

## Writing Creatively About Evolution: Overlapping Threshold Experiences

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### Introduction

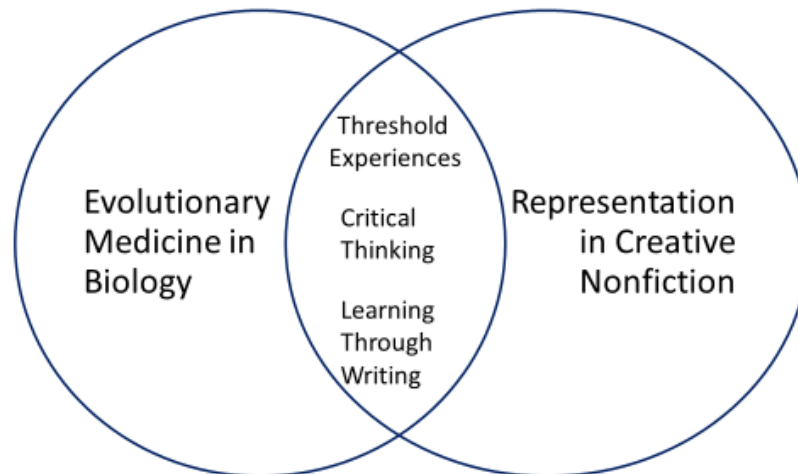
A *threshold concept* is a doorway that leads to an entirely new way of thinking about something, resulting in a shift in perception (Meyer & Land, 2003). The pedagogical value of a threshold concept lies in its power to compel students to think about problems and issues much like experts in a field. A threshold concept is both *transformational* and *troublesome*: transformational because it produces a paradigm shift in the learner's thinking; troublesome because it can be intellectually and emotionally challenging. In order to grasp a threshold concept, a student needs to enter what Meyer and Land describe as a *liminal space*, which is not unlike an adolescent state where the individual oscillates between childlike ways of thinking and newer, adult ways of thinking punctuated by feelings of frustration, moments of clarity, and confusion. A learning process is rarely linear, but involves venturing out or taking bold excursions into unfamiliar waters of the new concept with recursions back into areas of confusion. The threshold experience is therefore a messy process characterized by *excursive* and *recursive* journeys within the conceptual landscape before the concept is grasped fully (Land, Cousin, Meyer, & Davies, 2005). Students who refuse to engage in the struggles associated with the threshold experience are said to exist in a *pre-liminal state* where their understanding of the concept remains vague at best. The role of the instructor then is to create a *supportive liminal environment*, which helps to draw the students into the liminal space and encourage them to engage in the messy process of trying to grasp the threshold concept (Cousin, 2006; Land et al., 2005).

Evolution is a threshold concept of biology (Taylor & Cope, 2007). The Human Anatomy & Physiology course at Bronx Community College has no biology prerequisite, so students enrolled in this course have little or no prior exposure to the principles of evolutionary theory. Evolutionary medicine is a branch of evolutionary biology that essentially asks the question "why do we get sick?" (Nesse & Williams, 1995). For example, a runny nose or a fever that is often regarded as an annoying symptom to be eliminated is viewed as an "evolved defense" in evolutionary medicine. Evolved defenses are protective mechanisms. They have been selected by nature to prevent further damage by pathogens (disease-causing microorganisms) or toxins. A runny nose prevents a pathogen from penetrating deeper tissues of the body while a fever retards the growth of pathogens. Thus, evolutionary medicine makes us think critically about the causation of a disease. In doing so, it looks for the *ultimate* causation of disease as opposed to the *proximate* or immediate causation of disease, which tends to be the dominant approach of mainstream medicine. In other words, evolutionary medicine asks the *why* questions of disease, whereas mainstream medicine asks the *how* questions of disease. Evolutionary medicine applies evolutionary principles to the understanding of health and disease and includes the troublesome and transformational elements of a threshold concept. It is troublesome because the concepts are difficult to grasp, and it is transformational because it has the potential to change the

students' perspective of the causation of disease. In addition to providing opportunities to develop critical thinking, it has a high degree of relevance to the students' everyday lives. When evolutionary theory is taught within the context of everyday life, using examples such as antibiotic drug resistance and sickle cell anemia, students are far more likely to engage with the concept (Wolf & Akkaraju, 2014). For these reasons, I chose evolutionary medicine as the topic for an essay assignment in a writing intensive section of the Human Anatomy & Physiology course.

