disease

NGSS Standards:

- MS-LS3-1. Develop and use a model to describe why structural changes to genes (mutations) located on chromosomes may affect proteins and may result in harmful, beneficial, or neutral effects to the structure and function of the organism.
- MS-LS3-2.: Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.

Common Core State Standards: ELA/Literacy:

- RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics. (MS-LS3-1),(MS-LS3-2)
- RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-LS3-1),(MS-LS3-2)

Introduction

In the book, ***Wonder***, by R.J. Palacio, the main character, August Pullman (Auggie), has a severe facial deformity related to a set of genetic mutations. The mutation most focused on in the story is on chromosome 5, in the gene TCOF1, which relates to Treacher Collins Syndrome. According to the book, the genetically inherited mutation is autosomal recessive, meaning that both alleles in a gene pair must be affected in order for the syndrome to be expressed in an individual. In reality, a mutation in the TCOF1 gene leading to Treacher Collins Syndrome is autosomal dominant in nature: one only needs a single mutated allele to express the syndrome.

In this set of activities, students will explore the relationship of genes to what is physically expressed. Students will focus on Mendelian genetics through the use of information from the book, as well as the Punnett Square technique, and will help to determine if what is written in the book follows what is currently known about the syndrome.

Suggested Inquiry Approach

In the chapters, ***Genetics 101***, and ***Punnett Square***, the genetics of Auggie's condition is briefly discussed, specifically using his sister, Via's, voice. A Punnett Square is a graphical tool used to predict the probability of offspring inheriting certain genes from their parents. The activities included in these lessons require the students to review some fundamental ideas in biology. Through discussion and inquiry, students will develop a basic understanding of genetics and to begin to question how genes are inherited.

Activity 1: Discussion and Review

The familiarity with genetic concepts will depend on the grade level and experience of the students. Younger students should be familiar with the concept of cells as smaller living units that work together – but inheritance typically is not introduced until middle school grades. Therefore, depending on the target age-group, adjusting the discussion from a pre-assessment to an introduction of concepts may be warranted.

To begin this activity, distribute pencils and the ***Discussion Information*** note sheets.

Utilize a line of questioning that is appropriate to the level of your students. The goal is for the students to discover how much they understand about genetics and inheritance and for the facilitator to discover what information needs to be supplemented. Suggested questioning techniques are listed below:

For students with less familiarity of topics:

- Do children tend to look similar to or different from their parents or siblings? Give some

examples.

- Why do you think there are similarities in appearance among biological family members? Biologically speaking, what do they share?
- Do you know what is responsible for these similar traits?
- If you have children in the future, do you predict they will look like you? Why/Why not?

If students have familiarity with cells and the material within:

- How do cells work as a single living entity?
- How is information transmitted in a cell and/or between cells?
- If a cell divides and another cell is formed, is it identical to the original cell? Why/Why not?

If there is familiarity with inheritance:

Focus on a review or application of concepts. It is helpful for students to derive metaphors to make conceptual information more concrete. Facilitate student development of their individual metaphors and allow for presentation and discussion of these. One common set of metaphors follows below:

- A full set of chromosomes (Genome) = A book of directions
- A Chromosome = A Chapter in the book
- A Gene = A paragraph detailing a specific set of directions
- DNA = Language or wording used in the book
- Nucleotides = Letters that make up the words

Next, lead the students into a question/answer session utilizing the following questioning technique: (you may want to refer the students to pages 103-106 in the book, ***Wonder****)*

- From where did Auggie get his genes? *(target answer: his parents)*
- Do these genes come from one parent, both parents? *(target answer: from both parents, they are paired)*
- Are all of Auggie's genes working well ?*(answer: no – at least one is damaged)*
- Do Auggie's Parents show the syndrome? *(answer: no)* How about his sister, Via? *(answer: no)*

Once a general genetic understanding has been achieved:

At this point, be sure the students understand that come in pairs. Introduce the term for these genes in these pairs: **alleles**; one allele comes from mom, one comes from dad. In the book, Wonder, Mom, Dad and Via don't have the syndrome leading to the deformity, but Auggie does.

