The Analysis of Learning Progression on Genetics

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Abstract: Learning progression (LP) or conceptual progression has been researched and discussed intensively since 2009. Some LP on biology has been formulated and tested by some scholars after the LP released by the National Research Center (NRC) the USA. However, the learning progression focused on genetic diseases have not been studied well. Genetic diseases is not a specific topic taught in Indonesia schools, but there is a specific sequence on learning genetic diseases as one of the life sciences topics taught from primary to higher education level. One of the sub topics learned at high school biology is genetic diseases. The research was aimed to analyze the possibilities of developing learning progression on genetics by systematically reviewing research articles published from 2009 to 2019. The PRISMA approach was used as the research method. The articles were collected from online databases using the keywords, "learning progression" and "genetic concepts, and 'conceptual progression' in open access databases. Two reviewers worked to determine the feasibility of all papers found. Twelve research papers were analyzed constitutively. The findings showed there were three models as a basis to develop the LP in genetics, i.e. inheritance, meiotic, and molecular model. Various instruments used to assess LP, such as: Order-multiple choice (OMC), interview protocols, and task assessment. While Rasch Analysis was used to validate the instrument of LP.

Keywords: learning progression, genetic concepts, conceptual progression, order-multiple choice

INTRODUCTION

Learning Progression (LP) is a method to find out the students' order of understanding in each level developed from the core idea into several big ideas (Duncan, Rogat, & Yarden, 2009). Various LP has been developed to help learn genetics in kindergartens (Elmesky, 2013), elementary and middle schools (Duncan et al., 2009), high schools (Duncan & Tseng, 2010; Todd, Romine, & Whitt, 2016), and higher educations (Todd, Romine, Correa-menendez, & Todd, 2017).

The LP for genetics currently available was followed the A-H constructs: A. (all organisms have hierarchically organized genetic information); B. (the genetic information contains universal instructions that specify protein structure); C. (proteins have a central role in the functioning of all living organisms and are the mechanism that connects genes and traits); D. (all cells have the same genetic information but different cells use (express) different genes); E. (organisms reproduce by transferring their genetic information to the next generation); F. (there are patterns of correlation between genes and traits and there are certain probability with which these patterns occur); G. (changes to the genetic information can cause changes in how we look and function (phenotype), and such variation in the DNA can serve as a way to identify individual and species); and H. (environmental factors can interact with our genetic information) (Duncan et al., 2009).

In each level, the components representing the big ideas will discuss an idea to answer two fundamental questions of genetics: How do genes influence how we and other organisms, look and function? Dan why do we vary in how we, and other organisms, look and function? The OMC (order multiple-choice) (Todd & Romine, 2016; Todd et al., 2016), assessment tasks pre-

post (Todd & Kenyon, 2016), were usually used as the assessment for LP. The Rasch model was used as the validation (Todd, Romine, & Todd, 2017).