Any writing intensive course offered on our campus must fulfill two requirements—*learning to write* and *writing to learn*. To fulfill the first requirement, I asked the students to write the essay using a true-to-life narrative similar to what is used in the creative nonfiction genre. Even though the use of creative nonfiction in writing usually falls within the culture of the humanities, when applied to the sciences, it can be quite effective. Ideally, the creative nonfiction narrative has the power to inform and engage the general public on scientific topics and promote scientific literacy (Shenk, 2009). The students would have to learn to explain evolutionary medicine concepts in everyday language and use storytelling as a way to communicate a difficult subject such as evolution to the general reader. Threshold concepts tend to be complex to a novice learner, and the creative nonfiction narrative compels the student to summarize a complicated concept in a simple way that can be understood by the general reader. When using this kind of narrative, the student must resist the temptation to hide behind scientific vocabulary and truly engage with the finer points of the threshold concept, thereby helping to fulfill the *writing to learn* requirement of this course. Creative nonfiction is defined as “true stories, well told” (Gutkind, 2012). However, this assignment had one major departure from the conventions of the creative nonfiction genre in that students were allowed to write imagined (or fictional) scenes if they were unable to draw relevant examples from their life experiences.

This writing style, which was unfamiliar to the students, introduced another threshold concept. It is the concept of representation in creative nonfiction (see Figure 1). Representation has been described as “an extremely elastic notion which extends all the way



*Figure 1.* Students were expected to grapple with two different threshold concepts, from two different disciplinary domains, with overlapping threshold experiences that provided opportunities for critical thinking and learning through writing.

from a stone representing a man to a novel representing the day in the life of several Dubliners” (Mitchell, 1995, p. 13). In literary representation, “the object” is the idea or concept or series of events that is being represented; “the means” of representation is the language; and “the manner” of representation is the genre—drama, poetry, creative nonfiction, or fiction. In effect, students were being asked to represent evolutionary medicine concepts using written language as the means of communication and the creative nonfiction genre (as it was implemented in this exercise) as the manner of representation. Even though the students were not expected to understand the concept of representation *per se*, by using this narrative, they had to explore the relationship between scientific fact and story, a learning process that can be potentially troublesome and ultimately transformational.

If a student has successfully negotiated a threshold concept, then we can assume that a paradigm shift in reasoning has occurred. The National Council for Excellence in Critical Thinking (NCEIC) (2014) applies the following standards to check for quality of reasoning—clarity, accuracy, precision, relevance, depth, breadth, and logic. This written assignment was designed to provide opportunities for students to demonstrate their quality of reasoning, thereby providing evidence of this paradigm shift.

In the following sections, I will (1) describe the design of the written assignment and demonstrate how a supportive learning environment nurtured student performance; (2) show how the two threshold concepts, evolutionary medicine in biology and representation in creative nonfiction, overlap and mutually reinforce each other throughout this writing process; and (3) explain how the assignment provided the opportunity for students to demonstrate critical thinking.

### Design of the Written Assignment

The first step in designing this assignment was to define student learning outcomes that could be tracked throughout the assignment. Defining learning outcomes is essential for the overall management of the project, including grading and assessment (Blumberg, 2009; Suskie, 2009). Learning outcomes were embedded in four stages of the written assignment, providing both structure and a timeframe for the writing process (Table 1). Scaffolding an

Table 1 *Student Learning Outcomes for the Assignment*

The Student will be able to...	Assessed in
Explain evolutionary medicine concepts in everyday language	Stages I & III
Distinguish between the perspectives of mainstream and evolutionary medicine	Stages I & III
Develop engaging stories or scenes of appropriate length and relevance to the scientific concept	Stage II
Write an essay that blends scientific concepts imperceptibly with the main narrative	Stage III
Write an essay free of major spelling, grammar, and punctuation errors	Stage IV

assignment into multiple stages allows for significantly raising expectations of student performance (Hogan & Pressley, 1999). During Stage I of the written assignment, students read a source article that addresses five major hypotheses or concepts proposed in the field of evolutionary medicine—evolved defenses, antibiotic drug resistance, evolution of

virulence, evolutionary trade-offs, and diseases of the novel environment (Nesse & Williams, 1998). They also had access to learning aids such as PowerPoint presentations and short video clips to help them grasp the main concepts. After reviewing the study materials, students answered a set of questions that probed their understanding of the main ideas in each subtopic.

Stage II required students to write stories or scenes related to each subtopic. In Stage III, the students combined Stage I (the science) and Stage II (the narrative) in a way that was both informative and engaging to the reader. Stage IV was reserved for proofreading and editing the essay for structure, grammar, and punctuation.

