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Development of Curriculum for Molecular Population Genetics

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Abstract

Design and development of a curriculum for the newly established discipline of Molecular Population Genetics is very challenging nationwide. In this manuscript, I used the Curriculum Theory and current application approaches to explore some possibilities for this challenge followed by a systematic performance and evaluation as a working project in the light of Aristotle's categorization of knowledge. It has been demonstrated that Curriculum Theory-based curriculum design has the advantage of the enhancement of students' excitement and involvement in their classroom studies and laboratory practice. It may also have a positive impact not only on their class performance, but also on their career development. As a result, this study has provided a model for construction of any other curricula in the future.

Key words: Curriculum Theory, Molecular Population genetics, Aristotle, Knowledge Categorization, Graduate Education

Introduction

The science of genetics has been developed through several scientific jumps in the past half century, from the discovery of DNA to the completion of the Human Genome Project and from decipher of genetic code for gene structure and function to population modeling of gene behavior in complex ecological systems. This amazing progress has enriched the life science and transformed the traditional genetics into modern genetics that has greatly promoted science and technology advancement in many areas such as agriculture, medical science, pharmacology, natural resources and even the military defense. Due to such a remarkable pace of growth in genetics and integration of many concepts, theories and technologies from other disciplines, a new discipline called Molecular, Cellular, Quantitative and Environmental Population Genetics has been proposed in recent years. This is a new historic Cxxxxe in science and has enforced many universities to consider if a new teaching course should be created for advanced graduate training for both master and Ph. D. degree. California State University Fresno is one of these universities and has been requested to develop an academic standard and a curriculum for this university course under the course title of Population Genetics. In this manuscript, I will only explore a model of graduate curriculum of Molecular Population Genetics based on the Curriculum theory and analysis model.

Molecular Population Genetics as a new discipline of science

There has been a long and mutually beneficial history of interaction between population genetics and statistics (Ewens, 1979). Experimental advance in Molecular Biology in past two decades has led to an explosion in DNA molecular data within and among populations. (Stephens et al. 2000.) The current major challenge in this area of study is how to integrate the concepts, theories and the methods from these five quite different scientific areas is very challenging.

As is a newly established sub-discipline of modern genetics, Molecular Population Genetics has five pillar stones: Molecular Biology, Genetics, Ecology, Statistics and Computer Science. Even though we have all textbooks for all of these courses, there is no specific textbook publically available for this course; all university instructors are still arguing what information should be included in the lecture and what experiments should be designed for teaching this course; and in fact, none of our faculty members has been previously trained to teach Molecular Population Genetics.

Curriculum theory and analysis model

Development of curriculum is a historical idea and has been theorized in many different ways to design, examine and support educational curricula through systematical analysis of curriculum and ways of viewing current educational curriculum and policy decisions. Even though there are many different views and models of the Curriculum theory (Schiro, 2007), the key concepts still remain unCxxxxed. According to Prof. Susan Schlievert's lecture, the first concept states that Learning is planned and guided. So, before we design a curriculum, we have to specify in advance what we are seeking to achieve and how we are to go about it. The second concept is that the definition refers to schooling, which means that we should recognize that our current appreciation of curriculum theory and practice emerged in the school and in relation to other schooling ideas such as subject and lesson. Therefore, there are in general four ways of approaching curriculum theory and practice, such as (1) Curriculum as a body of knowledge to be transmitted; (2) Curriculum as an attempt to achieve certain ends in students – product; (3) Curriculum as process; and (4) Curriculum as praxis. In brief, the four ways of approaching curriculum theory and practice can be depicted in the light of Aristotle's categorization of knowledge into three schools, which are: the theoretical, the productive and the practical (Figure 1).

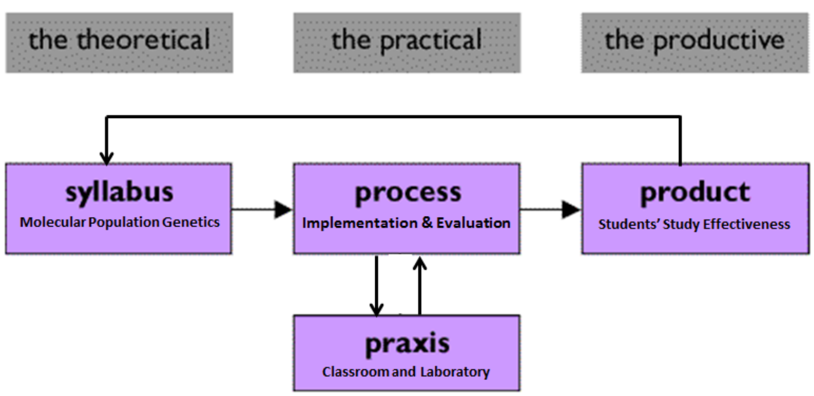

Figure 1. Aristotle's categorization of knowledge for Molecular Population Genetics Education: the theoretical, the productive and the practical (modified from http://www.infed.org/biblio/b-curric.htm).