The research of LP has been emerged recently, started by the researches by Duncan and colleges (see Duncan, Castro-faix, & Choi, 2016; Duncan et al., 2009; Elmesky, 2013; Shea, Duncan, Shea, & Duncan, 2013; Todd & Kenyon, 2016; Todd & Romine, 2016; Todd, Romine, & Todd, 2017; Todd et al., 2016), also (Duncan et al., 2016, 2009; Shea et al., 2013; Todd & Kenyon, 2016; Todd & Romine, 2016; Todd, Romine, & Todd, 2017; Todd et al., 2016). Some LP tackling the molecular genetics (Todd & Kenyon, 2016), Mendelian genetics and molecular genetics (Duncan et al., 2016). Some validated the LP on modern genetics for high schools (Todd & Romine, 2016; Todd et al., 2016). Also the LP with two instruction sequences to find out the more effective one (Duncan & Choi, 2017).
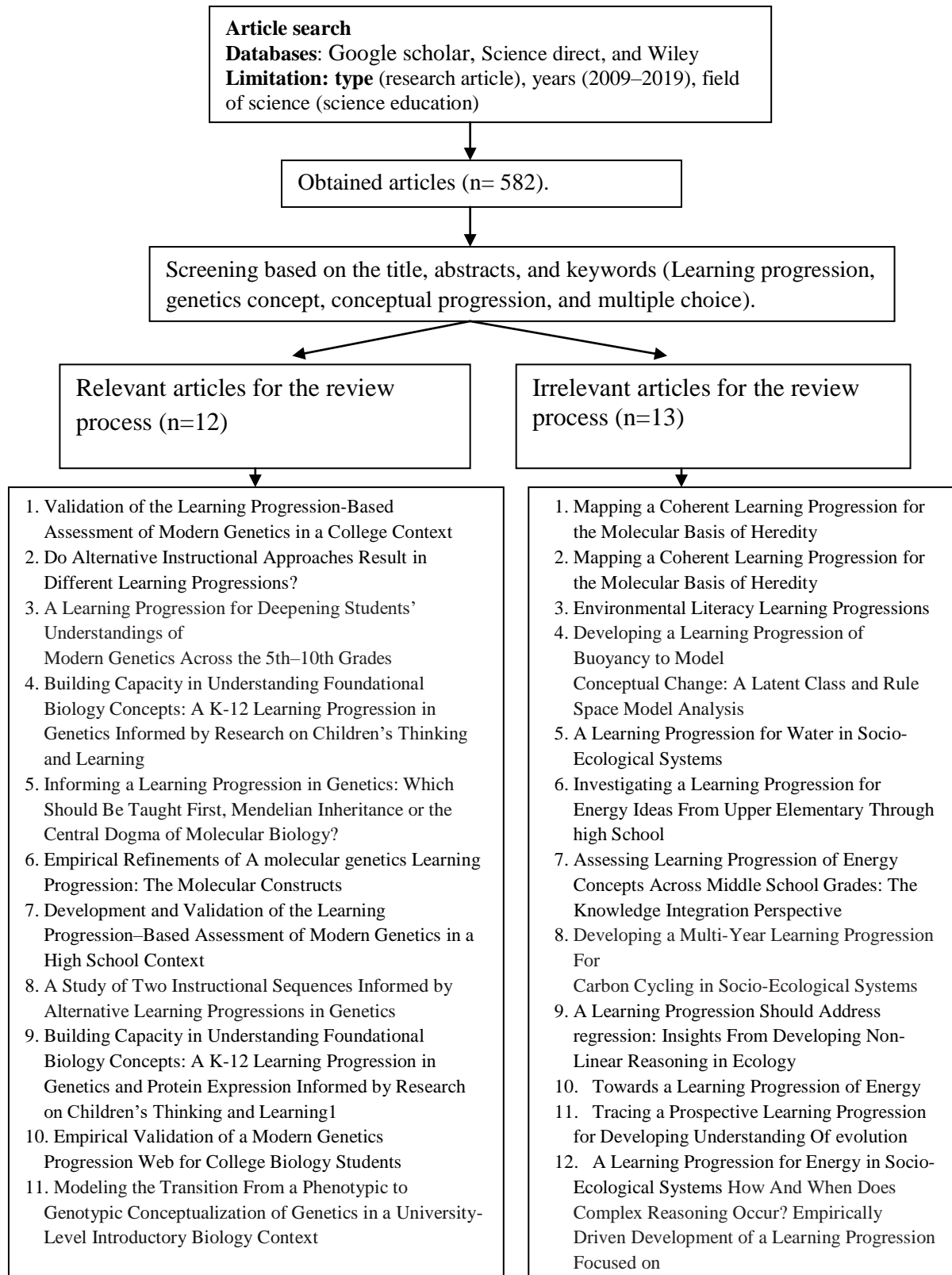
In 24–26 June 2009, the first conference on LP held in Iowa the US. Eighty-two experts were present as representatives from various scientific fields: Science Educators, Scientists, Curriculum Developers, Assessment Specialists, Psychometricians, Policymakers, and Teachers. Four topics were discussed in the conference: 1). Defining learning progression (the construct of LP and conceptualization of student progress). 2). Developing assessments to elicit students' responses relative to a learning progression (the multiple ways to elicit evidence of students' knowledge and practices), 3). Modeling and interpreting students' performance relative to a learning progression (the inferences made about students 'learning progression levels based on their response to assessment tasks), and 4). Using learning progressions (the many ways learning progression may influence science education, including the design of standards, curricula, and teacher education). Even though they unable to agree upon definition, model, assessment, and usage of LP, they agree that LP was '*potentially important, but as yet unproven tools for improving teaching and learning ...development and utilizing this potential pose some challenges.*' After that, the research on LP was developed at a fast pace, including from Duncan and colleges which consistent about the LP for genetic learning.

Research Questions

1. How far the progress of research on the LP for genetics?
2. What instruments used for the LP?

METHODOLOGY

The PRISMA was used as the research method. The articles were collected using an online-based search method from three databases: Science direct, Google scholar, and Wiley. The articles were collected using keywords and build in filters from the databases to meet the criteria from researchers. The articles were limited by the type, field of science, and years of publication. Articles then reviewed to determine the proper articles for review.