Table 2 *Guidelines for the Assignment*

Assignment Stage	Guidelines for Completing Each Stage
Stage I	Read the article “Evolution and Origin of Diseases” by Nesse and Williams and summarize it <i>in your own words</i> by doing the following: Explain the concept of evolved defenses against diseases. <ol style="list-style-type: none"> <li>1. Explain how and why human actions alter the virulence of microorganisms. You may use HIV or swine flu as an example.</li> <li>2. Explain the concept of antibiotic drug resistance, using ear infection as an example; explain the consequences of antibiotic overuse – examples to use – TB or MRSA.</li> <li>3. State what the authors mean by the novel environment and discuss diseases of the novel environment.</li> <li>4. Explain the connection between malaria and sickle cell anemia.</li> <li>5. Explain the difference in how Darwinian medicine and mainstream medicine view (not treat) an individual’s ailments.</li> </ol>
Stage II	Each subtopic needs a human interest story. Write one story or scene of your own for each subtopic.
Stage III	For each subtopic follow the general format very closely: <ol style="list-style-type: none"> <li>1. Begin with a human interest story (story/scene)</li> <li>2. Introduce the subtopic (science/technical)</li> <li>3. Explain the main points of the subtopic with an example (science/technical)</li> <li>4. Summarize the subtopic with a single concluding phrase (science and story combined)</li> </ol>
Stage IV	Visit the writing center to proofread your essay for spelling, grammar, and punctuation.

### The Learning Environment

In fulfilling the requirements for the written assignment, students had two major tasks at hand: they had to grasp a major threshold concept and write creatively about the concept. However, both the concept and the narrative style were unfamiliar to them. Therefore, a thoughtfully designed learning environment was crucial. A supportive learning environment must do the following:

1. Reflect the scaffolded nature of the project
2. Clarify expectations for all stages of the project

3. Keep channels of communication open throughout the process
4. Address the excursive and recursive nature of the threshold experience

The Bb (Blackboard) platform can be customized to meet all the above-mentioned needs of a supportive learning environment. It allows for effective scaffolding of the writing assignment into stages (see Table 1) and for clear communication of guidelines and expectations for each stage of the writing process (Table 2).

In many ways, Stage III is crucial because the student must creatively combine personal stories with the science. At this point, it is necessary for the student to understand one major point: the science and the storyline must be balanced in such a way that the final essay is both engaging and enlightening to the reader. One way to help students achieve this would be to provide them with a pattern or a recipe. A former writing fellow at Bronx Community College helped to deconstruct a magazine article on a science-related topic with students, revealing the stylistic pattern that it generally followed. This pattern was applied in the guidelines provided in Table 2, for Stage III of the essay (E. Troseth, personal communication, 2005).

### Collection of Student Performance Data

Overall student performance data was collected over a period of three semesters from a total of 61 students. One set of students (n=18) was followed more closely to study their performance in all stages of writing. For each stage of the writing process, rubrics were developed and used for both grading and assessment (Table 3).

Table 3 *Grading Criteria Used in Rubrics*

Rubric	Grading Criteria
Stage I	Completion, Evidence of Plagiarism, Engagement, Grasp of Concept
Stage II	Engagement, Length, Relevance
Stage III	Engagement, Originality, Depth of Scientific Content, Balance between Science and Stories, Flow
Stage IV	Spelling, Grammar, Capitalization, Punctuation

A benchmark of 70% was set for the writing project with the expectation that at least 70% of the students would earn a grade of B (good) or better for this assignment. The students were also asked to fill out a survey during the early stage of the writing project in order to provide a sense of how they perceived the writing process.

### Supportive Learning Environment Nurtures Overall Student Performance

Students responded favorably to the positive learning environment and performed well in the written assignment. Overall student performance for all three groups (sections) was above the benchmark that was set at 70%. The average overall student performance was 78%, with each group performing at 74%, 83% and 78% for groups 1, 2 and 3 respectively (Figure 2).

On closer examination of the performance data for students in Group 3, it became apparent that those students struggled mostly in Stage I and had the fewest problems in Stage II. For Stage I, only 4 students (22%) truly grasped all the concepts on their first

attempt, 7 (39%) grasped some of the concepts, while the remaining 7 (39%) missed the main point of most concepts. The latter group was also more likely to resort to mimicry, and the students' writing displayed many more instances of "cut-and-paste" plagiarism. At Stage

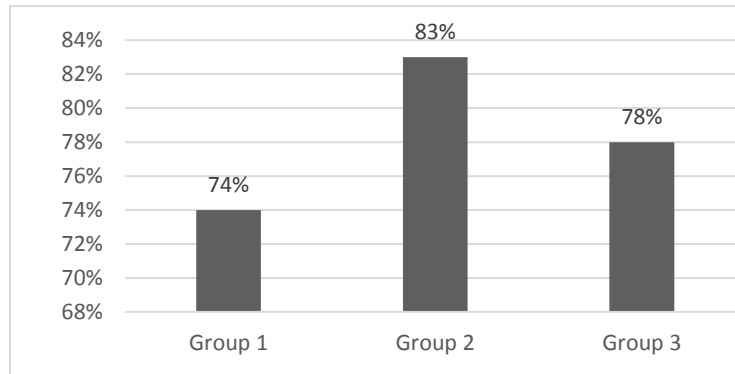


Figure 2. Overall student performance: students achieving a grade of B or better for the written assignment.

