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ABSTRACT

The purpose of this study is to examine one possible source of misconceptions that are held by students of genetics--the teachers. Is there evidence to suggest that prospective biology teachers might have misconceptions about genetics and related concepts? If prospective biology teachers have misconceptions in genetics, how do these misconceptions relate to common students' misconceptions in genetics? To address these questions a study was conducted at Pennsylvania State University in a secondary science methods course. Data were collected from six prospective biology teachers who had experience with concept mapping prior to this study. The teachers were given a list of concepts and were asked to construct a concept map using those concepts. Maps were analyzed and compared. A major finding is that concept maps clearly demonstrate that prospective teachers do not have conceptual understanding of concepts and that they are suffering lack of organizational and hierarchial knowledge among these concepts. There is a need for research on teachers' alternative conceptions. Appended are a "Workshop on Concept Mapping with an Introduction to Technology Tools" and a comprehensive concept map. (Contains 26 references.) (MM)

Prospective Biology Teachers' Understanding of Genetics Concepts

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A Paper Presented at the Annual Meeting of the Association for the Education
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Purpose of the study

The purpose of this study is to examine one possible source of misconceptions that held by students about genetics, the teachers. Is there evidence to suggest that prospective biology teachers might have misconceptions about genetics and related concepts? If prospective biology teachers have misconceptions in genetics, how do these misconceptions relate with common students' misconception in genetics? To address these questions a study was conducted at Pennsylvania State University in secondary science method course.

Significance of the study

Many studies focus on misconceptions—those ideas and notions that students bring with them to science lessons that are inconsistent with those accepted by the scientific community (Pfdunt & Duit, 1994). Although the identification of alternative conceptions is an obvious and important stage in the remediation of misconceptions, Driver & Easley (1978) state, "...Not until the reasons for the misconceptions are understood will progress be made in instructional terms". Lawson (1989) points out "students derive.Misconceptions.... from a variety of sources and the source of those alternative views may well influence the way they should be treated in the classroom" (p. 825). Knowledge of the causes and processes of development of such informal views is essential for designing and constructing effective instructional strategies that aim to prevent or rectify misconceptions.

The National Research Council (NRC, 1990) argued, "The high school biology course should be a synthetic treatment of important concepts and of how these concepts can shape our understanding of ourselves and our planet". In order to achieve this goal, teachers must possess an integrated understanding of the content taught and have the skills necessary to translate such understanding to their students.

Literature review

Science educators have suggested several factors that could influence the development of misconceptions (Yip, 1998). Children's misconceptions in science can be broadly categorized into three groups according to the nature and sources.

- 1) Informal ideas that are formed from everyday experiences which children bring with them to the classroom;
- 2) Incomplete or improper views developed by students during classroom instruction;
- 3) Erroneous concepts propagated by teachers as well as by textbooks.

First type misconceptions are generated through students' life experiences and indiscriminate use of everyday language. They are commonly detected in basic biological concepts which are encountered by students in real-life context prior to instruction, such as the concept of living, animals and plants, sources of plant food, photosynthesis, respiration and inheritance (Mintzes et al. 1991, Driver et al. 1994). In biology, however, a large number of misconceptions may not be influenced by the personal experiences of the learners (Barrass 1984, Cho et al. 1985, Sanders 1993). Lawson (1988) indicated that the primary source of knowledge in biological sciences is adult authority; for example, books and television, rather than personal knowledge. He suggested that only a few students bring with them highly formulated alternative conceptions about biological sciences. These errors are mainly of the second and the third categories, i.e. caused by ineffective learning or poor teaching in the classroom.

Second type misconceptions are formed as a result of instruction. Undue emphasis on the acquisition of factual information, which is a common practice in biology teaching, presents a block to conceptual development. In terms of work that is incorrectly taught, two possible sources of erroneous ideas have been singled out, textbooks (Fisher & Lipson, 1988; Storey,

1989, 1990) and teachers (Nussbaum, 1981). The third source of misconceptions is teachers who are less competent in subject-matter knowledge. They may propagate incomplete or erroneous views to their students through inaccurate teaching or uncritical use of textbooks (Barrass 1984, Sanders 1993). This type of error is particularly prevalent among students who assume a rote mode of learning with unconditional acceptance of information delivered from the teacher.