- Do you believe the parents would need to have at least one damaged allele.
- DoesVia necessarily has to hold one damaged allele.

At this point it is helpful to refer to the book. The book states some genes are dominant over

others.

- What does this mean? *(answer: some versions of the gene – allele – will be stronger and will be physically expressed over the other allele)*

Introduce the terms: **Autosomal dominant** (when one allele is stronger), and **Autosomal recessive** (the weaker expression). *The book states that the syndrome Auggie has is recessive, which means he needed two altered alleles of the gene to show the disease.*

Either ask the students to determine how to label different alleles in a pair, or have them label the non-syndrome (normal) allele = N, and the altered (leading to the syndrome) allele = S.

- If everyone has a pair of these alleles – how do you think Auggie's pair looks like *(answer: S,S)*

In the book, it states that Via has an altered gene, but not the syndrome.

- What does Via's gene pair look like? (answer: N,S)

We know that Auggie got an S allele from each parent, and that the parents do not have the syndrome.

- What do Auggie's parents gene pairs look like (answer: N,S)

Inform the students that in the next activity, they will be constructing a Punnett Square, which is a tool that helps to predict how likely it is a person will receive certain gene pairs.

Activity 2: Part 1: Punnett Square – Auggie's Parents

For this activity, group the students into pairs and distribute the ***About a Gene, Part 1: Punnett Square – Auggie's Parents Student Sheet*** (one to each pair of students). Instruct the students to place Auggie's parents' allele pairs onto the colored lines outside the square: one allele per line (for the Dad, they place and **N** on the green or blue line above the square, and an **S** on other space, for the mom, they are placing these letters or alleles on the side purple and orange lines)

Next, instruct the groups that now they must "distribute" these alleles by placing the letter on each color line outside the square on the same color lines inside the square

Each square should now have an allele pair! Allow 2-4 minutes for each group to answer the questions on the sheet.

Debrief:

Discuss the questions on the student sheet with the full group of students. The gene pairs they should have found are as follows: Square A – N, N; Square B – N, S; Square C – S, N; Square D – S, S.

Answers to the second question may vary. You may need to refer back to the discussion notes

sheet to remind the students that both parents and Via had one S allele and one N allele, and that Auggie was the only one who has two S alleles. You may choose to ask the students:

- Out of the four possibilities, how many children/offspring (squares) have both S alleles? The answer here should be ¼.

Inform the students that what they have been looking at in this Punnett square is allele pairing – the alleles of a gene pair a person has is considered a genotype. Therefore, Via's genotype would be N, S. *Ask :*

- Does she have the syndrome?

Inform the students that they will now look at what these genes do… they lead to a physical characteristic.

Activity 3: Part 2: Is What You See What You Get?

For this activity, the focus is on modeling how genes can affect physical traits. Distribute the ***Part 2: Is What You See What You Get Student Sheet*** to each student pair, along with one set each of the transparent squares.

Ask for a student volunteer read aloud the directions on the sheet and ask the students to work through the activity in their groups. Be sure to allow for time to answer the questions on the sheet and then debrief the activity as a whole class.

Debrief:

In the large group, discuss student answers for the two questions on the sheet.

- Regarding the second question, it may be helpful to refer to the discussion notes and recall the terms **Dominant** and **Recessive**.
- Explain that whereas the first Punnett Square activity focused on the genotype, or the genes distributed in each pair, this activity focuses on something called a phenotype – or the physical expression of the genes.

Activity 4: Part 3: Punnett Square Analysis – Reality

Distribute the ***Part 3: Punnett Square Analysis – Reality Student Sheet*** (one per pair of students) and ask for a student volunteer to read aloud the introductory paragraph on the sheet.

Allow the students to work through this activity in their groups, and allow time for the questions to be discussed and answered within their student pairs.