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│ Article search                                │
│ Databases: Google scholar, Science direct,    │
│ and Wiley                                     │
│ Limitation: type (research article), years    │
│ (2009–2019), field of science (science        │
│ education)                                    │
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        ┌──────────────────────────────┐
        │ Obtained articles (n= 582).   │
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│ Screening based on the title, abstracts, and  │
│ keywords (Learning progression, genetics       │
│ concept, conceptual progression, and multiple  │
│ choice).                                       │
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Relevant articles for the review process (n=12)	Irrelevant articles for the review process (n=13)
1. Validation of the Learning Progression-Based Assessment of Modern Genetics in a College Context	1. Mapping a Coherent Learning Progression for the Molecular Basis of Heredity
2. Do Alternative Instructional Approaches Result in Different Learning Progressions?	2. Mapping a Coherent Learning Progression for the Molecular Basis of Heredity
3. A Learning Progression for Deepening Students' Understandings of Modern Genetics Across the 5th–10th Grades	3. Environmental Literacy Learning Progressions
4. Building Capacity in Understanding Foundational Biology Concepts: A K-12 Learning Progression in Genetics Informed by Research on Children's Thinking and Learning	4. Developing a Learning Progression of Buoyancy to Model Conceptual Change: A Latent Class and Rule Space Model Analysis
5. Informing a Learning Progression in Genetics: Which Should Be Taught First, Mendelian Inheritance or the Central Dogma of Molecular Biology?	5. A Learning Progression for Water in Socio-Ecological Systems
6. Empirical Refinements of A molecular genetics Learning Progression: The Molecular Constructs	6. Investigating a Learning Progression for Energy Ideas From Upper Elementary Through high School
7. Development and Validation of the Learning Progression–Based Assessment of Modern Genetics in a High School Context	7. Assessing Learning Progression of Energy Concepts Across Middle School Grades: The Knowledge Integration Perspective
8. A Study of Two Instructional Sequences Informed by Alternative Learning Progressions in Genetics	8. Developing a Multi-Year Learning Progression For Carbon Cycling in Socio-Ecological Systems
9. Building Capacity in Understanding Foundational Biology Concepts: A K-12 Learning Progression in Genetics and Protein Expression Informed by Research on Children's Thinking and Learning1	9. A Learning Progression Should Address regression: Insights From Developing Non-Linear Reasoning in Ecology
10. Empirical Validation of a Modern Genetics Progression Web for College Biology Students	10. Towards a Learning Progression of Energy
11. Modeling the Transition From a Phenotypic to Genotypic Conceptualization of Genetics in a University-Level Introductory Biology Context	11. Tracing a Prospective Learning Progression for Developing Understanding Of evolution
	12. A Learning Progression for Energy in Socio-Ecological Systems How And When Does Complex Reasoning Occur? Empirically Driven Development of a Learning Progression Focused on

RESULTS

Table 1. Article LP

Articles	Title	Participant	Methodology	Instrument
Duncan, Ravit Golan Rogat, Aaron D Yarden, Anat. (2009)	A Learning Progression for Deepening Students ' Understandings of Modern Genetics Across the 5th–10th Grades	Grades 5–10 students	Qualitative	-
Todd, Amber Romine, William L.(2016)	Validation of the Learning Progression-based Assessment of Modern Genetics in a college context	Undergraduate Students	Qualitative and quantitative	Order multiple choice (OMC)
Castro-faix, Moraima Romine, William. (2018)	Do Alternative Instructional Approaches Result in Different Learning Progressions?	Grades 10–11 students	Qualitative	Order multiple choice (OMC)
Elmesky, Rowhea. (2013)	Building Capacity in Understanding Foundational Biology Concepts: A K-12 Learning Progression in Genetics Informed by Research on Children's Thinking and Learning	Grade 12 students	Qualitative	-
Duncan, Ravit Golan Castro-faix, Moraima Choi, Jinnie. (2016)	Informing a Learning Progression in Genetics: Which Should Be Taught First, Mendelian Inheritance or the Central Dogma of Molecular Biology?	Grades 6–7 students	Qualitative	Order multiple choice (OMC)
Todd, Amber Kenyon, Lisa. (2016)	Empirical Refinements of a Molecular Genetics Learning Progression: The Molecular Constructs	Grades 10–11 students	Qualitative and quantitative	Order multiple choice (OMC)
Duncan, Ravit Golan Choi, Jinnie. (2017)	Study of Two Instructional Sequences Informed by Alternative Learning Progressions in Genetics	Grade 11 students	Qualitative and quantitative	Order multiple choice (OMC)
Todd, Amber Romine, William L.(2017)	Empirical validation of a modern genetics progression Web for college biology students	Undergraduate students	Qualitative	Order multiple choice (OMC)
Todd, Amber Romine, William L Whitt, Katahdin Cook. (2016)	Development and Validation of the Learning Progression–Based Assessment of Modern Genetics in a High School Context	Grade 10 students	Qualitative	Order multiple choice (OMC)
Rowhea Elmesky. (2014)	Building Capacity in Understanding Foundational Biology Concepts: A K-12 Learning Progression in Genetics and Protein	Grade 12 students	Qualitative	Order multiple choice (OMC)

Articles	Title	Participant	Methodology	Instrument
	Expression Informed by Research on Children's Thinking and Learning			
Todd, Amber Romine, William L Correa-Menendez, Josefina Todd, Amber. (2017)	Modeling the Transition from a Phenotypic to Genotypic Conceptualization of Genetics in a University-Level Introductory Biology Context	Undergraduate Students	Qualitative and quantitative	Order multiple choice (OMC)