II, 83% of the students were able to write real life or imagined scenes of appropriate length and relevance (see Figure 3). At the end of Stage III, 78% of the students were able to produce essays that were above the benchmark. Stage IV of the essay involves proofreading and polishing. Only 56% of the students submitted essays that were acceptable in terms of spelling, grammar, and punctuation (Figure 3).

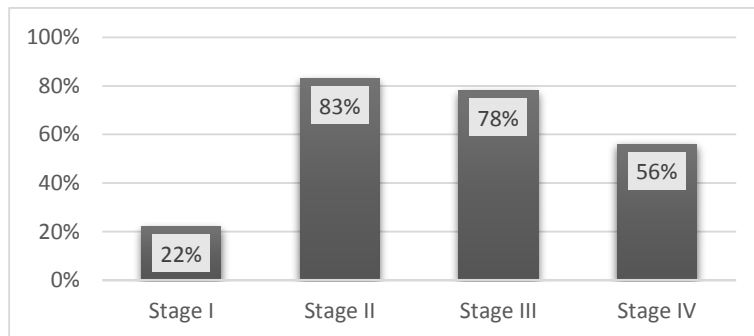


Figure 3. Students achieving a grade of B or better for each stage of the essay.

Students who did not pass the benchmark for Stage I rewrote their assignment at least once for this stage, with more than half of them submitting multiple rewrites. Only 20% of the students needed to submit rewrites for Stage II. Half of the students submitted rewrites for Stage III, and no students submitted rewrites for Stage IV (Figure 4).

Following rewrites and interventions in the form of detailed and encouraging feedback and small group discussions, students were permitted to proceed to Stage III. This is the critical stage that involves combining Stages I and II into a seamless narrative. The results were much improved for Stage III following multiple rewrites of Stage I, with 5 out of 18 (28%) students producing essays that exceeded expectations, 9 out of 18 (50%) students

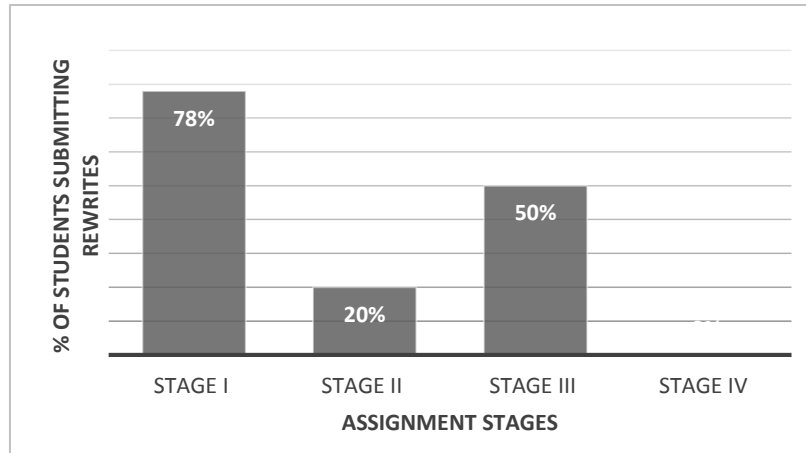


Figure 4. Students submitting rewrites for each stage of the writing process.

producing good essays and 4 out of 18 (22%) students producing essays that were below the benchmark (Figure 5). Clearly, the students responded favorably to the learning environment by displaying a significant shift in understanding of evolutionary medicine concepts and a clear recognition of the narrative style as evidenced by their marked improvement in performance (Figure 5).

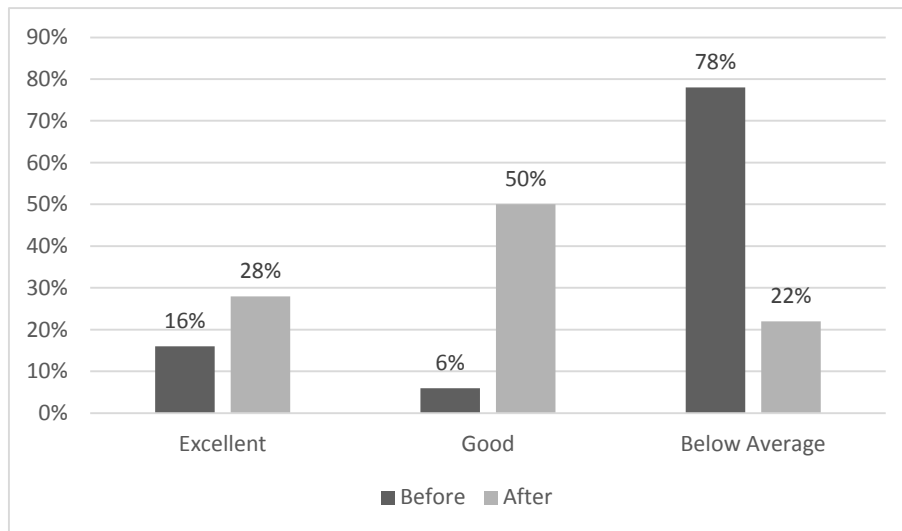


Figure 5. Student performance in Excellent, Good, and Below Average categories before and after revisions.