Syllabus of Molecular Population Genetics:

As an instructor, I am authorized and responsible to design and develop a syllabus to teach Molecular Population Genetics at a graduate level. I considered this work as a research project and started it with a collection of textbooks and research articles in the areas of Molecular Biology, Genetics, Ecology, Statistics, and Bioinformatics. I used these books as the major references in addition to other research articles:

(1) Cox MA, Doudna JA, and O'Donnell M. 2012. Molecular Biology: Principles and Practice. W. H. Freeman and Company, New York, NY10010.
(2) Berk L, Krieger K, Ploegh B and Scott A. 2008. Molecular and Cell Biology 7th Ed, W. H. Freeman and Company, New York, NY10010.
(3) Russell PJ. 1992. Genetics 3rd Ed, Harper Collins Publisher.
(4) Lynch M. 2007. The Origins of Genome Architecture. Sinauer Association Inc., Sunderland, MA01375.
(5) Lynch M. and Walsh B. 1998. Genetics and Analysis of Quantitative Traits. Sinauer Association Inc., Sunderland, MA01375.
(6) Scheiner SM and Willig MR. 2011. The Theory of Ecology. University of Chicago Press.
(7) May R and LcLean A. 2007. Theoretical Ecology: Principles and Applications. 3rd Ed., University of Oxford Press.
(8) Bolouri H. 2008. Computer Modeling of Gene Regulatory Networks – A Primer. Imperial College Press.

Upon tentative review of these books, I designed the first syllabus of Molecular Population Genetics as shown in Table 1.

Table 1. Syllabus: Molecular Population Genetics 2013

Date	Chapter	Lecture Topics	Experiments
TBD	Chapter 1	Introduction: Molecular Population Genetics	
TBD	Chapter 2	Principles of Molecular Genetics	DNA structure and sequence analysis
TBD	Chapter 3	Principles of Quantitative Genetics	Quantitative variation and analysis
TBD	Chapter 4	Principles of Population Genetics	Gene flow and gene frequency in fruit fly room
TBD	Chapter 5	Principles of Ecology	Geographic distribution of butterflies in SJV areas
TBD	Chapter 6	Principles of Ecological Genetics	Genetic polymorphism of butterflies in SJV areas

TBD	Chapter 7	Computer Modeling and Bioinformatics	Population modeling of butterflies in SJV areas
TBD	Brain-Storm	From Different Principles to Giant Theory in Science	
TBD	Chapter 8	MPG Theory I. Random Genetic Draft	Spatial variation of virulence in bacteria
TBD	Chapter 9	MPG Theory II. Darwinian Evolution and Neutral Theory	Molecular evolution of Taq pol in test tubes
TBD	Chapter 10	MPG Theory III. The Molecular Clock	Observation of morning and evening genes in plants
TBD	Chapter 11	MPG Theory IV. Gene Genealogies	GenBank usage for phylogenetic analysis
TBD	Chapter 12	MPG Theory V. Genetic Models for Molecular Variance	Protein structural modeling via bioinformatics
TBD	Chapter 13	MPG Theory V. Transposons in Natural and Artificial Populations	Gene jumping in test tubes
TBD	Chapter 14	MPG Theory V. Population Genomics	The World 1000 Genome Project (Demo)
TBD	Brain-Storm	Hot Research Topic in Molecular Population Genetics	Group discussion and student presentations
TBD	Brain-Storm	Review and Final Wrap Ups	

Implementation, Evaluation and Practical Tests

The proposed curriculum of Molecular Population Genetics can be implemented as specific course sequences in several ways as shown in Table 2.

Table 2. Implementation of Class and Laboratory

	Lecture	Laboratory	Lecture + Lab
One Lecturer	**X**		
Multiple Lecturers	**X**		
One TA		**X**	

Multiple TAs		**X**	
One Lecturer + One TA			**X**
Multiple Lecturers + Multiple TAs			**X**

Implementation #1. One instructor teaches all lecture classes and one teaching assistant teaches all laboratories.

Implementation #2. Multiple instructors teach all lecture classes and multiple teaching assistants teach all laboratories, but each person teaches different chapters or laboratories based on each person's expertise.

Implementation #3. All lectures and laboratories are carried out in the same laboratory by one instructor and one TA for whole classes or by different instructors and different TAs.

Effectiveness of Curriculum and Feedbacks

In last three years, several professors, teaching assistant and I were working together to teach different classes including Molecular Biology, Genetics and Introductory Biology. Even though I was not the major instructor for this implementation, I have used the evaluation data to test the efficiencies of different implementation tests.