One area of biology in which students have learning difficulties is genetics. A survey of high school teachers (Stewart, 1982a) indicated that Mendelian genetics, meiosis and mitosis, and the chromosome theory of inheritance are considered among most difficult and the most important topics of study for students. Hackling & Treagust (1984) reported a study in which results revealed that the concepts and propositions about chromosomes, genes, meiosis, and fertilization were necessary for an understanding of the mechanism of inheritance.

Misconceptions of the first and second categories have been extensively studied in life science, but those originating from teachers are relatively unexplored. An unacceptably large population of the teachers surveyed in Sanders' (1993) study appears to have erroneous ideas about the process of respiration. This preliminary study suggests that teachers could be a factor contributing to the formation of errors and/or misconceptions in their pupils, a claim made by Barrass (1984) without supporting evidence. It is clear that formal instruction may promulgate misconceptions. In biology, one area of particular concern that may involve conceptual difficulties arising from instructional practice is the study of genetics.

In view of the deficiency of research in this aspect of science learning and the great impact of the teacher as a direct agent for passing misconceptions to the students, the present study is launched to address the issue of whether prospective biology teachers in Penn-State University possess an adequate understanding of genetics to teach the school curriculum.

Method

Concept mapping tasks have been used in a variety of ways to research topics in science education. Surber & Smith (1981) investigated concept-mapping tasks as a means of investigating students' misconceptions. Barenholz & Tamir (1992) and Trowbridge & Wandersee (1994) used concept-mapping tasks to assess the effects of science instruction. Concept maps are seen as a viable assessment of an individual's knowledge because they display the connections and relationships between concepts, as well as evaluate higher order thinking skills (Rafferty & Fleschner, 1993).

Construction of concept map provides a quick means to elicit how subjects link and organize concepts together. Concept maps are two-dimensional, hierarchically organized, node-link diagrams that depict the major concepts within a domain of knowledge and the significant relationships among those concepts. The nodes correspond to relevant concepts in a domain and the lines express a relationship between a pair of concepts. The label on the line expresses how the two concepts are related (Shavelson, Lang, & Lewin, 1993). The lines should be labeled so that the meaning between the two concepts is explicitly expressed (Novak, Gowin, & Johansen, 1983). The combination of two nodes and a labeled line is referred as a proposition. By examining concept maps made by students we can infer much about the propositional validity and structural complexity of their knowledge (Pearsall, Skipper & Mintzes, 1997).

Data were collected from six prospective biology teachers. All of them had experience with concept mapping prior to this study. However, to remind the basic components of concept maps and potential significance of them in teaching and learning, workshop (Appendix A) was conducted before task was given to students. The prospective teachers were given a list of concepts and were asked to construct a concept map using those concepts. The concepts used in

the list were drawn from those suggested by Steward (1982) who pointed out those students' encountered difficulties in describing the relationship between those concepts. However, some of concepts will be removed or added as deemed appropriate for the objectives of this study. Concept maps were analyzed by paying attention to relationships, hierarchy, branching, and cross-links. One master concept map was constructed after reviewing relevant literature and extract propositions from them (Appendix B).

After each student has completed his or her map privately, they shared their maps and interacted with each other to create a more comprehensive and better-organized map. Students were allowed to add or remove some concepts from the list when they think doing so is appropriate.

Data analysis

By examining concept maps made by students we can infer much about the prepositional validity and structural complexity of their knowledge. For instance, the number and quality of scientifically acceptable concepts and propositions; the extent of progressive differentiations as reflected in the number of hierarchical levels and amount of branching, and the cohesiveness or degree of integrations seen in the number of cross links. Concept maps assessed considering each proposition separately. The proposition is the least complex structure represented in a concept map.

Students had difficulty in assigning linked words for connected concepts. Generally they omit linking words. They aware of the relationship, however, could not be able to define the nature of association. Concept maps represent what an individual knows as well as how they organize their knowledge. Misconceptions are seen when a linkage between two concepts leads

to a false proposition. Such as “traits give genotype”, “chromosomes give traits”, “zygote is a gamete”.

Hierarchical order was completely absent from all of the concept maps. Since students do not have conceptual knowledge sometimes they used very general linkage words to create a proposition. Such as, “zygote has chromosomes” it may seem true but the fact that all human cells have chromosomes or “inheritance includes alleles” such statements are irrelevant and hierarchically inappropriate. Besides there are very severe and important erroneous misunderstanding like “zygote splits through meiosis” and “inheritance due to chromosomes”.