### Overlapping Threshold Experiences

In a general survey given to students, 100% agreed with the statement that prior to this, they had never been asked to write creatively about science. Representation was undoubtedly a new and sometimes troublesome concept for the students.

This was seen particularly at Stage I, in which students were asked to represent complex evolutionary medicine concepts in everyday language as a creative nonfiction narrative (see Table 1). Students struggled most during this stage of the writing process, with only 22% being able to perform at or above the benchmark (see Figure 2). They

struggled equally with both the creative writing and the comprehension of evolutionary medicine concepts. Of the five evolutionary medicine concepts, 78% of the students struggled to varying degrees with three concepts—antibiotic drug resistance, evolution of virulence, and evolutionary trade-offs. This is understandable because all three concepts demand a deep comprehension of evolution through natural selection.

Students were given detailed feedback that included the graded rubric for Stage I. Thirty-nine percent of students had to be reminded to write “in their own words” and strongly discouraged from borrowing phrases or, as in some cases, entire paragraphs from the Internet. It was necessary to explore this tension between “mimicry” in the form of cut-and-paste plagiarism and “mastery” in the form of reflective writing about a complex topic. The student survey helped with this problem. In this survey, only 5 students disagreed with the statement “The guidelines for Stage I of the essay are confusing.” In response to this, the reflective questions for Stage I of the essay were made far more explicit, and difficult areas were discussed in class. This was followed by small group discussions where students were able to ask specific questions to expand their knowledge, clarify doubts, and reinforce their understanding. All the students who did not pass the benchmark for Stage I submitted rewrites for this stage, and the second attempt was vastly improved (see Figure 5). Seventy-eight percent of students were able to demonstrate their ability to grasp all five concepts and to explain these concepts in everyday language. In effect, a transformation had occurred.

In the sample of student writing presented in Table 4, it is apparent how the student has struggled with the concept of *evolution of virulence* before grasping it. The term *virulence* refers to the degree of severity of a disease. A disease can be classified as being either mildly,

Table 4 *Writing Sample of a Student Struggling to Understand the Evolution of Virulence Concept*

Stage I – 1 <sup>st</sup> attempt	Stage I - rewrite	Stage III
<p><i>“The relationship between the level of virulence of a pathogen and the behavior of the host species is that the level of virulence of a pathogen may be lower depending on the behavior of the host.”</i></p>	<p><i>“The relationship between the level of virulence of a pathogen and the behavior of the host species is that depending how severe the level of virulence of a pathogen is it can determine how mobile the behavior of a host is. For example virulence in the terms of AIDS or Swine flu would be considered high because these are deadly diseases and will decrease the mobility of behavior in the host. With medication it can increase the mobility in behavior and lower the virulence of these diseases but in most cases it eventually leads to death.”</i></p>	<p><i>“...the virulence of the pathogen evolves in response to the behavior of the host.....if everyone in the world used protection and was careful whom they chose as sexual partners, then the severity of the disease can decrease with time.”</i></p>



moderately, or highly virulent, depending on the ability of the pathogen causing the disease to harm or even kill its human host. Evolutionary epidemiologist Paul Ewald proposed a new germ theory of disease in which he explained how pathogens evolve in response to the behavior of the host species. For example, if we use more precautions and prevent the spread of a pathogen, then the pathogen responds by evolving to a milder form. We can, in essence, domesticate pathogens with proper hygiene and vaccinations (Ewald, 1993). In the first attempt, the student states that there is some sort of relationship between the level of virulence and the behavior of the host species but fails to explain correctly what that relationship might be. In the rewrite, the student tries a different explanation for this relationship by stating that the mobility of the host species is a causal factor for the evolution of virulence. In Stage III, the student appears to have correctly understood the relationship between the host species and the pathogen as proposed by Ewald.

At Stage II, the main problem was that students were unwilling to get started on their writing because they didn't understand the task. It was too unfamiliar. They were being asked to write real or imagined scenes that were relevant to evolutionary medicine topics. They would have to choose a story from their personal experience (or create one) and then evaluate each story or scene to make sure that it actually helped to illustrate the scientific concept associated with it. After many students expressed their bewilderment, yet another intervention became necessary. A class discussion on how a creative nonfictional narrative can help to explain scientific facts in an engaging manner was effective in helping students approach Stage II. The results were highly encouraging, with 83% of the students submitting a set of scenes that were at or above the benchmark. They appeared to relish the opportunity to describe personal stories to fit the concepts.