Debrief:

Reconvene as a large group, and discuss the student answers to the questions on the sheet. Be sure that the students understand the difference between **Autosomal Dominant** and **Autosomal Recessive** (you may focus on the words: Dominant and Recessive, leaving out Autosomal). Review the differences between what a **genotype** is (the gene pair a person has) versus what a

phenotype is (what is physically represented).

Activity 5: Part 4: Rethinking the Genetics

For this last activity, distribute the ***Part 4: Rethinking the Genetics Student Page*** – 1 per each pair of students. Ask for a volunteer student to read aloud the paragraph on the page, and allow students time to work on the activity in their groups.

Debrief:

Take any time left at the end of this activity to discuss the student answers in this activity and allow the students to make connections to the book. Be sure to facilitate connections with the genetic concepts, the information presented in the book, along with the actual genetics of the disease presented.

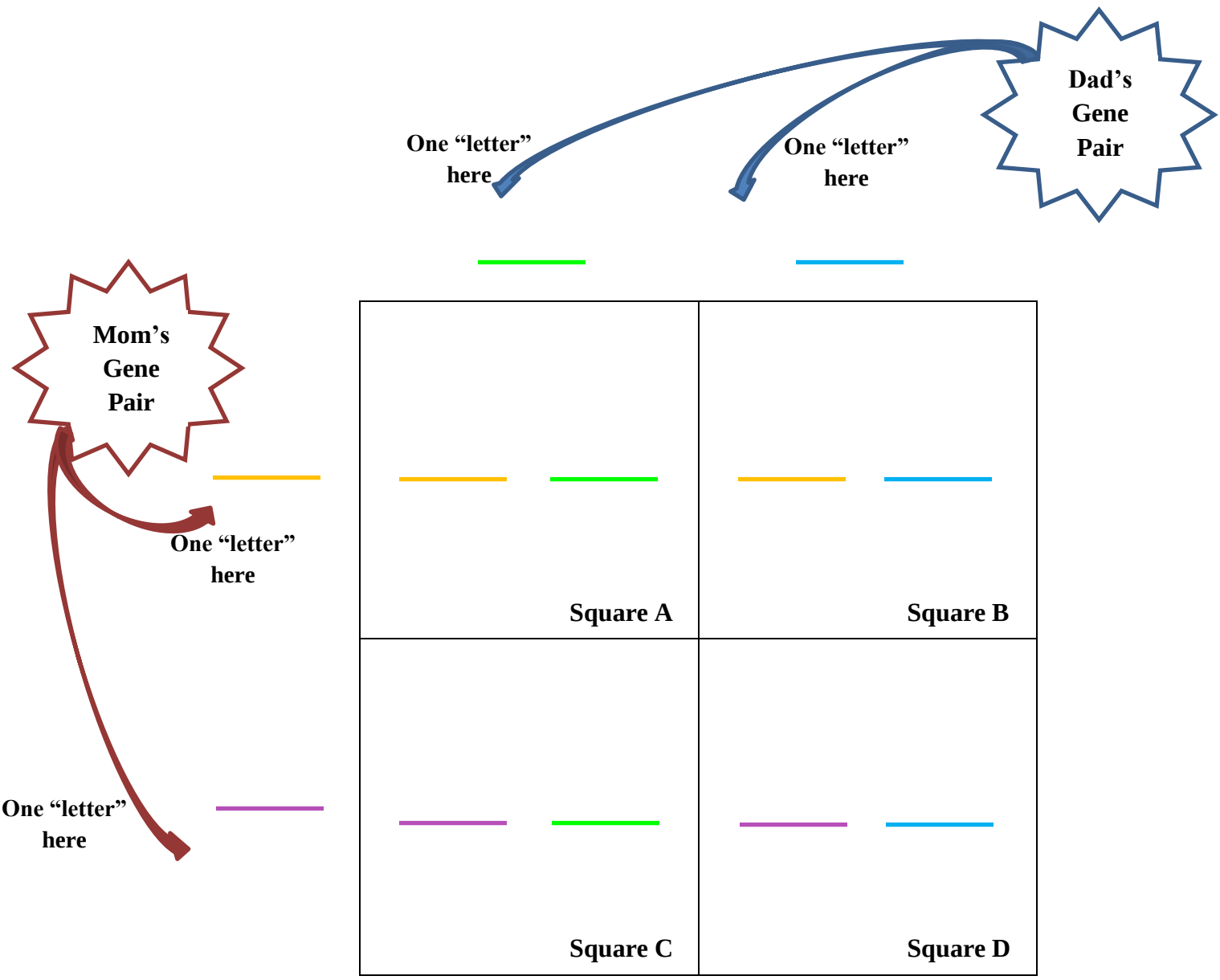
About a Gene

Discussion Information
(Notes Page)

- A Genome is like a _____
- A Chromosome is like a _____
- A Gene is like a _____
- DNA is like _____
- Nucleotides are like _____

About a Gene

PART 1: PUNNETT SQUARE – AUGGIE'S PARENTS



Q: List the gene pair combinations in this Punnett Square:

Q: What do you think these genetic combinations indicate for the possible children?

About a Gene

PART 2: IS WHAT YOU SEE WHAT YOU GET?

1. To aid in the understanding of how these genes work together, you are provided with a set of color or clear transparent squares.
2. Using Punnett Square #1 – redo the answers with these transparent squares:
   - "N" = Color Transparent Square
   - "S" = Clear Transparent Square
3. Place one transparent square on top of the other for each square in the Punnett table (ex: color square on top of the clear square for N, S pairing)
4. In the table below, write down what color is seen for each of these pairings.

Square A	**Square B**
Square C	**Square D**

Q: How do the results in the table above apply to Auggie and his family?

Q: List at least two terms describing the relationship between the "N" allele and the "S" allele:

About a Gene

PART 3: PUNNETT SQUARE ANALYSIS – REALITY

In the book, Auggie is said to have multiple genetic differences, most notably one in the gene TCOF1, which provides directions to make a protein called Treacle (thought to be involved in facial bone development). Various alterations in the gene can bring about Treacher Collins Syndrome. A person only needs to have **one** altered copy of the gene to express the syndrome, which is different than how it is described in the book. Considering this new information, review Parts 1 and 2, now using the following scenario: N = Clear Transparency, S = Color Transparency. *Hint: the answers in Part 1 will not change.*