Students in the Molecular Population Genetics class come from different department with a very wide range of scientific backgrounds. For example, students with a biological background easily meet many prerequisites for this class, students with chemical background easily understand the molecular structure and function, and students from agricultural and environmental background easily solve many population modeling problems, and students from medical background prefer to use medical and clinical data for human population health studies, and so on. However, no students have the training background in Bioinformatics, Statistics, or computer programming. Therefore, I asked students to work in groups in classroom and laboratory in order to minimize the background differences in classrooms.

The student study scores can’t be used as a public data for this investigation because of university policies. Therefore, the evaluation of this curriculum is only based on classroom survey and instructor-student interviews. As results, I received many points of views, comments and suggestions from both students and faculty members. Here is an example of faculty evaluation of my curriculum and performance process for this class:

RE: Peer Evaluation, Biology 150 (Molecular Biology)

DATE: 21 March 2012

Biology 150 (Molecular Biology), MWF, 10-10:50, Science I 141

14 students were present in class

Dr. Cxxxx walked into the classroom at 11:56 AM. He instructed the class where the homework was, and students got up and took copies of the homework. The students made small talk and Dr. Cxxxx prepared to start his PowerPoint.

Dr. Cxxxx took roll at 12:01 PM. The students raised their hand as their names were called. Dr. Cxxxx finished taking roll at 12:03 PM.

Dr. Cxxxx began his lecture at 12:03 by stating that the exam will be moved.

12:04, Dr. Cxxxx began his PowerPoint lecture by giving the students a quick review. He lectured for this part of the class, and the students listened quietly. Dr. Cxxxx used an outline to discuss the review, and asked some questions. Once, one student answered one of the questions. Usually, Dr. Cxxxx would ask a question, only to pause for a second and answer it on his own.

Dr. Cxxxx finished the review on double stranded DNA break repair system at 12:11 PM.

Dr. Cxxxx began his lesson on Schematic of the Mitotic Cell Cycle at 12:11 PM. The students with computers followed the lecture with the PowerPoint on their laptops, and took notes.

At 12:40, Dr. Cxxxx began his review of the lesson covered in class.

Overall Assessment: Dr. Cxxxx possesses a powerhouse of information concerning his subject matter, though the intonation of words seems to pose a significant barrier in the full comprehension of the lesson plan. It is not the accent so much as the intonation of the words that prevents the students from fully understanding the words. Dr. Cxxxx should follow the suggestion to take listening and speaking courses through the American English Institute on campus. I believe that with proper training, Dr. Cxxxx will be able to articulate the lesson of the day well enough to make it accessible for the students.

Dr. Cxxxx provides a lot of information that is useful, and provides the students with the right answers to the homework and quizzes, out of which the exams are based.

The students seem to passively follow Dr. Cxxxx –they only listen to him, and they don’t ask questions, and nor does Dr. Cxxxx solicit answers from the students. It is recommended that Dr. Cxxxx ask more questions, so that the students are more involved with the development of the lesson plan. If Dr. Cxxxx were to ask questions, the students would tend to concentrate more on the lesson at hand, and would be able to think about the information Dr. Cxxxx is providing. If necessary, the main questions should be written down on the whiteboard so that the students can write and then process the information in order to arrive at the correct answer. If the time is too limited to write on the whiteboard, insert the question into the PowerPoint so that the students can see it written down, and thus be able to think about an appropriate answer.

It is also suggested that the PowerPoint slides be broken down in bullets that are displayed one at a time. With the PowerPoint slide as it stands, the students see the entire amount of information to be discussed at once, and it is more difficult to follow the lecture without having each one displayed at a time.

When displaying the summary for the lesson of the day, again, it is recommended that each of the 9 points of information be given one at a time, so that the students are able to better follow the concepts. The font should also be bigger. At the end of the summary, it is fine to display all of the 9 items together.

At 12:45, Dr. Cxxxx displayed: Looking for Answers for Unanswered Questions. This slide had 4 questions displayed. These were great questions that stimulated the students to project the lesson plan of the day to other areas that are still uncharted. It is also recommended that these questions be given one at a time, and that the possible answers be given in small conceptual, bullet-point answers that are able to serve as an associative word that will lead to the understanding of the greater questions. At 12:50, Dr. Cxxxx asked for questions and there were none. One student asked about the exam and Dr. Cxxxx answered it. He knew her name, which shows great investment on behalf of the professor to his students.

I believe that Dr. Cxxxx is a dedicated and concerned professor. His lesson plan was well prepared, and the information was explained in detail. The PowerPoint was informative, and it seems that Dr. Cxxxx invested much time in developing it. With just a few improvements, this course could be highly engaging and interesting.

