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Using case-based guided-inquiry instruction to produce significant learning in an undergraduate clinical parasitology class

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ABSTRACT

Professional and pre-professional education in medical and allied health fields have undergone significant changes in the last century. In response to the calls for transformative education an undergraduate clinical parasitology class was created to produce a significant (transformative) learning experience. The objective is to describe the case-based pedagogy that was used in this course and the evidence that significant learning took place. Thirty one case studies were written using a learning cycle guided-inquiry approach. Student performance on exams and responses to a student assessment of learning gains instrument were evaluated to determine if significant learning took place. Student performance on exams was high, and responses to both Likert scale and free response questions on the SALG instrument indicate that all six dimensions of significant learning were present in the course experience. Integrated course design in a case-based guided-inquiry learning environment can produce a significant learning experience.

INTRODUCTION

Since the publication of the Flexner report in 1910 [1], professional and pre-professional education in the United States has undergone tremendous changes in attitudes and practices. Unfortunately, those changes have not kept pace with the rapidly-evolving environment in which those in medicine and allied health find themselves working [2]. The inability of most medical educational programs to produce highly functioning graduates for the 21st century workplace has been attributed to the curricula and pedagogical approach to current medical education [2,3]. A Lancet Commission Report[2] advances a vision of medical education in which “all health professionals in all countries should be educated to mobilize knowledge and to engage in critical reasoning and ethical conduct so that they are competent to participate in patient and population-centered health systems as members of locally responsive and globally connected teams”. In order to achieve this lofty vision, the commission report calls for a shift towards what they call “transformative learning” [2]. Transformative learning, as elucidated by the authors, requires a shift toward higher-order thinking, away from seeing course work as a necessary but ultimately purposeless endeavor (i.e. a ticket-punching mentality), and a movement toward learning to work as part of a team [2]. Similar calls toward a re-thinking of pedagogy can be found in the Carnegie Foundation’s report on medical education in which the authors recommend adoption of teaching strategies that encourage the learner to think like a professional from the very beginning and place foundational knowledge in the context of patient care [3]. Similarly, the accreditation standards of the LCME require that medical schools employ teaching methods that are active and stimulate critical and higher-order thinking [4]. There does not appear to be any reason why these changes should be limited to professional education. Rather, these approaches to learning could be introduced in the pre-professional curriculum and could, perhaps, better prepare students for entry into a medical curriculum in which these recommendations are being employed.

In the fall of 2011, the Department of Health Sciences in the East Tennessee State University College of Public Health decided to revive its undergraduate Clinical Parasitology class. This course is an elective course for students in the Bachelor of Science in Health Sciences program, the vast majority of whom go on to pursue professional medical education post-graduation. In light of the anticipated environment in medical professional school, Clinical Parasitology was viewed as an opportunity to lay the foundations of transformative learning.

The recommendations laid out by the Carnegie Foundation Report [3], the Lancet Commission Report [2], and the LCME accreditation standards [4] have a great deal in common, but they lack a cohesive vision for how to achieve this "transformative learning". Such a framework does, however, exist. Fink [5] proposes an integrated course design approach that results in what he calls "significant learning experiences". In the significant learning model, mastery of content (which he refers to as "foundational knowledge") is but one component of a taxonomy of interrelated dimensions that work synergistically to create what is essentially transformative learning [5]. Fink's taxonomy of significant learning contains six interrelated dimensions: foundational knowledge, application, integration, human dimension, caring, and learning how to learn [5]. Foundational knowledge is simply content knowledge and provides the intellectual framework necessary in any field [5]. Application is using that knowledge to perform higher-order cognitive tasks like critical thinking or developing new skills [5]. The dimension of integration refers to the cognitive linkages between the course content and other courses and aspects of life [5]. The human dimension refers to the impacts of the course on the student and how it impacts other people [5]. The dimension of caring assumes that significant learning will result in new attitudes or a different appreciation for the subject [5]. Finally, learning how to learn implies that significant learning, regardless of the course content, results in students who are more independent learners by the conclusion of the course [5]. These six components are not hierarchical; rather they each contribute to the successful acquisition of the other dimensions. In light of the similarities between Fink's significant learning experience [5] and the Lancet Report's transformative learning [2], Clinical Parasitology was designed to provide students with a significant learning experience.

