在生物学教学中通过提问培养学生的创新思维

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无论在中国还是美国,生物学教师都在考虑如何使学生将盲目的记忆转变成为追求切实的生物学知识,包括培养学生提出新的关键问题的能力。授课是最有效的交流形式,而且如果各种概念能够与学生的生活经历联系起来,或者实验室或野外工作能提供使这些概念具有实质意义的多种感性经历,这种授课便会很有效果。但是,阅读课本中描述的科学结果以及重复已经详尽编排好的实验,并不能激励学生成为新一代创新研究者。提出探索性问题的能力是对成功的研究者的普遍要求,有些教师能够在课堂教学中通过提问培养部分学生的这种能力,这种方法被称为"探究式教学"。

为了阐明鼓励学生提问并像科学家那样思考这样一种教学过程,兹将有关朊病毒这种新病原体的常规教案与探究教案作一比较。

1　常规教案提纲

(1)朊病毒是一种新的感染源。

(2)朊病毒(prion)由蛋白质(protein)及感染(infection)两词而来。

(3)朊病毒疾病:疯牛病(BSE),使牛痴呆;人类痴呆症(CJD),遗传或与疯牛病相似途径引起;人类痴呆症(Kuru),由吃人肉风俗引起;疯羊病(Scrapie),使羊痴呆。

(4)其它症状及流行病学:通过食用神经组织而感染;发病缓慢,通常在感染后一年发病;宿主不产生免疫应答。

(5)病原体是一种异常蛋白质;与DNA或RNA无关;正常蛋白质命名为PrP;朊病毒蛋白质是PrP^{SC};感染涉及到$PrP \rightarrow PrP^{SC}$;PrP^{SC}的α链较少,而β片层结构较多;因为PrP^{SC}是正常蛋白质的另一种三级结构形式,故宿主不产生抗体。

2　探究式教案提纲

(1)什么是传染病?区别非传染和接触感染。

(2)哪种病原体会导致传染病?寄生虫(蠕虫、阿米巴,真菌等)(DNA);细菌(DNA);病毒(RNA/DNA);(?)(?)(上面两圆括号内容留待进行后面有关练习后再填写)。

(3)既然宿主死亡时寄生虫通常会死亡,那么寄生虫如何免于灭绝?寄生虫会生殖;什么分子使遗传复制成为可能?DNA或RNA/DNA(与第(2)步进行对照)。

(4)下面列出一些怪病:疯牛病,使牛痴呆;人类痴呆症,遗传或与疯牛病相似途径引起;人类痴呆,由吃人肉风俗引起;疯羊病,使羊痴呆。

(5)若有一种原因未明的疾病,如何着手寻找传染性病原体?从被感染的动物提取病原体,在健康动物进行实验(Koch氏假设,即分离病原体的步骤)。

(6)根据第(4)步提供的信息,我们应从哪里寻找传染性病原体?神经组织。这可得到证实:如果我们注射从患病动物提取的脑组织或脊髓液,健康动物最终得病。

(7)陶瓷纤维过滤可以滤去寄生虫和细菌,但会让病毒和化合物通过。若经过滤的和未经过滤的神经组织都能使健康动物得病,那么该病原体的性质和大小应做何判断?它应当或者是一种病毒,或者是一种化合物,因为经过滤的液体不可能含有细菌或寄生虫的整体。(图1)

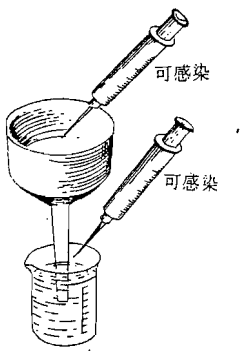

图1　陶瓷纤维过滤试验结果

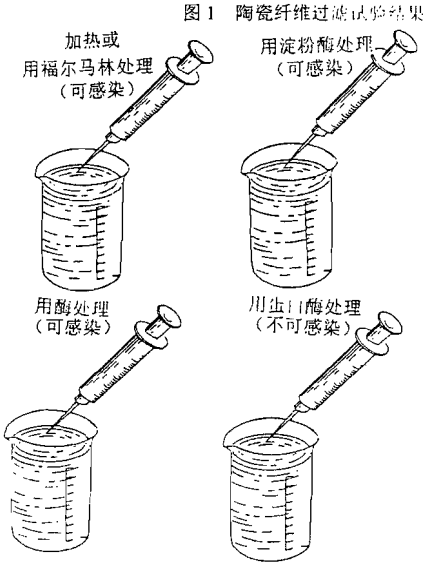

图2　感染性试验结果

(8)经过滤的溶液用变性剂处理。福尔马林或加热可以破坏 DNA 和 RNA。何种酶破坏糖、脂肪、蛋白质? 感染性试验结果见图 2 所示。说出传染性病源体的性质。(是一种蛋白质。至此,请填写(2)下面的括号)。

