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Using Learning Progressions to Map High School Student Understandings of Molecular Genetics

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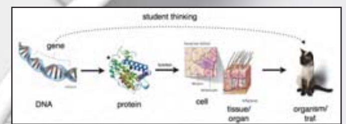

student thinking before instruction

What Do We Already Know?

- Concepts in molecular genetics are difficult to both learn and teach (e.g. Stewart, Cartier, & Passmore, 2005; Stewart & Van Kirk, 1990; Venville & Treagust, 1998)
- Two learning progressions (LPs) have been produced (Duncan, Rogat & Yarden, 2009; Roseman, Caldwell, Gogos & Kurth, 2006) in molecular genetics
  - Both LPs are hypothetical as neither have been fully empirically tested
  - Middle school portion of the Duncan et al. (2009) progression tested in one context (Freidenreich, Duncan & Shea, 2011)
    - Group refined constructs B & C with this data (Shea & Duncan, 2013)
- Empirical studies of the progression lead to revisions and refinement of progression based on classroom data obtained
  - Makes LPs more practical and useful for teachers and researchers to support students

RQ1: Where do students align with the Duncan et al. (2009) LP?

RQ2: How can the Duncan et al. (2009) LP be revised and refined?

What Did We Do?

- Theoretical framework for study is based on:
  - Duncan et al. (2009) molecular genetics LP
  - Stewart et al. (2005) - molecular genetics literacy is being able to understand and integrate three inter-related conceptual models
  - Duncan & Reiser (2007) - "hybrid hierarchical" structure of molecular genetics
- Three different 10th grade biology contexts in 2011-2012 school year:
  - Suburban public school (6-12) with a STEM focus (Context A)
  - Two classrooms in urban public school with arts focus (Contexts B & C)
- Three molecular genetics intervention units created
  - Differ from normal classroom instruction
    - Introduce proteins and their functions before addressing DNA and it structure
    - Specifically target instruction to components from Duncan et al. (2009) LP
  - Teacher A taught three units in their entirety
  - Teacher B taught the first unit and shortened version of second unit
  - Teacher C did not teach any of the units
- Pre/post written assessments (n = 121) were administered to all the students
- Interviews conducted (n = 54) with students in contexts A & B
- Student ideas mapped to the Duncan et al. (2009) LP
  - Coding scheme based on the LP empirically developed for each of the eight "Big Ideas"
  - Data shown in this poster is preliminary, reliability has not yet been established

explanation of Siamese cat coloration after instruction

Refinements of Construct B

new idea between levels

Original LP	Revised LP	Description
	0	No knowledge of genes
0	1	Genes are non-informational in nature, passive particles associated with traits
	2	Genes are non-informational in nature, active particles associated with traits
	3	Genes are active instructions that "tell" proteins, the cell, or the body to carry out specific functions
1	4	Genes have information about biological entities and function at multiple organizational levels
2	5	Genes are instructions for molecules (many of which proteins) that carry out functions within the organism
3	6	The genetic code is translated into sequence of amino acids that makes up the protein

		Number of Students in Each Context Written Assessments						Number of Students in Each Context Interviews				
Level	My Proposed LP	A Pre	A Post	B Pre	B Post	C Pre	C Post	A Pre-I	A Mid-I	A Post-I	B Pre-I	B Post-I
0	No knowledge of genes	36	22	21	21	34	26	13	4	1	11	4
1	Genes are non-informational in nature (DNA is passed down/is genes/is letters)	1	3	1	1	3	1	0	0	0	2	2
2	Genes are informational in nature (DNA is your ID code/has information/has instructions for your body, "tells" your body, etc.)	14	4	5	2	2	6	12	7	0	5	1
3	Genes contains instructions to "tell" your body how to grow/function/develop at different organizational levels (cells, tissues, organs, etc.)	4	2	0	3	0	4	3	1	0	6	9
4	Genes code for molecules/ amino acids/proteins inside cells that carry out functions	0	9	0	0	0	2	2	7	7	0	2
5	Genes code only for proteins (which are made of amino acids)	0	5	0	0	0	0	0	8	10	0	3
6	Genetic code is translated sequence of amino acids that make up proteins	0	3	0	0	0	0	0	3	8	0	1

Refinements of Construct F

Original LP	Description
1	There are different versions of traits, organisms can have different versions
2	Each chromosome carries one allele of a gene, patterns determine the resulting trait
3	Alleles differ in nucleotide sequence affecting protein which gives trait variation; dominant/ recessive relationships explained by protein interactions

