Article

The TRIPSE: A Process-Oriented Exam For Large Undergraduate Classes

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Abstract

The TRIPSE (tri-partite problem solving exercise), a process-oriented exam that mimics the scientific process, was used previously in small classes (15–25). Provided limited data, students frame explanations and design experimental tests that they later revise with additional information. Our 6-year experience using it with larger numbers (155–204) in a freshman biology course, suggests that it could provide a means of assessing individual student performance. Students rated the learning value of this experience to be significantly higher than a standard MCQ on a 10-point scale (TRIPSEs 8.2, CI 8.1/8.4 vs. MCQs 4.9, CI 4.8/5.1, n = 712). Additionally, we tested one cohort (n = 146) with a group TRIPSE (groups of 6), and found that this variant also provided a valuable learning experience (8.0, CI 7.7/8.3).

Keywords: active learning; assessment of educational activities; problem-based learning; inquiry-based teaching; PBL; effective in-class problems; scholarship of teaching and learning; molecular biology; cellular biology; cellular physiology

Introduction

Assessments are central to the education process and assessment procedures must be consonant with the educational objectives or goals of courses and programs [1,2]. Interestingly, a number of assessment practices have persisted over the centuries [3]. Madaus and O’Dwyer [4] wryly note all “assessments, exhibitions, examinations, portfolios, or just plain tests—whichever you choose—are all based on the same basic technology.” There is a large domain of knowledge or skills that can be potentially assessed, but student performances are often gauged on a limited subset. From their performances on this limited subset, the abilities of the student to perform similarly when tested on the whole domain is inferred and this potential is extrapolated to future performance. The assessments that are used fall into a few limited categories. The examinee supplies answers: (a) either orally or written to a series of questions; (b) produces a piece of work or an object; (c) provides a performance; or, (d) select answers from a list of probable answers [4]. The specific choices made are dependent on the objectives laid out by specific courses and programs, as well as on resources available. Kramer et al. [5] provide a fairly comprehensive toolbox that summarizes well a body of information in this issue.

In most freshman undergraduate science courses, assessments are generally designed to capture how students have acquired the necessary content taught. However, different assessments are needed in courses that place a premium on engaging students in the learning process [6], so that they learn not only content, but also develop effective self-directed learning skills [7], to take charge of their own learning and to seek, synthesize and integrate information from multiple sources. Assessment procedures that are consonant with the goals of such courses must, to a certain extent, be open-ended and process-oriented.

Several years ago, one of us described an exercise (the TRIPSE or tri-partite problem solving exercise) that sought to mimic the scientific process [8]. This was based on an earlier model, the triple-jump exercise (a three-part
exercise) that had been designed by a group of medical students and their tutor at McMaster University [9]. The tutor worked with an individual student. In Part 1, the tutor presented a new clinical problem omitting information that the student had to elicit by questioning the tutor. The problem required the student first to use of prior knowledge to pose questions and then to frame a plan to gather more information to tackle the problem. Part 2 corresponded to the phase in which the student gathered more information independently, and in Part 3 the tutor and student reconvened to discuss the case further. This was an exercise that allowed the tutor to assess the student’s capacity to frame learning tasks, identify resources, gather, evaluate and synthesize information—the very skills that problem-based learning sought to foster. In return, the students received specific feedback on their performance. The triple-jump exercise was fully consonant with the goals of the course and has been used subsequently in professional courses [5,10,11].

The triple-jump exercise as practiced with medical students was an exercise conducted one-on-one. Despite the exercise’s pedagogic merit, it was resource intensive, particularly on a tutor’s time. For example, to work with a group of six students, a tutor would have had to block off the entire day. Hence, this approach required a considerable amount of faculty time and could not be used with larger classes. Therefore, we adapted that approach to deal with larger classes where the same prompt could be given to an entire class, but the abilities of individual students could be assessed. The TRIPSE, which replaced the triple-jump exercise, was specifically designed for undergraduate science courses. An emphasis was placed on experimental design, rather than solving clinical problems. In Part 1, students were presented a situation and given limited information to use as a starting point to frame a set of possible explanations. In Part 2, they were asked to either design experiments (to test their hypothesis) or propose avenues for further exploration (such as searching databases or patient charts). In Part 3, they were provided additional information and asked to re-assess their original answers. This approach was particularly useful for problem-based courses. The third part provides them an opportunity to reflect and revise. There were really no specific “correct” answers, only answers with varying degrees of probability.