探究式教学以教师通晓许多所提问题为基础,这些问题要求学生去分析、提出可能的实验以及解释研究结果。在常规讲授中,朊病毒这种新病原体的蛋白质本质在讲课开头就被给出,并且以一种编排好了的形式讲述,学生不用深入理解就很容易记住。而在探究式教学中,学生是在经过与原始研究过程十分相似的充分思考之后,于教学结束阶段才知道朊病毒是蛋白质。这种教学要求教师掌握比通常课本所提供的多得多的有关该研究的知识。显然,这种教学占时更多,故假如被广泛采用的话相应的教学内容就会减少,学生也就会没有机会钻研应付高考所必须的许多概念。与应试式常规教学相对照,探究式教学试图通过对科学充分思考的自然兴趣来激发学生的学习。探究式学习和探究式提问的提倡者认为,引导学生提问并由他们自己萌发思想而产生的智力开发,能增加他们的批判性思维并有助于培养未来的创新科学家。

3 不同程度题目的分类

科学家使用的创造性思维、创造性提问及创造性态度不仅可以通过课堂提问式讨论,而且可以通过各种不光是用来检测记忆的知识测试和重大考试而得以促进。下面的题目分类可能有助于一些教师对题目类型的了解。

(1)*确认性术语记忆题* 涉及学生不必理解其意义而记住和复述的信息;问题形式与课本、讲授提纲、或者实验指导中的完全一样;学生通过"死记硬背"将这些信息短期或确认性记住;这类测试题用以评判学生回忆特殊词汇或定义的能力,而并不能使学生理解这些概念。

举例 以下有关朊病毒的叙述哪些是对的? A)朊病毒是新的病毒形式。B)朊病毒能够抵御宿主免疫应答。C) * 朊病毒是蛋白质感染。D)朊病毒迅速破坏红血球。(* :正确答案)。

功能 本题是低水平的题目,学生能够直接从课文中回想起"蛋白质感染"这一术语。

(2)*理解题* 所涉及内容能表明学生理解概念;学生所回答的问题已经根据课本或讲课内容进行了重新组织;学生可以用自己的语言对事物进行比较、描述或衬托;这类题目常常要求使用一段新的语言对关键词进行解释。

举例 以下病症中的哪一种可能由朊病毒引起? A)炎症;头疼;高血压;恢复期长;B)咳嗽;发热且感染后马上死亡;C)红血球计数高;恶心;病程长;D) * 红血球计数正常;感染后数年找不到发病原因;最终死亡。(* :正确答案)。

功能 本理解题相当复杂,学生必须理解有关概念,仅仅记住课文中的例子不能正确回答。

(3)*应用题* 所涉及内容要求学生用于新的情景,或者利用生物学知识去解决新的问题;这类题目常常要求学生在研究中应用、选择或提供新的结果,将新事件归类,或者提出新的步骤等等。

举例 探究式教案的第(6)步,即要求学生确定新出现疾病的传染性病原体所在部位。

功能 本题要求学生应用他们所学知识去理解有关情况解决新问题。

(4)*分析解释题* 所涉及内容要求学生分析资料,根据图表发现趋势,并确定相关性和因果关系;大多数涉及数学的问题会被归结为分析题;学生必须由那些与课本中或课堂上讨论过的问题相似的但并不完全一致和问题中得出结论;分析题可以要求学生预测、解释、结论,为结论提供理由或得出结论。

举例 探究式教案的第(8)步,即要求学生分析试验结果并确定病原体化学组分。如果病原体是蛋白质这样一个结论在课堂讨论前就给出,那么此后的测试题将只能测试对已有结论的简单确认。而让结果在实验中得出,也就是使学生目睹变性处理后溶液中 DNA/RNA、脂肪或糖组分不再有传染性了,教师就可以测试学生是否真正能够分析试验结果。