Nuclear division and its function were not mentioned in any of the concept map. Three of the students out of six did not use meiosis concept in their maps, however nobody indicated that it is irrelevant concept and should be removed from the list. This suggests that nature of meiosis and its function are not understood. Relationship between meiosis, nuclear division, and its logic are lost from their understanding. None of the six participants indicated that as a result of meiosis the chromosome number of the gametes is reduced to haploid number.

When very important linkage and proposition is absent between two central concepts, concept map indicates lack of solid and conceptual understanding. In many cases, students made no connection between gamete and zygote, gene and allele, meiosis and gamete, alleles and trait. The following propositions were expected to be established by the students who has basic understanding of concepts that involved, unfortunately concept maps are not demonstrate any one of them:

With the formation of zygote the diploid number of the species is restored.

Alleles are the alternative forms or variants of a gene.

Each trait exhibited two variants: one dominant and one recessive.

Genes are related to alleles as traits are related to their variants or forms.

Concept maps clearly demonstrated that prospective teachers do not have conceptual understanding of concepts that they were introduced and they are suffering lack of organizational and hierarchical knowledge among these concepts. Prospective teachers have conceptual difficulties with alleles and their nature and location. This is very common misunderstanding among high school students too (Steward, 1982a). The students first need to appreciate the relationship between gene, allele so that they are aware that an allele is merely a particular form of a gene. This will then allow them to appreciate the idea that alleles can be dominant or recessive, and this in turn will allow them to understand the heterozygous and homozygous conditions.

Limitations of the study

This study might not necessarily indicate that the participants do actually have misconceptions. However, it seems likely that someone constructing inappropriate concept map, suggesting wrong propositions between concepts, and being unable to construct hierarchical order for given concepts could have an incorrect idea about that topic. It is not possible to claim that this is a valid misconceptions test, or even that it identifies the presence of alternative conceptions, as no effort was made to check any other factors could have caused the participants to construct inappropriate maps. Rather, purpose of the study was to establish whether or not there was cause for concern, and consequently whether further investigations were required. However, whatever the reason for the unsuccessful concept mapping, their assessment gives cause for concern.

Although no claims can be made about the reliability of these results, this does not lessen the importance of the aim (and findings) of the research, which suggests that there are problems

that could well have an effect on the development and perpetuation of students' errors, and that this is an area requiring further research.

Discussion and implications

Recommendations for teacher education:

It may be assumed that secondary school teachers, having completed their undergraduate degree courses in the appropriate discipline, should have acquired adequate knowledge for teaching subject matter in the school curriculum and their subject knowledge will improve with increased teaching experience. As a result, most teacher education programs focus mainly on educational principles, instructional methodology, and teaching practice; they seldom address the need for promoting for deeper understanding of subject matter knowledge to make a teacher more competent. As well as this study, a number of studies, however, reveal that many biology teachers, including those with experience, show misunderstanding of various biological concepts would be conveyed to their students through inaccurate teaching or uncritical use of textbooks (Sanders, 1993; Yip, 1996).

There is a need for research on teachers' alternative conceptions. Teachers who possess alternative conceptions themselves cannot help students to develop accurate understandings of scientific concepts. If college science and pedagogical course instructors become more aware of the alternative conceptions that their students (future science teachers) might bring to their classes, they may be able to guide those student teachers to more accurate conceptualization. Further, authors of the teachers' guide can address the topic of alternative conceptions and suggest ways by which teachers can both correct them and avoid introducing them.

Recommendations for genetics instruction:

The lack of precision in the use of genetic terms generates confusion and may contribute in a subtle way to misunderstandings. Terms like gene, allele, gamete, zygote, and trait should be described in the clearest way considering its correct and incorrect use. An integration of concepts needs to be stressed by using diagrams and models prepared by the students. Since there are diverse effects of diagrams, following a diagram or model is less effective for conceptual understanding than preparing the diagram or model. The events of the DNA duplication and meiosis should be emphasized as a part of the cell cycle. The management of genetics and meiosis should be an integrated one and the instruction of meiosis needs to emphasize the location of alleles in the chromosomes.