Table 2. Constructs of LP by Duncan (2009)

Component of big idea	Level 1: grades 5–6	Level 2: grades 7–8	Level 3: grades 9–10
Question: How do genes influence how we, and other organisms, look and function? Big ideas: All organisms have universal genetic information and specifies the molecules that carry out the functions of life. While all cells have the same information, cells can regulate which information is used (expressed). Question: How do genes influence how we, and other organisms, look and function? Big ideas: All organisms have universal genetic information and specifies the molecules that carry out the functions of life. While all cells have the same information, cells can regulate which information is used (expressed).			
(A) All organisms have genetic information that is hierarchically organized	Humans, animals, plants, fungi, and bacteria have genes (genetic information) in their cells	The genetic information is found in the chromosomes of cells. Most sexually reproducing organisms have two sets of chromosomes. All cells of an organism have the same two chromosomal sets (except sex cells).	Genes are nucleotide sequences within the DNA molecule. DNA molecule makeup chromosomes that make up our genome
(B) The genetic information contains universal instructions that specify protein structure	Genes are instructions for how organisms grow, develop, and function	Genes are instructions for molecules (many of which are proteins) that carry out functions within the organism. All organisms use the same genetic language for their instructions.	The genetic code is translated into a sequence of amino acids that makes up the protein. Almost all organisms use the same genetic code.
(C) Proteins have a central role in the functioning of all living organisms and are the mechanism that connects genes and traits	Cells have to carry out many essential functions to live. Within cells organelles do specific functions. The structure of cells, tissues, and organs determine their function. Our body has multiple levels of organization and changes at one level may affect another.	Proteins are like little machines that do the work of the cell. Proteins have shapes and properties that afford their functions. There are different types of proteins (enzymes, receptors, etc.). Changes to genes can result in changes to proteins, which can affect the structures and functions in the	Proteins have particular three-dimensional shape determined by their amino acid sequence Proteins have many different kinds of functions that depend on their specific properties. There are different types of genetic mutations that can affect the structure and thus function of proteins and ultimately

Component of big idea	Level 1: grades 5–6	Level 2: grades 7–8	Level 3: grades 9–10
		organism	the traits.
(D) All cells have the same genetic information but different cells use (express) different genes	Different cells have some common and some different structures and functions	Different cells have different repertoires of proteins. Proteins carry out the basic ("housekeeping") and unique functions of the cell.	All cells have the Same genetic content, but what genes are used by the cell (expressed) is regulated

Question: Why do we, and other organisms, vary in how we look and function? Big Idea: There are patterns of gene transfer across generations. Cellular and molecular mechanisms drive these patterns and result in genetic variation. The environment interacts with our genetic makeup leading to variation.

Component of big idea	Level 1: grades 5–6	Level 2: grades 7–8	Level 3: grades 9–10
(E) Organisms reproduce by transferring their genetic information to the next generation	All organisms reproduce and transfer their genetic information to their offspring. Cells divide to make new cells each with all the genetic information. In larger organisms each parent contributes half the genetic information to the new generation.	Before cells divide, the chromosomes sets are duplicated and then two new cells are formed each with two chromosomal sets. In sexually reproducing organism chromosome sets are randomly assorted into gametes through the process of meiosis (one full set in each sex cell). This process creates sex cells that have only one set of chromosomes	DNA replication is tightly regulated to prevent errors. During the process of meiosis chromosomes can swap sections and create new combinations of gene versions on a given chromosome. This creates more genetic variation.
(F) There are patterns of correlation between genes and traits and there are certain probabilities with which these patterns occur	We vary in how we grow and function. For a given trait there are variations. Different Organisms Have Different Versions of the Trait	Individuals have two versions for each gene (alleles). Each chromosome in the set carries one version of the gene. There are patterned correlations between the variants of the genes and the resulting trait.	The gene variants differ in their nucleotide sequence resulting in different or missing proteins that affect our phenotype. Dominant and recessive genetic relationships can be explained at the molecular level as a consequence of the function and interaction of gene products.
(G) Changes to the genetic information can cause changes in how we look and function (phenotype), and such variation in the DNA can serve as a way to identify	Different organisms vary in how they look and function because they have different genetic information. Even within a group of organisms there is variation in traits.	The genetic information can sometimes change. Changes in the genetic information can result in changes to the structure and function of proteins. Some changes can be beneficial, other harmful, and some neutral to the organism in its environment. Chromosomes, like X and Y, also vary in boys versus girls	DNA mutations are the source of genetic variation. Some DNA sequences can vary between species while others do not, therefore, we share some genes with other species (mice, flies). DNA sequences can vary between individuals and allow us to differentiate between individuals
(H) Environmental factors can interact	The environment can affect our traits. Even	The environment can influence cell function	Environmental factors can cause mutations in

Component of big idea	Level 1: grades 5–6	Level 2: grades 7–8	Level 3: grades 9–10
with our genetic information	organisms that are related may end up looking or behaving differently.	through changes at the protein level (type and amount)	genes, or alter gene expression

Table 3. Construct of LP revised by Todd and Kenyon (2013).

