Intellectual Development and Critical Thinking Skills in Biomedical Engineering and Applied Biology Students

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Abstract

The three courses of the general biology sequence at Rose-Hulman Institute of Technology serve as the foundation for the education of both the biomedical engineering and applied biology majors. The first biology course, cell structure and function, is normally taught entirely in a lecture format with handouts of lecture notes provided to help students in their study. Exams in this course consist of questions falling into the knowledge or comprehension level of Bloom's taxonomy of knowledge. Recently, one of the four sections of this course has implemented several activities to facilitate the development of skills related to learning and to practice asking complex questions and performing critical thinking. The third biology course, evolution and diversity, incorporates active learning exercises to help the students develop skills necessary for success in the sophomore curriculum. Students in this course are introduced to application level questions (according to Bloom's taxonomy) on the exams. In the third course, students have had difficulty developing critical thinking skills (as demonstrated by performance on application level problems) and, the overall performance measured by student grades declined from the first course. In addition, students have exhibited a negative attitude towards this course and its content. These observations led to a research study examining intellectual development and critical thinking skills in students enrolled in the general biology courses. A survey was designed to measure 1) student attitudes towards biology, 2) student confidence regarding performance in biology, 3) intellectual development according to the Perry scheme of cognitive development, and 4) critical thinking skills among students enrolled in biology courses. The survey was administered to students enrolled in the first course of the general biology sequence in fall, 2007. The same students will participate in similar surveys in the third biology course and the genetics course (a requirement for biomedical engineering and applied biology majors). Data collected from students in the section incorporating the learning exercises will be compared to data from students in the other sections to determine the effect of an earlier introduction of study skills and critical thinking activities on student development in future biology courses.

Key Words

Education Methods, Lifelong Learning

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Introduction

This pilot study is the precursor to a larger study investigating the intellectual development of engineering and science students within the context of a general biology sequence. At Rose-Hulman Institute of Technology, the general biology curriculum is divided into 3 courses offered in sequence over the course of the academic year and serves as the first year foundation for both the applied biology and biomedical engineering majors. The motivation for this research stems from personal observation of a difference in student performance in the first and third courses in the general biology sequence as an instructor in both courses. The first course, cell structure and function, focuses on the cell, its structure, and the various molecular and cellular processes occurring within the cell. Traditionally, this course is taught entirely in a lecture format and, students are provided with a handout of lecture notes to help their study. The exams in this course focus on the information provided in the lecture handout and, exam questions usually fall in the knowledge or comprehension categories according to Bloom's Taxonomy of Knowledge. In the third course of the general biology sequence, evolution and diversity, students are introduced to application level questions (according to Bloom's taxonomy) and, classroom activities are implemented to help the students develop skills necessary for success in the sophomore curriculum. Students are provided detailed learning objectives and a handout that helps facilitate note-taking. During the term, an entire laboratory exercise and weekly classroom activities were devoted to helping the students improve their critical thinking skills and prepare them to answer more challenging questions. Despite these efforts, the students had difficulty developing these skills and, the overall student performance as measured by grades declined (in cell structure and function, 30% of students earned an A and 60% of students earned a B whereas only 3% earned an A and 54% earned a B in evolution and diversity). In addition, students exhibited a negative attitude towards the course and its content (stating it was unnecessary).

Currently, many skill sets required for success in courses in the biological sciences are not specifically taught to students prior to the evolution and diversity course; students must gain the more complex thinking skills without any guidance from the instructor. It is apparent from test scores in evolution and diversity that many students have not practiced and developed these skills and continue to study through review and rote memorization. This study seeks to test the hypothesis that the introduction of study and critical thinking skills (study strategies, note-taking, outlining, concept mapping, asking and answering complex questions) in the first biology course will facilitate student intellectual development and enhance performance in the third biology course. Another question that will be examined in this study is whether students educated in

these skill sets in the first biology course have improved attitudes towards the third biology course compared to their peers.

Method

Pilot study

Four sections of the cell structure and function course were offered in fall, 2007. Three of the courses were taught in the traditional format described in the introduction. One of the sections was supplemented with activities to introduce the students to study strategies, note-taking, concept mapping, and asking and answering questions. The lecture notes were still provided to the students but were not given to the students until after the material had been presented.

A survey was devised to test 1) student attitudes towards biology, 2) student confidence in biology, 3) intellectual development according to the Perry scheme (1, 2, 3), and 4) critical analysis of a paragraph on a scientific topic and critical thinking skills. The survey consisted of a few questions from the field-tested learning assessment guide for science, math, engineering, and technology instructors relevant to biology to test the attitudes towards biology and confidence level in biology of the students (4). Only a few questions were chosen in order to increase the likelihood of student response to the survey. In addition, a question designed to assess intellectual development according to the Perry scheme of intellectual and ethical development was included (5, 6). The question was "Describe a course that would represent the ideal learning experience for you. Please be as specific and concrete as possible about what this course would include; use as much detail as you think is necessary to present clearly this ideal situation. For example, you might want to discuss what the content or subject matter would be, what the teacher/s would be like, your responsibilities as a student, the evaluation procedures that would be used, and so on. Please explain why you feel the specific course aspects you discuss are "ideal" for you." A paragraph describing a scientific discovery was included and students were requested to state the hypothesis of the paragraph and write a short persuasive essay arguing for or against the claim. Rubrics were designed and used to measure and compare answers for both the hypothesis statement and persuasive argument.