Individual	Gene Pair	Check Box if Syndrome is Expressed
Auggie's Mom		
Auggie's Dad		
Child, Square A		
Child, Square B		
Child, Square C		
Child, Square D		

Q: How do these results differ than those from activity 2?

Q: What did we alter in this activity that brought about any differences noted in the question above? Explain how this relates to Auggie and his family?

About a Gene

PART 4: RETHINKING THE GENETICS

Considering that Auggie's main disorder is, in reality, an "Autosomal Dominant" disorder (where the altered allele is the one that is always physically expressed), would our initial assumptions about Auggie's parents gene pair necessarily be true?

Discuss the possibilities and in the space below, devise a Punnett Square (or two or three) to explain your answer:

Lesson Plan: Let the Chips Fall…

Logistics

Class age/size: 20 Students
Materials:

- Student Sheets (20 sets)
- Calculators (20)
- Pencils
- 20 labeled (one side T, one side t) pink chips
- 20 labeled (one side T, one side t) blue chips

Time: 50 minutes
Location: Classroom
Safety: N/A

Objectives/Standards

Students will:

- Learn general definition of probability and how it relates to genetics
- Explain differences between theoretical and experimental values
- Determine differences in probability within small and large sample sizes
- Relate mathematics and science to philosophical questions raised in the book, ***Wonder***, by R.J. Palacio

Common Core State Standards:
CCSS.Math.Content.7SP.6
CCSS.Math.Content.7SP.7
CCSS.Math.Content.7SP.8
CCSS.Math.Practice.7.1-5

Next Generation Science and Engineering Practice Standards:
NGSS.SEP.1, 2,4,5,7, and 8

Introduction

Auggie, the main character in the book, ***Wonder***, has multiple genetic mutations, one of which said (in the book) to be a recessive gene inherited from his parents. In an earlier activity, students

explored the hereditary transmission and the use of Punnett Squares as a tool to determine probable outcomes for offspring. Probability is an integral part of genetics and heredity, but was not fully explored in the prior activity. The following activity is designed to focus students on determining what is meant by "probability" and how it applies to genetics. Another important focus is on the effect of sample size upon data, especially when comparing experimental values to theoretical – hence getting to the real meaning of "probability" and how it applies to genetics.