功能 分析题可以锻炼学生发现趋势,找到相关性,作合理的联系以及得出有根据的科学结论。

(5)*综合题* 要求学生解决问题,设计新的实验,或者利用不同课文中学过的几种知识,"融会贯通"地进行预测;综合题常常要求学生进行设计、发展、预言、创建等等。

举例 假如生物学科的学生已经讨论过 Koch 氏的假设(分离病原体的步骤)并且已经学会了将较大的细胞与病毒及化合物分子分离的陶瓷纤维过滤法,那么上面的探索性教案的第(5)、(7)以及(8)步便形成了一个综合题,该题的解答要求学生以有科学意义的方式,综合运用已学过的许多知识。另一个问题,即"为什么朊病毒这个概念起初在生物学界遭到了这么多的怀疑?"——也需要学生能对多种核心生物学概念运用自如,其中包括:所有其它病原体都具有 DNA 或 RNA,那么没有核酸编码的蛋白质是如何复制的呢? ……等等。

功能 综合题需要学生"综观全景",横跨生物学各次级学科,进行合理的联想。这是一种非常高级而

复杂的能力，我们企图让研究生发展这种能力，但通常对于年轻学生不进行大量的测试和课堂讨论，因为他们还不具备坚实的生物学基础。

4 小结

学生需要实验室及野外工作的经历，以便使生物学概念和实验方法赋有实际意义。在考试的压力下，学生能够背出课文和实验结果。促进生物学学科学生创新思维的关键之一是课堂讨论中及测试题中问题的运用，这些问题应当要求学生能理解和运用知识，分析和综合生物学概念。通常意义上的好学生习惯于记忆简单的书本上的知识片段，可能会首先抱怨这些问题“不公正”，因为在课本中找不到答案。记忆是容易的，但要理解和运用所学概念就比较难了，这需要教师每天都在课堂上提出较高水平的问题。若学生离开课堂时说：“这堂课或这次测试确实使我动脑了”，这就意味着这是一堂好课或是一次成功的测试。

老教师知道，在课堂上提出这类问题以及撰写复杂的测试题并不像直接使用课本中设定的题目那样容易。了解如何将问题按程度分类并不能使出题变得更容易。由于撰写探究式教案及高水平的题目要化巨大的精力，故实习教师不可能独立撰写全部教案和测试题。早期《美国生物科学课程学习丛书》中的课文及试题手册以及 Mader 的《探究生命》和 Hickman 的《动物学综合原理》中的当代试题手册，提供了这类高水平的题目。更重要的是，一旦开始养成根据研究图表等提出更多的记忆性问题以及撰写更多测试题的习惯，教师也就会对课堂提问变得熟能生巧。这种技巧能引导学生像科学家那样思维，并提出自己的问题。高水平的课堂提问也可以将生物课堂教学从令人厌倦的练习转化为智力开发活动。

Teaching Creative Thinking in Biology Through Questioning

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In both the United States and China, biology teachers are asking how to encourage students to move from memorization-without-understanding to a meaningful knowledge of biology including the ability to ask new and critical questions. Lecture is the most efficient form of communication and is effective when concepts can be associated with students' life experiences or where laboratory or field work provides multi-sensory experiences that make the concepts meaningful. However, the reading of science results described in textbooks and the repetition of cookbook laboratory experiments does not stimulate a new generation of students who are creative researchers. The ability to ask probing questions is a universal requirement of successful researchers and some teachers appear to be able to encourage this skill in some students in their classrooms through questioning. This approach has been labeled "inquiry teaching."

To understand the process of encouraging students to ask questions and to think like a scientist, a standard lecture outline about the new disease agents called prions is compared with an inquiry lesson outline about prions.