With IRB approval, the survey was administered online through the ANGEL course management system. Responses to the survey were exported from ANGEL and analyzed.

Long-scale project

The larger scale project will follow the students in the both the traditional and activity supplemented sections of cell structure and function through the third course of the general biology sequence and into the genetics course (a requirement for both the applied biology and biomedical engineering majors). The grades of the students from the traditional and activity-supplemented sections will be followed and analyzed for differences in the evolution and diversity and genetics courses. Surveys will be administered at the end of the cell structure and function course, at the beginning and end of the evolution and diversity course, and at the end of the genetics course.

Applied biology majors will be assessed in the first and third courses of the general biology sequence during the fall and spring of the freshman year. Assessment will be administered again during the genetics course during the fall of the sophomore year. Biomedical engineering students complete the third course of the general biology sequence in the spring of the sophomore year and will be assessed at that time. Biomedical engineering majors will be assessed in the genetics course which is scheduled for the fall of the junior year. To acquire a larger population, the study will be repeated using the freshmen entering Rose-Hulman in 2008. This study should be completed by end of the fall term of 2010.

Results

Twelve students responded to the survey in the pilot study; this response was 13% of the total students enrolled in the 4 sections. Of the 12 students responding, 7 were in the test group and 5 were in the control group. Student responses to the questions pertaining to attitude and confidence are summarized in table one. With regard to the questions concerning student attitudes towards biology, 100% or all twelve students had a positive attitude concerning biology. Regarding student confidence, 8 of 12 students (67%) were confident in their abilities to perform a biology experiment. One student was not confident in this ability and the other student was neutral towards this ability. Seventy-five percent (9 of 12) felt confident in their abilities to solve biology problems with the other 3 students being neutral towards their problem solving abilities.

Table 1. Student responses to the questions evaluating attitudes toward biology and confidence in biology.

Student Response	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
Biology is very interesting to me.	8 (67%)	4 (33%)	0	0	0
In general, I have a good feeling toward biology.	7 (58%)	5 (42%)	0	0	0
It makes me nervous to think about doing a biology experiment.	0	1 (8%)	3 (25%)	2 (17%)	6 (50%)
I feel confident in my abilities to solve biology problems.	4 (33%)	5 (42%)	3 (25%)	0	0

Eleven of the 12 students responded to the question prompting an essay for placement according to the Perry scheme of intellectual and ethical development. Of these eleven responses, 4 responses did not appropriately address the question (students misread the question) and were excluded. The remaining answers were analyzed to determine what level of intellectual development the students according to the Perry scheme (1, 2, 3). The responses were rated by a single rater. All 7 students placed into the dualism level in Perry's scheme of intellectual development. Answers to the essay question were not comprehensive enough to place students into specific numbered positions outlined by Perry.

A short paragraph describing a virus that specifically targets and kills cancer cells was presented and students were asked to summarize the hypothesis in one sentence and then write a short persuasive paragraph arguing for or against the claim. Rubrics were used to compare and rate the quality of the hypotheses and persuasive arguments. Ten of the 12 students summarized the hypothesis for the paragraph. The rubric ratings for the hypotheses and arguments from the students are shown in table 2. The abilities to critically determine the hypothesis and make a persuasive argument varied with many of the students struggling at performing one or the other task.

Table 2. Rubric ratings of student responses to the paragraph on the study of a virus that specifically targets and kills cancer cells. Students were asked to 1) state the hypothesis of the paragraph and 2) write a persuasive argument for or against the claim. Student answers were scored using a rubric. For summarizing the hypothesis, the students received no points for an incorrect hypothesis, 1 point for a hypothesis that was only partially stated, 2 points for a correct hypothesis that missed information, and 3 points for a complete correct summary of the hypothesis. For the persuasive argument, students received 1 point for arguing a position, 1-2 points for providing (1 piece of evidence = 1 point; 2 or more pieces = 2 pts.) evidence learned in the paragraph, and points for examining future questions that need to be addressed (1 piece of evidence = 1 point; 2 or more pieces = 2 pts.)

Student	Hypothesis	Persuasive argument
A	2	3
B	n/a	n/a
C	0	2
D	2	2
E	n/a	n/a
F	0	2
G	1	n/a
H	3	4
I	0	3
J	2	2
K	0	1
L	2	3

Because the low number of students involved in the survey, an adequate comparison between sections was not able to be performed. An examination of the averages for each section revealed no statistical difference in the grades among the four sections of cell structure and function.

Discussion

This pilot study successfully tested data collection and analysis techniques, and provided a baseline for measuring any gains made by the students as they are introduced to more skills for biology learning in the third course of the general biology

sequence. Data collected from surveys administered during this course will enable comparisons to be made among the two populations of students from the first biology course.

The results of the survey from the pilot study were not very surprising as it would be expected that students choosing to major in biomedical engineering and applied biology would have a favorable attitude towards the subject and some level of confidence in their abilities to study biology. The rating of the students at the dualism or first level according to the Perry scheme of intellectual and ethical development may explain why the students feel more comfortable with rote memorization than open-ended problem solving. The varied abilities to state the hypothesis and provide a persuasive argument in response to paragraph describing a scientific discovery are anticipated as students enter college with a variety of educational backgrounds and, this ability was not addressed in the first general biology course.

An unfortunate low response rate to the online survey produced poor numbers for comparison of the two populations. In the large scale project, the survey will be incorporated into the course as a classroom exercise rather than an online survey performed out of class to ensure a larger population size.

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