Suggested Inquiry Approach

Activity 1 (Student Page 1):

For the following activity, hand each student a copy of ***Student Page 1*** from ***Let the Chips Fall***. Make sure a pencil is provided for each student. Read aloud the quote at the top of the page and then ask for a student volunteer to read aloud the two paragraphs that follow the quote.

Next, instruct all students to individually answer the questions on the sheet. Once students have completed their answers individually, reconvene as a large group to debrief the activity.

Debrief:

Review the questions on the sheet, being sure to allow a sampling of students to provide their answers. Example answers may include:

- **Random/ chance events:** winning the lottery, winning a prize in a raffle, hearing your favorite song on the radio right when you turn it on, rolling a die and getting a 5. **Likelihood** varies – ex: how many raffle tickets were sold.
- **Non-random events:** playing a particular song on an ipod by choosing it, the bell ringing at a certain time to alert students to the end of the school day, the anniversary of your birth, the amount of eggs in a carton of a dozen eggs (if produced correctly). A weighted coin/die. **Likelihood** should be more predictable.

Activity 2 (Student Pages 2-4):

Distribute each student copies of ***Student Pages 2-4*** from ***Let the Chips Fall***. Read aloud the first paragraph on ***page 2*** and then do a "check for understanding" : ask students if they understand or recall the information and explain or ask other students to explain if some do not understand or recall.

Next, ask for a student volunteer to read aloud the second paragraph, again doing a "check for understanding" after the reading.

Instruct the students to work through **page 2** until students are visibly done with their work. Once students have completed their work, reconvene as a large group to discuss their answers.

Debrief Page 2:

To debrief the activity, have a sampling of the students read their answers to the questions presented in the activity. Some answers may include:

- Possible allele pairs are TT, Tt, and tt
- Probability of an offspring having tt genotype is ¼
- Answers will vary for what a theoretical value represents… at this point do not direct the students to any particular answer; allow them to debate and discuss its meaning

Next, instruct students to look at **page 3**. Read aloud the first sentence as well as the first question and allow time for the students to answer the question. Ask the students to read their answer aloud and discuss their answers for a few minutes (***do not provide a correct answer***).

Hand each student one **pink** labeled chip and one **blue** labeled chip and read aloud the directions. Instruct the students to run through the ***"Family 1"*** activity.

Ask the students to answer the rest of the questions. Answers will vary for the values – write a few of the answers on the white or chalk board for comparison. Next, instruct the students to continue to **page 4** and do the activity for ***"Family 2".***

Again, **debrief** the questions with the students by having some students read aloud their answers and discussing these answers. Answers will vary, so again – write values and brief summaries of the answers on the board.

Activity 3 (Student Pages 5-6):

For this activity, you may choose to provide a calculator for the students. Distribute the calculators along with ***Student Pages 5-6*** from ***Let the Chips Fall***, to each of the students. Read aloud the first two sentences on **page 5**, along with the bullet pointed questions. Give time for the students to answer the questions.

Briefly survey the student responses and then ask how they chose their predictions. Next, direct the students to the activity on the page – it contains a table to fill in class data. You may use the transparency provided, an "Elmo" device and student page; or, reconstruct the table on **page 5** on the board.

Have the students enter the data from their ***"Family 1"*** and ***"Family 2"*** trials onto the table. Ask the students to calculate the totals and then enter that onto the table as well. Then, read aloud the directions on **page 6** and ask the students to answer the questions provided on the page.