The TRIPSE that we had described earlier was used in classes of 15–25 students in a variety of courses [8,12], mostly in upper-level (third- and fourth-year) courses. Though these were clearly larger than the standard groups in PBL courses, the numbers were relatively small compared to those taking undergraduate science courses, particularly freshmen ones. When asked to rate this exercise on the standard university scale, 40 out of 47 students gave it a mark in the A range (A− to A+) suggesting that it had pedagogic merit. Therefore, we set out to determine whether that approach could be scaled up to much larger classes. Here we report on our efforts to use TRIPSEs in larger classes of 155–204 students in a freshman biology course.

Materials and Methods

The Course

The course was a required full-year (two-term) introduction to cellular and molecular biology taken by first-year students in a Bachelor of Health Sciences (Honors) Program at McMaster University. The first-term consisted of didactic sessions (18 in all), whereas in the second-term, we wanted to foster self-directed learning, there were no lectures and no TRIPSEs and only group projects [13–16]. The course followed a general framework of looking at signaling molecules (see Fig. 1).

At each session, the instructors gave formal lectures for an hour. These lectures dealt not only with the facts themselves, but also with the approaches used to obtain those facts. We repeatedly emphasized that science was constructed, so students were thus exposed to the principles underlying a variety of approaches (organ bath studies, cell cultures, electrophysiology, subcellular fractionation, molecular biological approaches, etc) used (cellular, molecular, in vivo, etc). In addition, students were taught about scientific research process (pathways to a publication, peer review process, etc). An attempt was made to make these sessions as interactive as possible during the lectures themselves. There were interruptions to permit questions, answers and discussion. Further, in the second hour, students were asked to come forward and summarize what they had learned from a particular session.

Two instructors taught different aspects of the course. One instructor discussed the processes involved in gene expression, protein synthesis and insertion of receptors into membranes. This involved a detailed consideration of replication (DNA, DNA polymerase, deoxyribonucleotides, telomers, and telomerase), transcription (RNA polymerase, ribonucleotides), translation (ribosomes, mRNA, tRNA, and amino acids) and their regulation (transcription factors, gene regulatory proteins). The other considered the synthesis of specific molecules, their packaging, release, responses elicited and termination mechanisms. Relatively few signaling molecules (histamine, acetylcholine, norepinephrine, prostaglandins, nitric oxide) were discussed in detail. Students were taught, not only about synthesis of the specific molecules, but the mechanisms involved in packaging them into either mast cell granules or vesicles, the release mechanisms, SNAREs, the responses elicited through multiple receptors, the transduction mechanisms and termination of responses. Considerable time was spent on receptor theory, the original Clark model and the more recent variations that led to conformational selection.
Orthosteric and allosteric antagonists were considered as well as inverse agonists. G-proteins were discussed in detail, particularly the activation of adenylyl cyclase, the formation of cAMP, protein kinase activation, phosphorylation–dephosphorylation steps. Given that the students were in a health sciences program, we drew attention to some of the pathophysiological implications (asthma, pain, narcolepsy, peptic ulcer diseases, scombroid poisoning, myasthenia gravis, glaucoma, hypertension, erectile dysfunction, etc).

The Students

The students were freshmen in a Bachelor of Health Sciences (Honors) Program. Entry to the program is based on high school grades (cut-off of 90%) and a supplementary application (three short essays). The program generally receives over 3000 applications and selects between 160 and 200. In the years 2006 through 2012, the class sizes ranged from 155 to 204. The information gathered here is based on a survey completed by 712 students over that period.

The Process

The general procedure for the TRIPSE is described below. An example of a TRIPSE is included in Appendix A. The TRIPSE problems were drawn from a wide variety of sources [8]. Instructors wrote them using the objectives of the course as a starting point. Several drafts were worked through by them to ensure that ambiguity was minimized. On occasion, we sought advice from other colleagues who are involved in teaching problem-based courses.

All students met in a large lecture theater that could seat up to 600 students. The students were seated individually and separated from one another. The TRIPSE was conducted like a formal exam, closed-book exercise (no notes, textbooks, dictionaries, etc), no electronic devices allowed (no internet, calculators, laptops, mobile phones, etc). Both instructors and six teaching assistants invigilated the TRIPSEs. The students were provided with an exam booklet that contained the TRIPSE.

Preamble

The TRIPSE had incomplete information about a given situation. This took many forms: a figure, a table with data, a clinical case, a pedigree chart, or a map. The students were asked to read the problem carefully, and in writing, list all of the key elements/observations from the problem that any good hypothesis/explanation must include. The time allotted is 30 min, and the space provided is one page. This section was worth five marks, and was marked from one being poor, to five being excellent.

Part 1

Based on the above information, the students were asked to provide two possible hypotheses/explanations in writing. The time allotted is 30 min, with each hypothesis taking up 0.5 page. This section was worth 10 marks, and was marked from 1 being poor, to 10 being excellent.