METHODS

Course Design

The course was designed to produce specific outcomes from each of the six dimensions of significant learning. Table 1 lists these desired outcomes, and how they are assessed. Given the directives of the LCME encouraging active learning [4] Clinical Parasitology was designed to be exclusively active (the course contained a total of less than 60 minutes of direct lecture during the entire 15 week semester), and used a hybrid androgogy consisting of elements of case-based learning (CBL), Team-Based Learning (TBL), and Process-Oriented Guided-Inquiry Learning (POGIL). The class was a combined lecture/lab and usually met in a laboratory classroom equipped with compound microscopes. The enrollment was capped at 24 students, who worked in self-selected groups of 3-5 that remained in place during the entire course. Each team worked through one or more case-based guided-inquiry activities during each class period. The course was broken into three large units, each with two subunits based on parasite taxonomy and mode of infection (Table 2). Each subunit came with a detailed study guide that contained all the expected content and application outcomes in a simple bulleted list. These study guides helped alleviate some of the unease that can accompany a non-didactic course delivery.

Activity Design

Each activity begins with a case presentation containing an overview of a patient or set of patients who is/are complaining of a particular suite of signs and symptoms. Some of the cases are pulled from the literature; however, most are based on fictional patients with signs and symptoms associated with a particular parasitosis. Each patient overview contains a photograph and some personal information, often including recent travel history. The inclusion of a photograph (often just stock photos) was a deliberate attempt to humanize the case subject and help the student empathize with the fictional patient. Following the patient overview, there are boxes of data containing notes from the initial physical examination, vitals, laboratory results (blood work, urinalysis, radiography, etc.), and micrographs.

These activities follow a learning cycle approach [6] that begins with engagement through the initial case presentation. The case presentation is followed by a series of guided-inquiry questions that begin with *exploration* of the case presentation (e.g. identifying salient signs and symptoms). The exploration phase is followed by *concept invention/term introduction* questions that require the students to use some sort of external information source in conjunction with the patient data to draw linkages between the biology of the particular parasite being examined and the patient's pathology. These external sources can consist of, but are not limited to, the course textbook, handouts, the CDC's website on the differential diagnosis of parasitic diseases (http://dpd.cdc.gov/dpdx/), and other online parasitology resources. These initial questions, along with the assigned reading before class account for the vast majority of foundational knowledge that the students acquire. Through the case presentation itself students become familiar with signs and symptoms of a particular parasitosis. By bringing in other sources of information they construct their own understanding of the disease process and use that to make a diagnosis. Finally, the activity will end with several *application* questions in which the students are required to make recommendations regarding treatment, personal prevention measures, and to identify possible public health measures that could be taken in order to reduce incidence of this particular disease. It is in these application questions that the students are challenged with tasks requiring higher-order cognition. For example, after diagnosing a patient, students might be asked to hypothesize what would have happened with a different travel itinerary or suggest alternate treatment regimes and *explain* why these might be better or worse. These questions are also where students are challenged to explain the intersection between parasite biology and life cycle, human physiology, and disease progression. For example, in the case on amoebic dysentery the students are asked to predict the results of a biopsy based on what they learned about the parasite's biology and the results of the patient's blood work. Specifically asking students to form a hypothesis based on prior knowledge requires synthesis (a cognitive task from near the top of Bloom's taxonomy) of what they already knew with what they have discovered over the course of the activity. In the case on disseminated strongyloidiasis the final question asks "What is the relationship between the organism's life-cycle, Mr. Davidson's [the patient] cancer, and his current presentation?". This question is challenging the students to analyze data, integrate it with prior knowledge (gained from the pre-class reading), and justify their answer. In a case about a *Cryptosporidium* outbreak the students must shift through multiple patient presentations and compare multiple aspects of the patients' habits and travel in order to find commonalities. This process requires both analysis and comparison. These relationships are rarely explicit in any of their primary or supplemental material; the students can't just look up the correct answer. Rather, the students must integrate prior knowledge with what they have just learned in order to answer these types of questions. The cases mentioned above can be found at http://faculty.etsu.edu/brownpj/CBL.

Course Requirements and Assessments

Students were assessed formatively each day through facilitation of the case study activities. As the instructor circulated about the room each group's conversation was monitored and responses to guided inquiry questions were assessed. Unless there were serious problems with the group's responses, instructor intervention was kept to a minimum. Each unit was summatively assessed by a 40 question multiple choice exam and a 10 question practical written exam (which was heavily weighted toward diagnosis of disease based on signs, symptoms, and microscopical imaging). There was also a comprehensive final exam that followed the same format. Each exam question was assigned (*post-facto*) to a particular level of Bloom's Taxonomy [7] using a rubric developed by the University of North Carolina at Charlotte for writing course objectives.