Debrief this page by asking students to verbally provide answers and discussing any differences (there should be no differences amongst values for all students).

Values may, however differ amongst the various classes doing the activity – discuss how well

these values matched their predictions and if they based their predictions on the best data or on the theoretical value.

For the last two questions, it is hoped that the values are not the same (but let the data fall where it may…) because questions **C** and **G** are focusing on two different aspects of the data:

- C: Probability of a family (sample size 40) having 1 offspring with the disorder
- G: Probability across the population (sample size 160) of having the genotype tt.

Going back to the question on **page 3**, it is entirely possible for a family to have no offspring with the genotype, to have 1 offspring, 2 offspring, 3 offspring, 4…

Sample sizes are different. This may affect data.

Conclusion (Student Page 7):

To conclude this activity, hand out ***Student Page 7*** to the students. Allow student volunteers to read aloud the first two paragraphs and allow time for students to answer the questions on the page. Next, discuss the first three questions (allow students to state their answers – answers will vary).

Target answers include*: probabilities between small and large group data are different, the bigger the sample size, the closer the experimental value gets to the theoretical value.*

Theoretical values look at the probability across a population – or for every possible situation and not just one specific family. The **Family 1** and **2** data represent just specific possibilities occurring.

Read and discuss the last question and answers – answers here should vary. Please allow for interesting, respectful discussion and debate to occur amongst the students.

Let the Chips Fall…

"so doesn't that make the universe a giant lottery, then? you purchase a ticket when you're born. and it's all just random whether you get a good ticket or a bad ticket. it's all just luck." – Justin (R.J. Palacio, Wonder)

In the book, ***Wonder***, the character Miranda tells Justin (Via's boyfriend) that "the universe was not kind to Auggie". That statement seems to make an impact on Justin as he contemplates what that means about how "things" work in the universe, and specifically about how things worked in such a way to leave Auggie with debilitating facial abnormalities.

When looking at the genetics behind Auggie's condition, the question – is it "all just random?" becomes incredibly relevant. Genetics involves a sense of randomness and ***probability***. Probability can be defined as: the chance or likelihood of some particular event occurring.

- List some things that you believe are ***chance*** or ***random*** events:

- Now, what is the ***likelihood*** (or ***probability***) of those events occurring in a given year?

- List some things you believe are **not random** events:

- Is the probability of these events occurring within a year different from the chance events you listed?

- Why/ why not?

Let the Chips Fall…

Using the information in ***Wonder***, Auggie has two abnormal alleles for the gene TCOF1, which leads to the syndrome. In a prior activity, we labeled these alleles "S" and saw they are recessive (you need two of these to have the syndrome). His parents and his sister, Via, each have one normal allele (we labeled "N") and one S allele, and show no abnormality. Therefore, the "N" allele is dominant and they do not have the syndrome even though they carry an S allele. This highlighted the difference between ***genotype*** (ex., NS) and ***phenotype*** (ex., no syndrome).

A Punnett Square analysis uses ***probability*** to find possible genotype and phenotype outcomes for offspring of a "gene cross". We used Auggie's parents as the cross, (NS x NS). Geneticists do not write gene pairs as we did. They write the alleles as one letter, with the dominant allele in uppercase and the recessive is in lowercase. Fill out the Punnett Square below, using the letter "T" to TCOF1 gene.

In the space provided, do a Punnett Square analysis for Auggie's parents using "Tt" as their genotypes:

Dad → **Mom ↓**		

Write the possible letter (allele) pairs for the four offspring (hint: Tt = tT), placing the uppercase letter first (when applicable):

What is the probability, out of four, of an offspring being "tt" (write as a fraction)?

*(Call this a "**theoretical value**")***:**

What is the theoretical value representing (what information is it telling you)?

Let the Chips Fall…

Look at the theoretical value for a "Tt x Tt" cross.

Does this mean that a family with four offspring *will always have* one child be like Auggie (tt)?

The following activity is a simulation designed to help you look closer at the question above.