All students provided their evaluations to me also. Here is a summary of this information: (1) This curriculum is an milestone of academic advancement of biology education; (2) The classroom performance varies, where one instructor is better than multiple instructors, but multiple teaching assistants is better than one teaching assistant; (3) Most of our graduate students are not well prepared for this class because of vast diversity of their training background; (4) Project-based laboratory is required for this class instead of individual laboratories; (5) Computer-aided simulation should be enhanced for this class.

Instructional and Learning Theory-Based Refinement of Curriculum:

How to use the evaluation information from instructional practice in classroom and laboratory to improve the curriculum of Molecular Population Genetics for next semester is still in controversy at present because of strong involvement of some political and social factors in decision making. My personal opinion is that the structure of curriculum was excellent and designed at a higher level, but the there are some problems in the process and praxis. Understanding the process and praxis of teaching Molecular Population Genetics through application of the Instructional Theory and Learning Theory would be the key to solve these problems and then to improve the current curriculum of Molecular Population Genetics for future development.

Instructional theory offers explicit guidance on how to better help learners learn and develop (Reigeluth, 1999). It focuses on how to structure material for promoting the education in schools. In comparison, the learning theory describes how learning takes place, while the instructional theory describes how to better help people learn. However, the two schools are often integrated and affect each other. The development of behaviorism (learning as response acquisition), cognitivism (learning as knowledge acquisition), and constructivism (learning as knowledge construction) is such a fact that the process of instruction is based on the models of people's understanding of knowledge (Mayer, 1992)

Gagné described the characteristics of instructional theories in terms their functions and foundations **(**Gagné, 1985). Based on this theory, instruction itself does not produce learning, but support the learner's internal process. Reigeluth (1999) used the term 'instructional-design theory', which is defined as a theory that "offers explicit guidance on how to between help people learn and develop. The kinds of learning and development may include cognitive, emotional, social, physical and spiritual." Problem-based learning (Allen and Tanner, 2003) and Inquiry-based laboratory instruction has also been recommended by several groups of educators (National Research Council, 2003; Bhattacharjee, 2005; Shane, 2009). Project-based laboratory instruction is thought to engage students more than "cookbook"-based laboratory practice because it often yields data by students themselves other than by instructor-centered demonstrations. Through these efforts, many project-based instruction and laboratory courses have been proposed and established to enhance student's scientific research skills (Sleister, 2007; Palombi and Jagger, 2008).

The refinement of the curriculum of Molecular Population Genetics began with the adoption of the guidelines from these theories and methods as described above. I designed following approaches:

(1) Development of curriculum in different stages. I refined the curriculum in testing through the development of three different curricula at three different levels, that is, the basic curriculum for most students from non-biology major; intermediate curriculum for master students; and advanced curriculum for Ph. D. students.
(2) Classroom is combined with experiments in the same laboratory.

(3) Project-based laboratory is constructed.
(4) Application of current education technologies in teaching.
(5) Invitation of guest speakers to teach specific topics.

Re-testing the effectiveness of the refined curricula for teaching Molecular Population Genetics is under the way of performance at present.

Conclusion and Prospect

Designing a successful curriculum is a long way process especially for new disciplines of science. Even though for many established courses, curriculum Cxxxxes over times in order to meet with different needs or emergencies. In this study to design a curriculum for newly development course of Molecular Population Genetics, I have applied the Curriculum Theory and practical strategies to every stages and steps following Aristotle's categorization of knowledge. The overall outcome is very successful, demonstrating the correctness, usefulness and effectiveness of Curriculum Theory in the design of curriculum of Molecular Population Genetics for graduate study. One possible criticism of this study is that it provides too many challenges in theory and experimentation for students at present. In fact, the contents of the curriculum are much more beyond the current standards of graduate education and the experiments are too expensive when compared with other courses. Therefore, it becomes very difficult for the department to provide enough financial support to continue this class next step.

As a project-focused laboratory teaching to support the lectures for this course, the advantage of the curriculum is the enhancement of students' excitement and involvement in the study, where each student in the class team depends on the results of every other student and that the final results are largely dependent on results of previous experiments. So the instructor needs to input more efforts to make sure that each step of experiments is correct, otherwise one mistake would lead to failure of all experiments. Therefore, division of whole class into several small groups will be very beneficial. In this case, few students working as each small group are encouraged to devise their own mini experiments, them they combine the results together to produce the complete information for whole experiments. Evaluation and judgment from the students' enthusiasm, interest, and achievement to score students' learning outcomes may have a positive impact not only on their class performance, but also on their career development. This project to design and develop a curriculum of Molecular Population Genetics is worth the efforts of the instructor and students as well as the administrative support from department and college offices. It will provide a model for construction of any other curricula in the future.

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