Original LP Duncan et al (2009)	Level description	Revised LP	Level description

Construct A

Original LP Duncan et al. (2009)	Level Description	Revised LP	Level Description
		Level 0	No correlation between concepts (DNA, gene, chromosome, nucleotide/base, cell, genome)
		Level 1	All incorrect correlations between concepts
Level 1	~~Humans, animals, plants, fungi, and bacteria~~ have genes (genetic information) in their cells	Level 2	Correct correlation between 2 concepts
Level 2	The genetic information is found in the chromosomes of cells. Most sexually reproducing organisms have two sets of chromosomes. All cells of an organism have the same two chromosomal sets (except sex cells)	Level 3	Correct correlation between 3-4 concepts
		Level 4	Correct correlation between 5 concepts
Level 3	Genes are nucleotide sequences within the DNA molecule. DNA molecules make up chromosomes that make up our genome.	Level 5	Correct correlation between all 6 concepts

Construct B

Original LP Duncan et al. (2009)	Level Description	Revised LP Shea & Duncan (2013)	Level Description	Revised LP	Level Description
		Level 0	No knowledge of genes.	Level 0	No knowledge of genes
		Level 1	Genes are non-informational in nature. They are passive particles associated with traits.	Level 1	Genes are non-informational in nature
		Level 2	Genes are non-informational in nature. They are active particles associated with traits.	Level 2	Genes are informational in nature. They have instructions for your body or "tell" your body what to do
		Level 3	Genes are active instructions that "tell" proteins, the cell, or the body to carry out specific functions.	Level 3	Genes contain instructions to "tell" your body how to grow, function, or develop at multiple different organizational levels (cells, tissues, organs)
Level 1	Genes are instructions for how organisms grow, develop, and function	Level 4	Genes have information about biological entities and function at multiple organization levels.		
				Level 4	Genes code for molecules or amino acids or proteins [i.e. some subcellular entities] inside cells that carry out functions
Level 2	Genes are instructions for molecules (many of which are proteins) that carry out functions within an organism. All organisms use the same genetic language for their instructions.	Level 5	Genes are instructions for molecules (many of which are proteins) that carry out functions within the organism. All organisms use the same genetic language for their instructions.	Level 5	Genes code for proteins, which are made of amino acids [at this level, students do not understand the mechanism of translation]
Level 3	The genetic code is translated into a sequence of amino acids that makes up the protein. Almost all organisms use the same genetic code	Level 6	The genetic code is translated into a sequence of amino acids that make up the protein. Almost all organisms use the same genetic code.	Level 6	Genes are translated into a sequence of amino acids that make up a protein [at this level, students understand the process of translation]

Construct C

Original LP Duncan et al. (2009)	Level Description	Revised LP Shea & Duncan (2013)	Level Description
		Level 0	No knowledge of proteins or cells.
Level 1	Cells have to carry out many essential functions to live. Within cells organelles do specific functions. The structure of cells, tissues, and organs determines their function. Our body has multiple levels of organization and ~~changes at one level may affect another~~	Level 1	Cells are one of the basic levels of organization in the body. They can perform specific functions. *[at this level, students understand the role of cells but not proteins]*
		Level 2	Proteins are good for you and provide positive health benefits. Without them, general health declines.
Level 2	Proteins are like little machines that do the work of the cell. Proteins have shapes and properties that afford their functions. There are different types of proteins (enzymes, receptors, etc.) ~~Changes to genes can result in changes to proteins, which can affect the structures and functions in the organism~~	Level 3	*Protein function is dependent upon their structure.* Proteins do the work of the cell. No examples given of how protein function (or a lack of function) contributes to the genetic phenomena. *[at this level, students understand that proteins do things inside of the cell (i.e. housekeeping, enzymes, receptors) but are unable to explain how the actions of proteins bring about traits]*
		Level 4	Protein function is dependent upon protein structure. Specific examples given of how protein function (or a lack of function) contributes to the genetic phenomena. *[at this level, students are able to explain how protein functions bring about traits]*
Level 3	Proteins have particular three-dimensional shape determined by their amino acid sequence. Proteins have many different kinds of functions that depend on their specific properties. There are different types of genetic mutations that can affect the structure and thus function of proteins and ultimately the traits	Level 5	The structure *and function* of proteins is dependent upon the properties of amino acids that make up the protein. ~~Changes in a gene can result in changes to specific amino acids, resulting in protein structure/function changes or loss of function.~~ *[at this level, students additionally understand that 3D shape and function is determined by amino acid sequence]*