Each student was also required to write two scientific review articles pertaining to a topic of their choice. Each paper was graded according to a rubric particular to the assignment and returned, with feedback, for revision and resubmission. The inclusion of a long-form written assignment was necessary due to the course being listed by the University as a writing intensive course. This requirement, however, integrated with and encouraged the significant learning goals.

Student Assessment of Learning Gains

In order to determine if significant learning was taking place and to assess students' own perceptions of the impact of the course, a custom student assessment of learning gains (SALG) instrument was created (http://salgsite.org/instrument/25950). The instrument contained both Likert scale questions as well as free-response questions. Of the 22 students taking the course, 20 participated in the survey. Free-response questions were coded to indicate if students' comments demonstrated that one of the six dimensions of significant learning was evident.

Table 1. Significant Learning Goals

Significant Learning Dimension[1]	Specific Targeted Outcomes	Assessment Method
Foundational Knowledge	Students will be able to explain the life-cycles and basic biology of each parasite featured	Activity responses[2], multiple choice exams, practical exams
	Students will be able to recommend the best treatment option(s) for a particular parasitic infection	Activity responses, multiple choice exams, practical exams
	Students will be able to relate the biology/life cycles of the various parasites to their ability to cause pathology	Activity responses, multiple choice exams, practical exams
Application	Students will be able to recognize parasites in their diagnostic stages using conventional microscopy	Practical exams
	Students will be able to use a combination of signs, symptoms, and imaging to accurately diagnose and provide a recommended treatment for a particular parasitic infection	Activity responses, multiple choice exams, practical exams
Integration	Students will express an appreciation for the interactions between medicine, public health, and governance	Activity responses, multiple choice exams
	Students will be able to use knowledge of basic parasite biology to suggest appropriate public health policies to reduce the incidence of particular parasitisms	Activity responses, multiple choice exams, practical exams
	Students will be able to explain the relationships between personal and community behaviors and disease risk	Activity responses, multiple choice exams, practical exams,
Human Dimension	Students will be able to articulate the social and personal consequences of parasitic disease	Activity responses, multiple choice exams, practical exams
	Students will be able to identify geopolitical disparities in incidence of parasitisms	Activity responses, multiple choice exams, practical exams
Caring	Students will discuss the subject with those outside the course	Survey instrument
	Students will read articles in the popular press related to course content	Survey instrument
Learning How to Learn	Students will increase proficiency in using multiple sources of information to provide an evidence-based diagnosis and treatment suggestion	Activity responses

1 All six dimensions were assessed generally through administration of the Students Assessment of Learning Gains survey.

2 Assessment of activity responses was a component of classroom facilitation and was not incorporated into the data analysis for this study.

Table 2: Content Units in Clinical Parasitology

Unit	Subunit Content
Unit 1	Intestinal Protozoa
	Blood and Tissue Protozoa
Unit 2	Intestinal Nematodes
	Trematodes
Unit 3	Cestodes
	Blood and Tissue Nematodes

RESULTS

Student Achievement

The first three levels of significant learning (foundational knowledge, application, and integration) could partly be assessed by student performance on examinations. The first two components of significant learning (foundational knowledge and application) are also rungs on Bloom's Taxonomy of cognition [7]. The third component of significant learning (integration) was largely assessed with questions that fall into the comprehension domain on Bloom's taxonomy. Each of the three regular semester exams predominantly assessed foundational knowledge (72%, 60%, and 65% respectively) with the remaining percentages being split primarily (but not exclusively) between comprehension and application questions. The final exam however, contained only 33% knowledge-type questions, with the remainder split between comprehension (33%), application (20%), analysis (7%), and synthesis (7%). Mean scores on the three regular semester exams as well as the comprehensive final were all in the eightieth percentile