During Stage III of the writing process the *troublesome* and *transformational* aspects of the threshold experience became evident as the students engaged in the act of balancing style and substance. The interplay between the two threshold concepts was heightened in Stage III, which required students to skillfully merge scientific facts with the nonfictional (or fictional) narrative. Considering the complex nature of this process, students were not allowed to begin this crucial stage or enter the metaphorical threshold of Stage III unless they had successfully completed Stages I and II. One could view this as a *Guarded Threshold*, with the instructor serving as the gatekeeper who makes sure that the students do not step into this threshold unless they have demonstrated proficiency or mastery of both threshold concepts—evolutionary medicine and representation. To this end, feedback provided to students was frequently accompanied by the phrase “You are ready to move on to Stage III” or, in some cases, “You need to return to Stage II (or Stage I) before you start Stage III.” Students responded very favorably to this *Guarded Threshold Design*, as shown by the results for Stage III (see Figure 3).

Yet some students struggled with the balance of scientific fact and storytelling in their representation while others were unable to demonstrate deeper comprehension of the concepts. Even the successful ones tended to oscillate between positions of clarity and confusion, which was evident in their rewrites. These so-called *excursive* and *recursive* journeys from the *pre-liminal* state to the *liminal* or even *post-liminal* state that ultimately result in deeper understanding are highly characteristic of the threshold experience (Land et al., 2005). In the writing sample provided in Table 4, this oscillatory aspect of the threshold experience is evident. In Stage I, the student explains the relationship almost correctly with the following statement:

*The relationship between the level of virulence of a pathogen and the behavior of the host species is that the level of virulence of a pathogen may be lower depending on the behavior of the host.*

If the student had instead stated that the virulence of the pathogen may *become* lower depending on the behavior of the host, then that would have been correct because the word *become* would imply that some kind of process, perhaps evolution (?), was taking place. Still, this is an example of an excursive journey into the conceptual landscape. However, we will now see that the rewrite is actually worse than the first attempt:

*With medication it can increase the mobility in behavior and lower the virulence of these diseases but in most cases it eventually leads to death.*

The student now states that increased mobility on the part of the host would somehow decrease the level of virulence, which is totally incorrect. The student has gone from a moment of near clarity to a point of utter confusion, an example of a recursive journey. Following this oscillation, the student manages to grasp the concept in Stage III:

*... the virulence of the pathogen evolves in response to the behavior of the host.  
... if everyone in the world used protection and was careful whom they chose as sexual partners, then the severity of the disease can decrease with time.*

The student applies the example of AIDS to illustrate the correct relationship between the behavior of the host species and the evolution of virulence in the pathogen.

At each stage of the writing process, it became evident that the two threshold concepts at play here—evolutionary medicine in biology and representation in creative nonfiction—not only overlapped but also mutually reinforced each other, thereby displaying the *integrative* nature of threshold concepts in general (Meyer & Land, 2003). The writing sample of a different student presented in Table 5 shows how scientific fact and storyline can be woven into a seamless narrative at the final stage of the essay. In Stage I, the student's writing demonstrates factual and conceptual knowledge of the evolution of virulence. In Stage II, the student uses storytelling as a means to draw the reader in. In Stage III, the student delicately balances scientific content with a scene set in an operating room of a hospital. This is a clear demonstration of procedural knowledge, the ability to apply a concept to a real life situation. The interplay of the two threshold concepts is evident in the final narrative, an example of the *integrative* nature of threshold concepts in general.

### **Assessment of Critical Thinking Skills**

I used the assessment of critical thinking as a way of demonstrating the paradigm shift in thinking that the students may have experienced during this learning process. The complex design of this assignment afforded many critical thinking opportunities for the students and the final draft of the assignment served as a reliable assessment vehicle. Critical thinking skills were assessed using a customized rubric based on the quality of reasoning indicators listed by the NCEIC (Table 6).