Construct D

Original LP Duncan et al. (2009)	Level Description	Revised LP	Level Description
		Level 0	Genes and traits are not connected
Level 1	~~Cells have to carry out many essential functions to live. Within cells organelles do specific functions. The structure of cells, tissues, and organs determines their function.~~ Our body has multiple levels of organization and changes at one level may affect another	Level 1	Changes in genes can change instructions or traits
		Level 2	Changes in genes can change cells, genes tell cells what to do (cell changes may or may not give traits)
Level 2	~~Proteins are like little machines that do the work of the cell. Proteins have shapes and properties that afford their functions. There are different types of proteins (enzymes, receptors, etc.)~~ Changes to genes can result in changes to proteins, which can affect the structures and functions in the organism	Level 3	Changes to a gene change proteins (no mention of protein-trait connection)
		Level 4	Changes to a gene change proteins to change traits (no explanation of how)
		Level 5	Changes to the gene change amino acid sequences that make up proteins (no indication that function could be changed)
Level 3	~~Proteins have particular three-dimensional shape determined by their amino acid sequence. Proteins have many different kinds of functions that depend on their specific properties.~~ There are different types of genetic mutations that can affect the structure and thus function of proteins and ultimately the traits	Level 6	Changes to the gene can change the function of a protein and ultimately the traits

Table 4. Constructs of LP by Elmesky (2013).

Construct for 6–8 grades

Classification Core Understandings and Priority Ideas

An adequate conception of classification includes understandings within these three areas.

I. LIVING AND NONLIVING

An adequate conception of the difference between living and non-living things depends on understanding basic characteristics of life. Living things: (1) have basic needs which must be met for their survival; (2) are able to grow and develop during their life cycles; (3) are organized systems; (4) reproduce; and (5) are adapted to their environments.

II. PLANTS AND ANIMALS

An adequate conception of this categorization includes the understanding that although plants and animals are both living things, they have fundamentally different characteristics. Plants make their own food, while animals obtain their food from their environment. Priority Idea: Plants and animals may be distinguished based on observable structures and behaviors.

III. UNICELLULAR AND MULTICELLULAR ORGANISMS

An adequate conception of this categorization includes the understanding that most organisms are single cells (unicellular) and microscopic; whereas the remaining are multicellular and either macroscopic or microscopic.

Priority Ideas:

□ Because they are so small, cells are invisible to the unaided eye. Microscopes are needed to see most cells.

□ Unicellular organisms, like familiar organisms, require food, water, air, means of waste disposal, and a habitat in which to live.

□ The cell is the fundamental unit of life.

Construct for 9–10 grades

Structure and Function Core Understandings and Priority Idea

An adequate conception of structure and function includes understanding that living things are composed of parts or structures that are either visible or invisible to the unaided eye. These structures enable living things to survive in their environment. Structures relate to their functions. The structures of an organism interact with each other to function as a whole.

Priority Idea:

The organization of structures for living things includes the whole organism, organ systems, organs, tissues, and cells. The various structures function together to promote the survival, growth, and reproduction of the organism.

Construct for 11–12 grades

Life Cycles/Growth & Development Core Understandings and Priority Ideas

An adequate conception of growth and lifecycles includes understanding that living things go through a cycle of life. The details of the cycle differ among living organisms.

Priority Ideas:

□ Life cycle is a period when organisms are born or emerge as juveniles, grow and develop into adults, reproduce, and eventually die.

□ Living things change during growth and development (e.g., butterfly, frog, cricket, chicken, humans)

Table 5. Instruments for LP

Article	Instrument			
(Duncan et al., 2009)	*Learning performances and assessment tasks for the progression*			
	Components of Big Idea	Level 1: Grades 5–6	Level 2: Grades 7–8	Level 3: Grades 9–10
	C. Proteins have a central role in the functioning of all in living organisms and they are the connection between genotype and traits	Cells have to carry out many essential functions to live. Within cells organelles do specific functions. The structure of cells, tissues, and organs determines their function. Our body is composed of multiple levels of organization and changes at one level may affect another	Proteins are like little machines that do the work of the cell. Proteins have shapes and properties that afford their functions. There are different types of proteins. Changes to genes result in changes to proteins, which can affect the structures and functions in the organism	Proteins have particular three-dimensional shape determined by their amino acid sequence. Proteins have many different kinds of functions that depend on their specific properties. There are different types of genetic mutations that can affect the structure and thus function of proteins and ultimately the traits
	Associated learning performances	Students explain or predict how the alteration of a cell's structure or function can affect the structure or function of the organ or organism it resides in	(1) Students explain or predict how a genetic mutation might affect the function of a cell or organ in an organism. (2) Students explain how a change in a protein shape might affect its function and the function of a cell it resides in	(1) Students explain or predict how a genetic mutation might affect the structure and function of a protein. (2) Students explain how a genetic mutation might influence the function or appearance of an organism by affecting the function or structure of a protein that acts with in a cell, which resides in a tissue, which functions in an organ
	Assessment task Example 1	Some people are born with a genetic disease called muscular dystrophy. People with this disease have great difficulty in walking or exercising. Can you explain what might be causing these problems?		
		Expected responses: Level 1: Maybe these people have muscle cells that do not work well or maybe they have fewer muscle cells	Expected responses: Level 2: Maybe their muscle cells do not move well because the proteins in these cells do not work well	Expected responses: Level 3: Maybe their muscle cells do not move well because the proteins in these cells do not work as a result of a mutation in a gene
	Assessment task Example 2	There is a protein called hemoglobin found in red blood cells that binds oxygen. It is possible that gene mutations could arise that prevents hemoglobin from binding oxygen. Explain how a mutation could cause this problem		
		Would not give assessment task at this level	Expected responses Level 2: Maybe a protein in the cell is changed so the cell cannot carry oxygen	Expected responses Level 3: Maybe the hemoglobin protein is changed in shape, because of a mutation in a gene, so that hemoglobin cannot bind oxygen