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Appendix A

Workshop on Concept Mapping with an Introduction to Technology Tools

Prepared by Mustafa ÇAKIR

Graduate Student in Science Education

Introduction

Concept maps were first introduced as a teaching tool by Joseph. D. Novak at Cornell University in the early 1980's. The principal goal of concept mapping is to help people organize and make sense of their experiences associated with selected concepts. Concept mapping has been found to be useful for improving science teaching and learning by facilitating meaning making and providing a sense of personal control over the way a person's understanding is displayed.

A very useful form of concept mapping for teaching and learning is to arrange the map in a hierarchical organization with the more general and more inclusive concepts at the top of the map and the more concrete and specific ones at the bottom. A concept map depicts hierarchy and relationships among concepts. Constructing a good concept map requires clarifying meaning and integrating crucial details. The concept map construction process requires one to think about the organization of ideas in multiple directions and to switch back and forth between different levels of abstraction.

Concept maps help to show relationships between concepts, and it is from these relationships that concepts can acquire enhanced meaning. An individual's understanding of the connections between many concepts can be demonstrated in one concept map. A good map provides a broad spectrum of information about the ideas of the person who constructed the map.

Benefits of using concept maps in teaching

Concept maps can be used for various purposes in teaching and learning such as:

- ◆ ***Encouraging meaningful learning:*** Concept mapping can be an effective tool for organizing one's understanding. Constructing concept maps can assist students in moving from ritualistic learning to more meaningful learning.
- ◆ ***Designing teaching:*** Concept mapping can be an effective tool for organizing a unit of instruction, a class, or even an entire curriculum.
- ◆ ***Overcoming alternative conceptions:*** Concept maps can be employed to help students to recognize and overcome misconceptions, especially when they are used in small group settings. In addition, concept maps are helpful to teachers, who need to identify their own conceptions and misconceptions and to find ways to clarify and develop their understandings.
- ◆ ***Student evaluation:*** Concept maps can serve as powerful evaluation tools (revealing a students' synthesis and evaluation of relevant ideas) by asking students to map a set of related concepts. Concept maps also provide specific information to teachers that can help them identify specific places where the instructional program has failed to teach important concepts or propositions.
- ◆ ***Cooperative learning:*** one of the difficulties many teachers have in using cooperative learning effectively is how to focus students' attention on key issues and how to engage all members of the group. Concept mapping can be an effective way to engage a group's attention and collaboration. Students can prepare individual maps of their understanding of the problem and then collaborate with classmates, with sources of "expert knowledge", and

with the teacher to merge their maps into a more comprehensive group map that has meaning for the individuals who have participated.

Steps in constructing a concept map

- 1.Select:** Focús on a theme and then identify related key words or phrases.
- 2.Rank:** Rank the concepts from the most abstract and inclusive to the most concrete and specific.
- 3.Cluster:** Cluster concepts that function at a similar level of abstraction and those that interrelate closely.
- 4.Arrange:** Arrange concepts in a diagrammatic representation.
- 5.Link and add proposition:** Link concepts with linking lines and label each line with a proposition.

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Workshop Task

You have been planning to teach Mendelian genetics to your high school biology students later this semester. You have decided that during that unit, you will ask the students to prepare a concept map to assist them in organizing their ideas and to help you assess the nature of their knowledge. After each student has completed his or her map privately, you plan to have the students share their maps and to interact with others to create a more scientific and better-

organized map. To facilitate that discussion and to help you better assess their understanding, you have decided to give the students a beginning list of central concepts and to ask them to use most or all of those concepts in constructing their maps.

Here is the list of central concepts you have been thinking you will probably ask the students to include in their map:

Dominant	Phenotype	Gametes	Inheritance
Alleles	Recessive	Meiosis	Zygote
Trait	Genes	Genotype	Chromosomes
Heterozygous	Homozygous		