		Number of Students in Each Context Written Assessments						Number of Students in Each Context Interviews				
Level	My Proposed LP	A Pre	A Post	B Pre	B Post	C Pre	C Post	A Pre-I	A Mid-I	A Post-I	B Pre-I	B Post-I
0	no understandings of genes or traits	39	14	17	15	31	26	4	0	0	4	2
1	There are different versions of traits, organisms can have different versions	6	8	3	1	2	4	0	4	0	3	0
2	Organisms get traits from both parents, the inherited traits can "mix" or one can "win" in an organism	10	10	4	8	4	4	19	9	5	13	11
3	Organisms get one allele of a gene from each parent, predictable patterns determine the resulting trait	0	15	3	1	0	4	7	16	19	4	8
4	Alleles received differ in nucleotide sequence which affects the proteins to give trait variation	0	1	0	0	0	0	0	1	2	0	1
5	Alleles differ in nucleotide sequence affecting protein which gives trait variation; dominant/ recessive relationships explained by protein interactions	0	0	0	0	0	0	0	0	0	0	0

Refinements of Construct G

removed to Construct H

Original LP	Description
1	Different organisms vary in look and function because they have different genetic information; within a group there is variation in traits
2	The genetic information can change, changes result in changes to the proteins; some changes beneficial/ harmful/neutral to organism; chromosomes also vary in boys v. girls
3	DNA mutations are source of genetic variation; some DNA varies between species and some does not (we share some genes with other species); DNA variations between individual allow us to distinguish between them

		Number of Students in Each Context Written Assessments						Number of Students in Each Context Interviews				
Level	My Proposed LP	A Pre	A Post	B Pre	B Post	C Pre	C Post	A Pre-I	A Mid-I	A Post-I	B Pre-I	B Post-I
0	no idea how genotype affect phenotype	39	16	16	11	26	17	1	0	0	4	0
1	Organisms have different traits/functions	2	3	0	2	2	2	0	0	0	2	1
2	Different organisms have different genetic information	5	9	6	7	9	3	10	9	4	6	4
3	Different organisms have different genetic information, even within a species (such as X and Y in boy v. girl humans), DNA variations between individuals can be used for identification	8	12	5	4	1	11	16	9	8	11	5
4	Organisms of other species can share the same genes (i.e. humans and flies/mice/ bacteria)	1	8	0	2	0	5	3	12	14	1	12
5	Shared DNA codes for things critical to life, the more conserved, the more critical the gene product	0	0	0	0	0	0	0	0	0	0	0

What do students think genes do?

Revised levels 1 & 2 can be combined
- Few students thought that genes were non-informational in nature (proposed level 1)
- Passive versus active distinction removed, very fine distinction between two

New level added to progression
- Proposed level 5 - genes code only for proteins, made of amino acids
- Several students understood genes code only for proteins and that the proteins are made of amino acids
- Were unable to describe how codons in DNA are translated into a sequence of amino acids which make up the protein (proposed level 6)

Dramatic shift pre to post-instruction in molecular model
- Basic understandings of molecular model before instruction
- Dramatic shift to higher levels after instruction
- Seen especially in context A interviews (highlighted in red box)

How are alleles related to traits?

New levels added to progression
- Data supports the three original levels of the construct
- Also supports addition of three new levels

Molecular model introduced to genetic model at this level
- Students have firm grasp of the molecular model (Construct B) and genetic model (Construct F, proposed level 3) after instruction
- Students have difficulties integrating the two models
- "Stuck" at level 3 because unable to add in molecular model
- Difficulty consistent with published literature (e.g. Allchin, 2000; Freidenreich, Duncan, & Shea, 2011; Stewart, Hafner, & Dale, 1990).

How different are humans and fruit flies?

Ideas about genes changing and evolution moved to Construct H
- Ideas may be better suited for Construct H
- Modified to include genetic changes through recombination, mutations, environmental factors
- Or creation of new construct for molecular evolution ideas

Ideas from original levels combined
- Ideas about the genetic similarities/differences between individuals found in all levels of original LP
- Ideas combined into one level (proposed level 3).

New lower and higher levels added to progression
- Data supports addition of four levels
- Lower levels added for more basic ideas
- Large portion of students held these ideas (proposed levels 0-2)
- Higher level added to the progression
- Idea discussed in the original LP, not included in the progression
- Questions did not probe this idea, no students achieved this level
- Many students able to achieve proposed level 4; some students may be able to achieve this higher level.