(Duncan & Choi, 2017)

Model 1: Attack and Destroy

Model 2: HIV Can't Get In
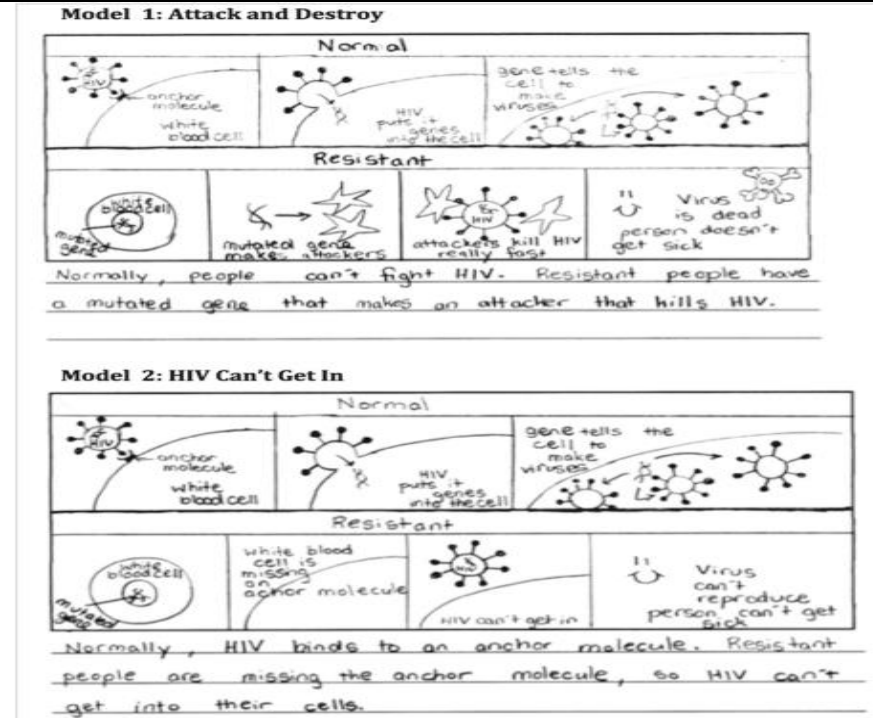
Todd et al (2016)

V4. Why is DNA sometimes called the "genetic code"? (B)
 a. DNA is your genes. (1)
 b. DNA codes for instructions for your body. (2)
 c. DNA codes for your cells, tissues, and organs. (3)
 d. DNA codes for things inside your cells. (4)
 e. DNA codes for proteins. (5)
 f. DNA sequences code for specific amino acids. (6)

How confident are you in your answer? (CRI)
 a. Guessing
 b. Uncertain
 c. Certain
 d. Very confident

DISCUSSION

LP (Learning Progression) on Genetic

Learning progressions (LP) developed by Duncan (2009) were focused on modern genetic, where the progress in genetics is very remarkable. Therefore, education requires the right learning method to explain the core concepts of genetics. The LPs from Duncan were designed for 5 to 10th-grade students. It because those grades were interconnected to each other and became the basis for the students to understanding concepts of modern genetic. The LP by Duncan has three key aspects of learning and teaching modern genetics. The first was the big ideas in modern genetics, knowledge, and skills to be mastered by students at the end of learning. The second was the development of the student learning expected for all levels. The third was to identify learning performance and develop the research for the proposed developments.