Table 5 Writing Sample of a Student Showing the Integrative Nature of These Threshold Concepts

Stage I	Stage II	Stage III
<p><i>“So how exactly are the level of virulence of a pathogen and its interaction with a host species linked? Host species that actively seek to prevent the spread of a pathogen will cause its virulence to dwindle and lessen. This is because the pathogen’s ultimate ‘goal,’ if you will, is to spread itself. If it kills its host before it can spread, then it has dead-ended itself out of existence (if it occurs on a great scale). Therefore, in order to allow itself time to infect other hosts, it must give that host time to allow it to come into contact with another prospective host. Take HIV and AIDS as an example. Before it was understood how HIV was spread, it would develop into AIDS and kill at an alarmingly high rate. However, now that HIV is actively prevented in most parts of the world through safer blood transfusions, ending the sharing of needles, and the wider use and availability of condoms, its virulence has diminished greatly, as indicated by its substantially lower mortality rate.”</i></p>	<p><i>“Dr. M* is a general surgeon specializing in breast cancer who has been practicing medicine in Queens, New York for over 40 years. He has saved more lives than he can count and seen more cases than he’d even care to remember. His years of experience and immaculate record speak for his familiarity with and expertise in safe medical practices. Of all the safety procedures in place, from sterilizing equipment to washing hands before and after examining every patient, the one he points to as most important is a safety procedure known as ‘universal precaution.’ This procedure is one in which not just medical professionals, but anyone, avoids direct contact with any patient’s bodily fluids. The idea is to treat any bodily fluids as one would if he or she knew the patient had a disease spread through fluids, known as a blood-borne pathogen.”</i></p> <p><i>* The identity of the doctor in the example has been obscured</i></p>	<p><i>“Dr. M is a general surgeon specializing in breast cancer who has been practicing medicine in Queens, New York for over 40 years. He has saved more lives than he can count and seen more cases than he’d even care to remember. His years of experience and immaculate record speak for his familiarity with and expertise in safe medical practices. Of all the safety procedures in place, from sterilizing equipment to washing hands before and after examining every patient, the one he points to as most important is a safety procedure known as ‘universal precaution.’ This procedure is one in which not just medical professionals, but anyone, avoids direct contact with any patient’s bodily fluids. The idea is to treat any bodily fluids as one would if he or she knew the patient had a disease spread through fluids, known as a blood-borne pathogen.</i></p> <p><i>It seems immediately intuitive; the most important procedure would be the one that keeps you safe from acquiring somebody else’s disease, but one reason Dr. M cites as why it is so important may come as a surprise. ‘Of course we don’t want to contract a deadly blood-borne disease ourselves’ he chuckles, ‘but simply by taking precaution we also help affect the virulence of any blood-borne disease as well.’</i></p> <p><i>For better or worse, humans are not the only species on earth that have evolved over time. Microorganisms, including bacteria, evolve as well, and at a rate much greater than that of humans. The way a microorganism evolves and interacts with humans is a strong factor in determining its virulence.”</i></p>

Students performed at or above the benchmark for 5 out of 7 of the quality of reasoning indicators and appeared to have trouble with *breadth* and *depth* of reasoning (Figure 6). On closer examination of the assessment data in the rubric, students had the most trouble with *breadth of reasoning*. Only two students performed at the enhanced proficiency level for this criterion. This may be a weakness of the assignment design, which did not place an emphasis on breadth beyond expecting students to make a general comparison between evolutionary medicine and mainstream medicine. The depth and breadth of reasoning problems can be addressed by improving the assignment design.

Table 6 Assessment Rubric for Critical Thinking Skills with Student Performance Data Included

Quality of Reasoning Indicators	Enhanced Proficiency	Proficiency	Needs Improvement
<b>Clarity</b>	Essay is clear with explanations and illustrations wherever appropriate. (11 out of 18 students)	Most of the essay is clear with explanations and illustrations wherever appropriate. (2 out of 18 students)	Areas of the essay are unclear with incomplete explanations and illustrations. (5 out of 18 students)
<b>Accuracy</b>	Scientific facts are accurate. (12 out of 18 students)	Most scientific facts are accurate with some errors. (1 out of 18 students)	Some scientific facts are accurate with many errors. (5 out of 18 students)
<b>Precision</b>	Explains all concepts fully with the right amount of detail for each. (12 out of 18 students)	Explains most concepts fully with the right amount of detail for each. (1 out of 18 students)	Explains only one or two concepts fully without sufficient detail for each. (5 out of 18 students)
<b>Relevance</b>	Evaluates and applies relevant examples or scenes to all concepts. (13 out of 18 students)	Evaluates and applies relevant examples or scenes to most concepts. (2 out of 18 students)	Evaluates and applies examples or scenes to only or two concepts. (3 out of 18 students)
<b>Depth</b>	Demonstrates firm understanding of complexities within each concept. (12 out of 18 students)	Demonstrates understanding of complexities within each concept. (0 out of 18 students)	Demonstrates only a superficial understanding within each concept. (6 out of 18 students)
<b>Breadth</b>	Insightfully compares the difference between mainstream and evolutionary medicine. (2 out of 18 students)	Effectively compares the difference between mainstream and evolutionary medicine. (10 out of 18 students)	Loosely compares the difference between mainstream and evolutionary medicine. (6 out of 18 students)
<b>Logic</b>	Demonstrates logical thinking throughout the entire essay. (10 out of 18 students)	Demonstrates logic thinking throughout most of the essay. (5 out of 18 students)	Does not maintain logical thinking in many parts the essay. (3 out of 18 students)