STANDARD LECTURE OUTLINE

1. **Prions** are a new category of infectious agents.
2. "Prion" is from "protein" and "infection."
3. Prion Diseases
   -BSE (Mad Cow Disease) causes cattle dementia
   -CJD is human dementia, inherited or near BSE
   -Kuru is human dementia from cannibalism
   -Scrapie causes sheep dementia
4. Additional Symptoms and Epidemiology
   -Infection is via consumption of nerve tissues
   -Onset is slow, often beyond a year after infection
   -Host does not launch any immune response
5. Disease agent is an aberrant protein.
   -Involves **no** DNA or RNA
   -Normal protein is named PrP
   -Prion disease protein is PrP^{Sc}
   -Infection involves PrP –> PrP^{Sc}
   -PrP^{Sc} has fewer alpha chains, more beta sheets
   -Because PrP^{Sc} is alternate tertiary form of a normal protein, a host forms no antibodies

[illustrations here]

INQUIRY LESSON (questions in bold)

1. **What is an *infectious* disease?**
   -distinguish from non-infectious and contagious
2. **What agents cause infectious diseases?**

Parasites (worms, ameba, fungi, etc.)	DNA
Bacteria	DNA
Viruses	RNA/DNA
[leave this blank for prions]	[protein]

3. **Since a parasite usually dies when the host dies, how does it prevent its extinction?**
   -It reproduces.
   What is the molecule that allows genetic replication? -DNA or RNA/DNA [add above]
4. The following are puzzling diseases:
   -BSE (Mad Cow Disease) causes cattle dementia
   -CJD is human dementia, inherited or near BSE
   -Kuru is human dementia from cannibalism
   -Scrapie causes sheep dementia
5. **With a disease with an unknown cause, how do we go about determining the infectious agent?**
   -extract an agent from an infected animal and test it on a healthy animal (Koch's postulates)
6. **From the above information (4), where would we look for the infectious agent?** -nerve tissue
   -This is confirmed; when we inject brain or spinal tissue from an infected animal, it causes the healthy animal to eventually get sick.
7. **A ceramic filter will hold parasites and bacteria but allow viruses and chemicals to pass. Both the filtered and unfiltered nerve tissues cause disease when injected into healthy animals. What is the nature and size of the disease agent?**
   -It is either a virus or chemical agent since the filtered solution could not contain either whole bacteria or parasites.
8. **Filtered solutions are treated with denaturing agents. Formalin and heat destroy DNA and RNA. What enzyme breaks down sugars? ...fats? ...proteins? The results of tests for infectivity are given to the left. What is the nature of the infectious agent?** -It is a protein.
   Now complete the 4th line in block 2 above.

The inquiry lesson is based on the teacher knowing a series of questions asked to require the students to analyze the problem, pose potential experiments, and interpret the results of research. In the standard lecture, the protein nature of prions is defined at the beginning and the information is presented in a format that is organized and easy to memorize without any deep understanding. In the inquiry lesson, students learn that prions are proteins at the end of the lesson as a consequence of having thought through the problem in a manner very similar to the original research. Such a lesson requires the teacher to know more about the research than is usually given in a textbook. It is also obvious that the lesson requires more class time; therefore if questioning is used extensively, less content will be covered and students will not have the opportunity to discuss the many concepts that need to be understood to test well on the gao kao. In contrast to standard teaching that may primarily use the test to motivate students, inquiry teaching attempts to add the natural interest of thinking-through real science to motivate students to learn. Advocates of inquiry learning and questioning contend that the intellectual excitement that occurs when students are led to ask questions and originate ideas themselves can increase critical thinking and produce future innovative scientists.

Creative thinking, questioning, and attitudes used by science researchers can be promoted not only by classroom discussion using questioning, but also by using quizzes and major tests that have questions that require more than memorization. It may help some teachers to understand types of questions based on the following classification heavily modified from Benjamin Bloom's *Taxonomy of Behavioral Objectives–Cognitive Domain.*

Classification of Questions by Level

RECOGNITION OF TERMS–MEMORIZATION

- The student remembers and repeats information without necessarily understanding its meaning.
- The question is in the same format as in the textbook, lecture outline, or laboratory guide; the student can commit this to short-term or recognition memory by "cramming."
- Test items assess the student's ability to recall specific words or definitions but do not establish that the student understands the concepts.

Example: Which statement is true about prions?

A) Prions are new forms of viruses.
B) Prions overcome the host immune response.
*C) Prions are protein infections.
D) Prions rapidly destroy blood cells.

Function: This question is a low-level question because the student can recall the term "protein infection" directly from the lesson.

COMPREHENSION

- The student demonstrates that he/she comprehends the concept.
- The student answers a question that is rephrased from the original textbook or lecture presentation.
- Students may compare, describe, or contrast items in their own words.
- Questions often require use of the word in a new context or setting.