You will be given one pink chip and one blue chip; both with an uppercase "T" on one side and a lowercase "t" on the other side. The pink chip represents the mom in the family and the blue chip represents the dad.

Family 1

1. Take the two chips and shake them around in your hands as you would shake coins you were about to flip.
2. "Flip" the two chips and see how they land on the table in front of you. Do this four times, recording the pair of letters you get each time in the chart below:

(Remember to record these pairs with the uppercase letter first – if applicable)

Offspring	**1**	**2**	**3**	**4**
Genotype				

From the family above, what is the probability (out of four) of an offspring having the genotype (tt)?

_____ *(This value is considered an "**experimental value**")*

Compare this experimental value to the theoretical value from your Punnett Square. Is it the same or different?

If different than the theoretical value, why do you think this occurred?

Let the Chips Fall…

Let us see what happens with another family whose parents have the same genotype (Tt):

Family 2

3. Take the two chips and shake them around in your hands as you would shake coins you were about to flip.
4. "Flip" the two chips and see how they land on the table in front of you. Do this four times, recording the pair of letters you get each time in the chart below:

(Remember to record these pairs with the uppercase letter first – if applicable)

Offspring	**1**	**2**	**3**	**4**
Genotype				

From this family, what is the probability (out of four) of an offspring having the genotype (tt)?

_____ *("**experimental value**")*

Does the experimental value from Family 2 differ from that of Family 1?

If so, why do you think this occurred?

Does the experimental value from Family 2 differ from the theoretical value?

Considering your experimental results, is the Punnett Square analysis a good tool to use for predicting the actual genetic outcome of offspring for a single family?

Let the Chips Fall…

The next part of the activity explores a probability using a larger "pool" of data.
Make a set of predictions for the following questions:

- **Out of 40 families whose parents both have the genotype "Tt", how many families do you think will have exactly 1 offspring with the genotype "tt"? _____**

- **Using the example above, how many offspring out of 160 (40 families x 4 children each) will have the genotype "tt"? _____**

In the table below place the NUMBER of "tt" outcomes for each family that each camper "flipped". Add the values across each row to fill in the fourth column (combined amount of "tt" outcomes per student). Add up the Combined values to get a Total value.

"Campers"	Family 1	Family 2	Combined
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
Total			

Family 1 # + Family 2 # = Combined #

Add all combine #'s to get total value

Let the Chips Fall…

Answer the following questions using the information from the previous table:

Regarding the families and the data:

A. **Out of a total of 40 families, how many families have exactly 1 offspring with a "tt" genotype: _____**

B. **Does this match your prediction?**

C. **What is the probability (expressed as a simplified fraction) that a family will have exactly 1 offspring will have the genotype "tt"? _____**

D. **Does this match the theoretical value? _____**

Regarding the offspring and the data:

E. **Out of a total of 160, how many offspring have a "tt" genotype? _____**

F. **Does this match your prediction?**

G. **What is the probability (simplified fraction) of an offspring having the genotype "tt"? _____**

H. **Does this match the theoretical value? _____**

Look at the answers to questions C and G. Are these the same value?

Were the questions for C and G asking for the same information (if not, explain your answer)?

Let the Chips Fall…

Analyzing a small group of data (as you did for your individual families) may be different than analyzing a larger group of data (as you did for 40 families and 160 offspring). The following questions require you to consider all of the data you have collected in the activity:

Compare the probabilities for your small group (individual families, 4 offspring each) and large group (40 families, 160 offspring total) – Are the probabilities for offspring having a "tt" genotype different or the same amongst these values?

If not, why do you think these values are different?

What does this data tell you about "*probability*" and how it is defined or used?

Let's go back to Justin and his thoughts on randomness, the universe and Auggie's situation: In the chapter, *The Universe*, Justin comes to the conclusion that, "no, it's not all random… the universe makes it all even out in the end."

After studying the genetics of Auggie's condition and related probability, do you agree with Justin's conclusion (*of course; explain your answer*)?