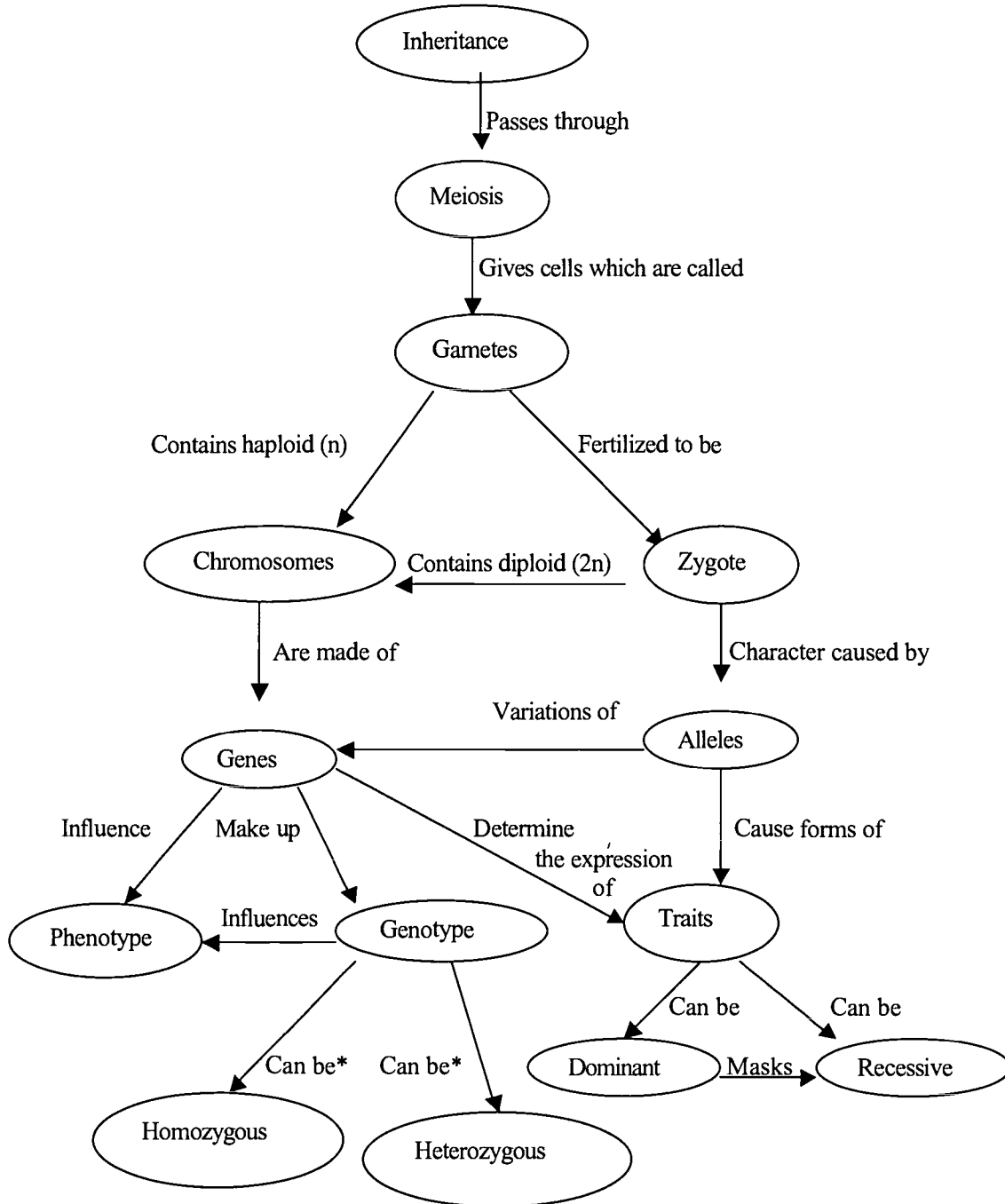
In this workshop task, you are a teacher who is participating in a workshop with other Biology teachers, perhaps at a regional NSTA meeting. This workshop has been designed to help high school Biology teachers teach Mendelian genetics more effectively.

At this point, do you agree that the concepts listed above are the most important? Would you add or remove some concepts from the list? If you would add concepts, please insert the concept name on a line in the table above. If you feel you would delete one or more concepts from your introductory course concept map, please draw a line through those names (above). For the purposes of this workshop, please construct the concept map you would hope to receive from the "best" student in the class using the concepts in the table above.

At the completion of this 411 workshop, your map will be reviewed (NOT graded) by Mustafa Cakir to gather information about the utility of the workshop and about your understanding of Concept Mapping. The map you construct in the workshop will not be influencing your grade in Scied 411.

Appendix B

Comprehensive concept map. Prepared by Mustafa CAKIR



* Depending on allelic combination



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