Example: Which of the following disease presentations might be caused by a prion?

A) inflammation; headache; high blood pressure; long recovery period
B) coughing; fever, rapid death rapidly follows infection
C) high WBC count; nausea; prolonged illness
*D) normal WBC count; onset of confusion is years after infection; eventually fatal

Function: This comprehension question is complex enough that a student must understand the concept involved and cannot get the answer correct by merely memorizing the textbook example.

APPLICATION

- A student applies knowledge to a new situation or uses biological knowledge to solve a new problem.
- Questions often ask a student to apply, choose, provide a new consequence, classify new items, or suggest the next step in research, etc.

Example: Step 6 in the Inquiry Lesson asks students to apply their knowledge to locate where the infectious agent would be in the newly presented diseases.

Function: Application questions practice them in using their knowledge to understand related situations and solve new problems.

ANALYSIS/INTERPRETATION

- The student is asked to analyze data, detect trends from graphs, and locate correlations and cause-and-effect relationships.
- Most problems involving mathematics will classify as analysis questions.
- Students must draw conclusions from evidence similar but not identical to what is in the textbook or what is discussed in class.
- Analysis questions may ask a student to predict, interpret, support reasons for, or draw a conclusion.

Example: Step 8 in the Inquiry Lesson asks students to analyze the results of the tests and determine the composition of the disease agent. If the class discussion follows the Inquiry Lesson plan which leads to the conclusion that the disease agent is a protein, a subsequent test question that repeats this question would only test for simple recognition. By changing the results in the experiments so that the DNA/RNA, fats or sugar fractions were no longer infectious after treatment, a teacher can test if the student actually can analyze the research results.
Function: Analysis questions practice students in detecting trends, finding correlations, making reasonable associations, and drawing valid scientific conclusions.

SYNTHESIS

- The student is asked to solve a problem, pose a new experiment, or make a prediction using several concepts taught in different lessons, and to "put it all together."
- Synthesis questions often ask students to design, develop, predict, construct, etc.

Examples: If biology students have already discussed Koch's postulates (the procedures to isolate a disease agent) and have also studied how ceramic filtration is a process that separates larger cellular material from viruses and chemicals, then the combination of Inquiry Lesson items 5, 7 and 8 constitute a sequence that requires students to put together many previous concepts in a scientifically meaningful way. Another question–"Why would the idea of prions initially meet with such skepticism from the biology community?"–would also require students to show a command of multiple core biology concepts including: all other agents possess DNA or RNA, how would proteins "replicate" without nucleic acid coding, etc.
Function: Synthesis questions require students to "see the whole picture" and make reasonable associations across biology subdisciplines. This is a sophisticated ability we seek to develop in graduate science research students and will generally not constitute a large portion of the tests and classroom discussions for younger students because they do not yet have a strong command of biology.

Summary

Students need experience with laboratory and field work in order to make biological concepts and experimental methods meaningful. However, students under test pressure can memorize both text and cookbook lab results. One key to promoting creative thinking among biology students is the use of questions in both class discussions and on tests to require the students to comprehend, apply knowledge, analyze, and synthesize biology concepts. Good students who are used to memorizing on simple recognition may be the first to complain that application questions "aren't fair" because the answer is not in the book. To memorize is simple. To study for understanding and application of concepts is more difficult and occurs mainly when a teacher is asking higher level questions in class each day. A hallmark of a good class period or a good test is when students leave with the comment "That class/test really made me think!"

Veteran teachers will realize that asking such questions in class and writing complex test questions is not as easy as using definition questions taken directly from the book. Understanding the classification of questions described here does not make writing such questions easier. Because composing inquiry lessons and writing high level questions takes tremendous time, most practicing teachers cannot compose every lesson and test themselves. Lessons and test item manuals from the earlier U.S. Biological Sciences Curriculum Study books as well as the current test item manuals from Mader's *Inquiry Into Life* and Hickman's *Integrated Principles of Zoology* (both by McGraw-Hill Publishers) provide a source of such questions. More importantly, a teacher who begins to develop the habit of asking more non-memorization questions and writing more test questions from research graphs, etc. will also become more skilled in class questioning. This technique promotes critical thinking because it leads students to think like a scientist and to ask their own questions. Another important consequence of higher level questioning is that it transforms biology classes from boring drillwork to exciting intellectual activity.