### Writing to Learn and Learning to Write

“Writing to learn is based on the observation that students’ thought and understanding can grow and clarify through the process of writing” (Bazerman et al., 2005, p. 57). As the students moved through this staged assignment, their understanding and clarity grew, as

evidenced by the increase in conceptual understanding that occurred between Stages I and III (see Figures 3 and 5; Table 4). The narrative style appears to have served them well to accomplish the course goal of writing to learn. As for learning to write, the students were able to balance scientific fact with fiction (see Table 5), but their writing needed to improve significantly in terms of grammar, spelling, and punctuation (see Figure 3).

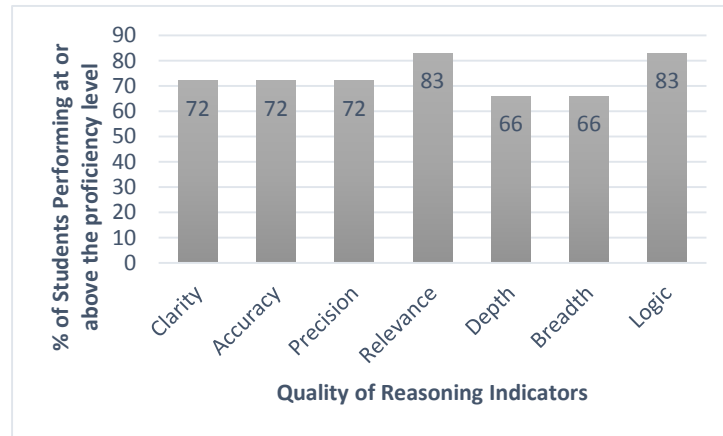


Figure 6. Assessment of critical thinking skills using quality of reasoning indicators.

## Conclusions

An idea within a disciplinary domain is considered to be a threshold concept when it is troublesome and ultimately transformational through a conceptual shift in understanding. Evolutionary medicine qualifies as a threshold concept because students wrestled with this unfamiliar concept throughout the writing process, followed by a clear shift in understanding towards the final stages of writing. This struggle was documented in Stage I of the writing process, and the conceptual shift was documented at the end of Stage III. Representation in creative nonfiction can be considered a threshold concept on par with evolutionary medicine because the students had never been asked to use this kind of narrative to represent scientific concepts. This was especially evident in Stage I when students had to explain complex concepts in simple, everyday language. Again the problem made itself visible in Stage III when students had to balance the science with the storytelling. Here, too, there was a gradual transformation in student attitude and performance, especially evident in Stage II when they began to enjoy writing real-life scenes to illustrate the evolutionary medicine concepts. Even though these two concepts are in two different disciplinary domains, they overlapped in each stage of writing and mutually reinforced each other in an integrative way, thereby fulfilling yet another requirement for a threshold concept (Meyer & Land, 2005).

One weakness in the assignment design was the lack of time allotted towards the end of the writing process for proofreading. As a result, even though 78% of the students submitted fairly well-written final drafts, 44% of this group still needed to improve their writing significantly in terms of spelling, grammar, and punctuation (Figure 3). The proofreading stage of the assignment can be made more effective by requiring the students to make regular appointments with the writing center on campus and to have their essays proofread at each stage.

The learning environment, or the *liminal environment*, in terms of instructional materials provided and the general layout of the assignment, appears to have adequately supported the students during these threshold experiences. However, the interventions that occurred at various points during the writing process could have been better managed. In the future, the interventions need to be designed at the same level of detail and focus as the written assignment itself. For example, small group discussions might be improved by providing students the opportunity to orally present evolutionary medicine concepts and fictional narrative pieces to their peers. Oral presentations of their papers might increase engagement and deepen comprehension of the topic by providing an opportunity for self and peer assessment (Sadler & Good, 2006).

Results from the critical thinking assessment show that although the students demonstrated a paradigm shift in their reasoning, they still had trouble with the depth and breadth of reasoning. Depth of reasoning can be addressed in the future by improving the intervention sessions as discussed above. Breadth of reasoning can be addressed by making this learning outcome more explicit and reflecting this outcome in the assignment design.

An interesting observation of students that was not formally documented was the transformation or shift in conception. This became apparent as students began to apply what they had learned during the course of this assignment to other topics in anatomy and physiology in ways that revealed an improvement in their understanding of health and disease. It would be interesting to explore this behavioral shift in cognitive and affective domains of learning in relation to threshold concepts (Atherton, Hadfield, & Meyers, 2008).

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