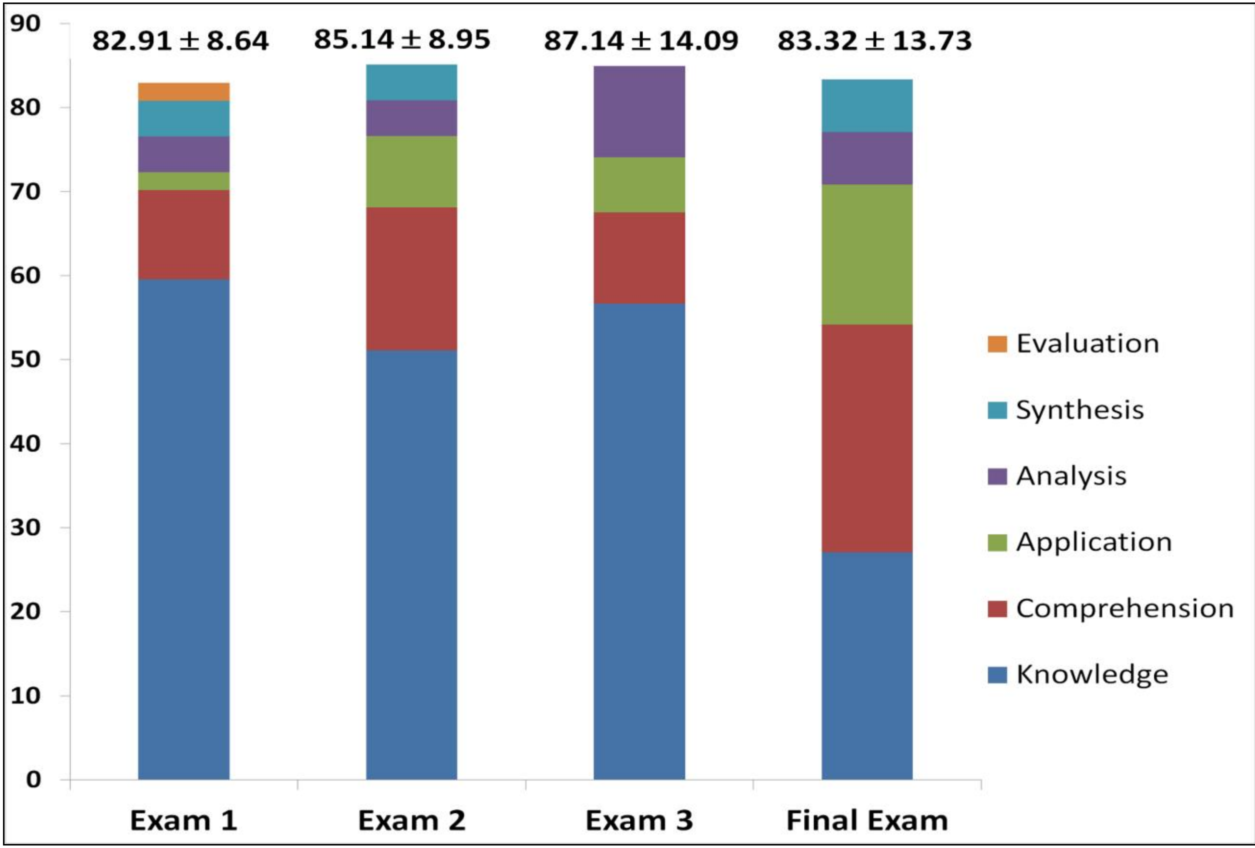

Figure 1. Exam performance and question composition. Student performance on all three regular semester exams as well as the final showed no statistical difference. Bar height represents average exam score (also indicated with standard deviation above each bar). The relative contribution of each level of cognition according to Bloom's Taxonomy is indicated by the proportion of each color.

(Figure 1). A single factor ANOVA analysis revealed no significant difference ($p = 0.63$) between exams.

Student Attitudes and Perceptions

All six dimensions of significant learning were represented by student responses to the SALG instrument (Table 3). The first three dimensions that were indicated by student performance on content exams (foundational knowledge, application, and integration) were also self-reported by the students (Table 4). Students expressed confidence that they understood the material (foundational knowledge) and felt that they made good or great gains in identifying patterns in data (application), and were more comfortable working with complex ideas (application). The integration dimension was well-appreciated by the students with some of the highest Likert-scale scores in students self-reported understanding of relationships between parasitic diseases and public health (91% reported good or great gains) and understanding of the relationship between ideas in this class and other classes outside this subject area (87% good or great gain). Eighty seven percent of students reported good or great gains in their understanding of how parasitology helps people address real-world issues (indicating gains in integration and the human dimension), with similar numbers for their enthusiasm for the subject and interest in discussing the subject with friends or family. The final dimension of significant learning, learning how to learn, was represented but at lower values than the other five dimensions. The lowest value was in students' self-reported gains in critically reading articles about issues raised in class (only 64% reported good or great gains). The other three questions regarding 'learning how to learn' showed support similar to the other dimensions.