These three aspects can be further divided into eight constructs for understanding genetics from level 1 (grades 5–6), level 2 (grades 7–8), and level 3 (grades 9–10). The eight constructs represent the three modern genetic concepts: genetic models, meiosis models, and molecular models. Those constructs further divided into two categories, constructs A-D and E-H. To understand these constructs, basic questions were made. First: How do genes influence how we,

and other organisms, look and function? And; why do we, and organisms, vary in how we look and function? The first question was for A-D construct and the second was for the E-H. Both help to understand the great ideas in Duncan's constructional rigidity. The results of Duncan's research noted many students failed to understand modern genetics, but they suggested the learning about modern genetic should be focused on the core ideas in accord with the latest curriculum. This was difficult considering that modern genetics also required knowledge in chemistry and physics related to biological processes.

Duncan et al (2016) also still focused on the LP for genetics with basic concepts of inheritance models, meiosis models, and molecular models. They blend the concept of inheritance models and meiosis model into Mendelian genetic. In this study, Duncan explained which one is better taught in advance between Mendelian genetics and molecular genetics. The aim was to find out the sequence to support the theories in genetic learning at the transition from level 2 to level 3. They concluded the molecular genetic learning can be used as the bootstrap for Mendelian genetics. They focused to apply the LP for 7th-grade students. Duncan & Choi, (2017) also focused on the learning sequences for molecular and Mendelian genetics for grade 11 students.

Research about LP also conducted by Elmesky (2013) which focused on the genetic and genes expressions by proteins. The reason was the data from Duncan (2009) stated many students failed to understand modern genetic at the end of learning process. They also argued the importance of basic understanding about genetic possessed from early child hood for students' understanding of genetic in 12 grade. Different approach also offered by Elmesky to direct the students' understanding, which is using concept map for each level.

Four of eight Duncan's constructs have also been revised by Todd & Kenyon, (2016). Revisions were focused on the constructs A-D used for 10th-grade students. The revised constructs were: A (genetic organization), B (genes code and proteins), C (proteins do work of cells, proteins connect genes and traits), and D (cells express different genes). Duncan's constructs along with Shea et al., (2013) also revised by Todd and colleges. Some of the levels were eliminated because of redundancy. They also found the construct by Shea, et al (2013) were more effective than the original Duncan's constructs (Todd & Romine, 2016; Todd et al., 2016).

Todd, Shea and their colleagues used the same constructs; A (Genetic information is hierarchically organized); B (Genes code for proteins); C1 (Proteins do the work of the), C2 (Proteins connect genes and traits); D (Cells express different genes); E (Genetic information is passed on to offspring); F (There are patterns of correlation between genes and traits); G1 (DNA varies between and within); G2 (Changes to genetic information result in increased variation and can drive evolution); H (The environment interacts with genetic); I (Only mutations in gametes can be passed on to offspring); and J (Gene expression can change at any point during an organism's lifespan). Those constructs were used as the basis to find out basic theory of understanding shift, from basic understanding to comprehensive one, or from high school to higher education level.

Instruments to Assess LP

Various instruments used in assessment of Learning Progression. Learning Performance task combined with inquiry practices such as observation and data analysis were used by Duncan et al., (2009). Written tests using combined OMC and short-answer questions used by (Duncan et al., 2016). They were divided into several groups with 20 answers to Mendelian genetic and

inheritance using Punnet squares (17 multiple choices and three open-ended questions) and 15 items for molecular genetics (7 multiple choice and eight open ended). The test was focused on the students' understanding about genetic information and categorization of trait inheritance from genetic materials (nucleotides, DNA, and chromosomes).

Order Multiple-Choice (OMC) test with 56 items were used by Duncan & Choi, (2017) and focused on the Mendelian and molecular genetics. Similar instruments also used by Castro-faix & Romine, (2018), which was OMC, but they selected four to five items for each construct and others were included in other relevant levels. Order multiple choice (OMC) also used by Elmesky, (2013). Meanwhile, analysis of written test and interview were used by Todd & Kenyon, (2016).

OMC used by Todd and colleges to revise four of eight Duncan's constructs. They focused on the molecular genetics and cytology (Todd et al., 2016; Todd & Romine, 2016; Todd & Kenyon, 2016). Semi-interview also used to collect data. The interview was conducted after the pre-test and post-test, using students' test result as the materials for the questions. The Rasch model was used as the validation method. Data were validated by mapping the difficulties present on the test items and the students' ability. The result showed the instruments were proper for each level and students' understanding about genetic. Thus they were valid and reliable.

CONCLUSION

Duncan's LP constructs for genetic can be divided into three models: Mendelian genetic, Meiosis models, and molecular. They can be further divided into three levels: level 1 (5–6 grades), level 2 (7–8 grades), and level 3 (9–10 grades). Duncan's construct has been a subject for various revisions. Four of eight constructs have been revised by Todd and colleges. The focused on the molecular genetics and used as the basis to develop LP for higher education.

LP constructs from various researchers (Duncan, 2009; Elmesky, 2013; Todd & Kenyon, 2016) have been used as the basis for newer research. Other researchers (Duncan & Choi, 2017; Todd, Romine, & Todd, 2017) sough to find out the more perfect LP constructs for genetic.

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