Student responses to open-ended SALG questions were also collected. Gains in foundational knowledge were readily apparent to the students with 73% responding positively to the request "please comment on HOW YOUR UNDERSTANDING OF THE SUBJECT HAS CHANGED as a result of this class". According to students' responses, this gain in foundational knowledge was largely attributable to the case-based guided-inquiry method of instruction. Seventy-three percent of students mentioned the case-study approach in response to the request to "please comment on how THE WAY THIS CLASS WAS TAUGHT helps you

REMEMBER key ideas". The review paper writing assignment was viewed as valuable and nearly half of respondents (45%) feel they became better writers following the course. Another 36% specifically mention gains in 'learning how to learn' when asked about skills they have gained as a result of the class, and 23% mention gains in some aspect of application. When asked how the class changed their attitudes on this subject (clinical parasitology), 68% indicated some aspect of caring, often with emphatic language and punctuation. When asked what they will carry with them into other classes and aspects of their life, 41% replied with comments indicating gains in 'learning how to learn', while another 23% indicated gains in application. The only course goal not mentioned spontaneously by respondents was the human dimension.

DISCUSSION

Student performance on exams in this course strongly indicates that the case-based guided-inquiry format did produce significant gains in foundational knowledge related to human clinical parasitology. Both the multiple choice and short-answer practical exam components indicate that the students in the course made significant gains in their fundamental knowledge of parasite biology and pathogenesis without a substantial didactic component to the course (Fig. 1). Students are also able to perceive their gains in foundational knowledge as evidenced by their responses on the SALG (Tables 3 & 4). Although content (foundational) knowledge is vital, many medical educators are also beginning to stress the importance of other, less tangible educational outcomes that go by names such as generic skills [8], process skills [9], or incidental learning [10]. Irby [11] outlined five principles of experiential learning particular to case-based learning but which are applicable to many active learning strategies and emphasize the importance of learning beyond content. All of these approaches to learning beyond content contain one or more dimensions of Fink's [5] model of significant learning, indicating this type of integrated course design as appropriate for a course intended to prepare students for the type of transformative medical education called for in the Lancet report [2], one that improves student content knowledge, but also results in fundamental changes in the learner. A portion of the exam questions were also designed to test gains in application and integration. Although the mean scores for these questions are often lower than those for more direct foundational knowledge questions, they are still largely above the 70th percentile, indicating that gains are taking place. More telling are the results of the SALG which indicate that students did make considerable gains, especially in the realm of integration. The highest Likert scale scores for any dimension of significant learning are on questions that relate to integration (Table 3), particularly integrating parasitology to public health (question 1.2.2). The student responses to open-ended questions are quite intriguing as several dimensions of significant learning appear the student responses without prompting. When

Table 3. Student responses to selected Likert-scale questions from the custom SALG instrument.

SL Domain	SALG question "As a result of your work in this class, what gains did you make in the following"	Mean (n = 20)	% 4 or 5
FK	3.4 Confidence that you understand the material?	4.5	77
AP	2.3 Identifying patterns in data	4.1	73
AP	3.6 Your comfort level working with complex ideas?	4.3	77
IN	1.2.2 Your understanding of the relationship between parasitic diseases and public health	4.8	91
IN	1.2.3 Your understanding of the relationship between a parasitic organism's life-cycle and how to treat it on the individual and public health levels	4.8	87
IN	1.3 Your understanding of how ideas from this class relate to ideas encountered in classes outside this subject area	4.3	73
IN	4.1 Connecting key class ideas with other knowledge	4.2	77
IN/AP	4.2 Applying what I learned in this class and other situations	4.2	72
HD	1.4 Your understanding of how studying this subject helps people address real-world issues	4.6	87
CA	3.1 Enthusiasm for the subject	4.5	82
CA	3.2 Interest in discussing the subject area with friends or family	4.7	87
LL	2.1 Finding articles relevant to a particular problem in professional journals or elsewhere	4.2	73
LL	2.2 Critically reading articles about issues raised in class	4.1	64
LL	2.4 Recognizing a sound argument and appropriate use of evidence	4.4	73
LL	4.3 Using systematic reasoning in my approach to problems	4.3	72

Significant learning domains are abbreviated as follows: FK = foundational knowledge, AP = application, IN = integration, HD = human dimension, CA = caring, and LL = learning to learn. Likert-scale responses are on a scale of 1-5 where 1 = no gains, 2 = a little gain, 3 = moderate gain, 4 = good gain, and 5 = great gain.

Table 4. Anonymous student comments indicating gains in various aspects of significant learning.

Student comment	Significant Learning Domains Indicated
"I have greatly increased by basic knowledge of the subject, and sharpened clinical skills while learning about the parasites."	Foundational Knowledge Application
"I knew very little about parasites prior to this class, and now I understand their importance to public health. "	Integration
"This class forces you to involve yourself with others as a means of problem solving, which is an ideal environment for anyone going on to professional school or, like myself, graduate school. "	Application Learning how to learn
"I honestly was mad when I first found out I had to take this course, but now after taking it with Dr. Brown, I am so glad that I took it! It's been neat to talk to my mentor in a clinical setting about the relationship between *Entamoeba histolytica* and exudate fluid extracted from a patient during a thoracentesis procedure....and actually understand what he was talking about."	Caring Integration Learning how to learn
"I find this subject to be quite fascinating. I would often go home and discuss subjects or certain cases with friends and family. It really made me aware that these issues impact other regions in the world and that Ii am fortunate to live in an area that has access to sanitation and clean resources. It made me realize that these infections are often times not the fault of anyone in particular, but instead a representation of the problem of Public Health conditions. But it did spark an interest in my desire to continue to learn about these and other problems like it."	Caring Learning how to learn
"Before taking this course I did not have the slightest knowledge about how to identify, treat, and diagnose parasitic infections. I can now easily determine the differences among many different parasitic infections."	Foundational Knowledge Application
"Dr. Brown teaches us to not just accept everything that we hear, even if it is from other legitimate scientific sources. Science was designed to make its followers critique one another, and this course helped me see the importance of that. "	Integration Learning how to learn

asked how their understanding of the subject has changed as a result of this class, five of the six dimensions were articulated at least once in the 20 student responses.

The latter three dimensions of significant learning (caring, the human dimension, and learning to learn) are not as straightforward to assess as the former three. The results of the SALG survey do indicate distinct gains in both caring and learning to learn. It is unsurprising that these two dimensions were apparent to the students, as Murdoch-Eaton and Whittle [8] observe "Doctors' overall attitudes to learning practice, social responsibility and contributions to society will be underpinned by an attitude to learning that recognizes the continuation of the educational process throughout professional life". Students who care more about a subject are more likely to invest the cognitive capital required to investigate the subject outside of the classroom which will strengthen their ability to learn and initiate the process of becoming a life-long learner. While there were no spontaneous remarks indicating gains in the human dimension element, a single Likert scale question (1.4) indicates that the students do perceive some gains in this dimension. The apparent lack of gains in this final dimension could be an artifact of the assessments used in the study. Future efforts to measure significant learning in this and other courses will require more effort in assessing the human dimension coupled with more emphasis within the course itself.

The use of case studies to improve learning is widespread and can be found in disciplines such as geology [12], international education [13], psychology [14], anatomy [15], engineering [16] and of course medicine[11,17]. A recent meta-analysis of 104 papers on implementations of various case-based courses in medicine[17] notes that implementation of a case-based learning strategy alone is rarely sufficient to see increases in learning (the authors are primarily concerned with foundational knowledge). It is not the cases themselves, the authors argue, but rather the ancillary factors associated with this type of learning environment that produce greater student engagement and therefore more learning [17]. Thistlewaite et al. [17] go on to postulate that the positive outcomes associated with a case-based environment are due to three main factors: 1) cases are more engaging that theoretical lectures which results in, 2) greater attendance during class meeting times, and 3) it is the guided-inquiry that is an implicit component of many case-based classes that actually produces the greater learning outcomes. This parasitology course was designed to make the guided-inquiry component explicit in order to take advantage of these factors. The case-study activities themselves are designed to not only deliver content but to increase engagement, stimulate construction of knowledge, and produce changes in students' attitudes and perceptions regarding parasitic disease and its effects on individuals and populations.

Medical education is rapidly changing, placing increasing emphasis on developing skills and attitudes beyond simple content knowledge. Using the significant learning taxonomy as a basis for course design can provide a valid framework for developing these skills, beginning with undergraduate education. The use of a case-based guided-inquiry format provides a scaffold on which to build experiences that can lead to significant learning in a majority of students. Students participating in this course saw significant gains in five of the six dimensions of significant learning, with foundational knowledge being the dimension in which the most progress was made. These results indicate that students made significant advances in intangibles like caring and integration while still satisfactorily mastering the content of a technical undergraduate clinical course.

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