Part 2

Students were then asked to select their best hypothesis/explanation and either design an experiment to test that hypothesis or suggest avenues for further exploration (such as searching databases or patient charts). The time allotted is 1 hour, and the space provided was one page. This section was worth 10 marks, and was marked from 1 being poor, to 10 being excellent.

Part 3

Students then handed the Preamble, Parts 1 and 2 to receive Part 3. They were then provided further information and asked to reassess their original hypotheses/explanations and experiments in the light of that information. The time allotted was variable (with variations described below), and the space provided was one page. This section was worth five marks, and was marked from one being poor, to five being excellent.

The above procedure was modified slightly on different occasions. Part 3 was usually done as a take-home, though recently we begun to do this in-class (time allotted was 1 hour). It was necessary to have several practice runs to get the students familiar with the process, before they were given the actual TRIPSE. In these sessions, the procedures were modified to permit discussions between parts. In general, these were Individual exercises. Though for one cohort, we experimented with a Group TRIPSE as well. The procedure followed was as described above, except that students were divided into random groups of six, and student groups were distributed amongst two adjacent large lecture theaters. Extra time was provided (30 min for each part) to permit discussions.
Evaluation
Each of the three parts was assessed independently. An example of a TRIPSE, the evaluation scheme, and the expected answers are shown in Appendices A and B. With one cohort of students, the inter-rater reliability was tested. Students were given, not only their marks, but also comments and a general framework providing an explanation for the range of expected answers. More details are provided later.

Each student completed two TRIPSEs. Both were held in the first term. The TRIPSEs were only one set of assessment exercises used in this course (typically worth 20% of their overall mark). In addition, they had a mid-year exam (four essay-type questions) at the end of the first term. In the second term, we focused on students’ abilities to transfer learning and complete several group projects [13–16].

Permission for this study was granted by Dr. D.G. Har- nish, Assistant Dean, Bachelor of Health Sciences (Honors) Program, McMaster University.

Results and Discussion
All TRIPSEs began with a situation that posed a problem. The information provided was limited but were carefully written to encompass the core elements of the course. Examples are shown in Appendices A and B. Given the limited time frame, and the fact that the students were in an exam situation, we kept the problems focused and brief. Generally, these problems were drawn from published material but revamped to suit the tenets of the course. We repeatedly emphasized to the students that the material used would not be that which had been specifically covered, so they could expect to deal with information about molecules or receptors different from the ones dealt with in the course. However, if they had digested the core material, they would be well able to transfer their learning to these novel situations.

After the TRIPSE, the instructors provided a list of expected answers (see Appendix B).

All examinations provoke anxiety. This was particularly true for TRIPSEs, as there were no specific correct answers, but only sets of answers ranging in credibility. We recognized this when students came to discuss their experiences. The students had just entered university from high school, and had rarely experienced open-ended examinations of this sort. Practice sessions became crucial to dispel anxiety. At these practice sessions, students dealt with the TRIPSEs in sections (part-by-part). Discussions followed each part, so we could deal with a variety of questions. We also shared sets of TRIPSEs that students could study on their own or in groups. After the first year, there were always students available who had taken the course previously, and done TRIPSEs, and they were able to run help sessions. All this served to emphasize our position that any evaluation exercise must have learning value for the student. After these practice sessions, the TRIPSEs in practice worked relatively well. In general, the student comments were relatively positive. This will be discussed later.

Marking Answers
With smaller classes, a single instructor can comfortably mark all the TRIPSEs. This of course is difficult to do with larger classes. With the first batch of students, we attempted to get some index of inter-rater reliability. All the answers were marked independently by SN and PKR. These were then given to an independent assessor who had not participated in the course and was also not a content expert. Our analysis showed that, when two raters were considered, the relative reliability was 0.73. When all three were considered, the value increased to 0.80. Though this was re-assuring, we realized that it would not be possible to sustain the approach of having three independent assessors.

We modified this in the following way: Each TRIPSE was marked jointly by the instructors who taught the course. They agreed on the crucial elements that needed to be addressed and the range of possible answers that were deemed acceptable. Each instructor then independently marked a small set of TRIPSEs (8–10). They then cross-checked their grading to ensure consistency. After this the entire set of answers were divided and each instructor marked their own set. When either instructor had some concerns, they set the answers aside. These were then discussed separately to reach agreement. Though this process was time consuming, we felt that it was important to ensure that the students got a fair deal. On average, each TRIPSE takes 15 minutes to mark. All the answers were returned to the students and a session was held to explain the rationale for the marking. Students had the option to seek us out to discuss their marks. Fortunately, there were very few. Our approach of discussing these issues, and making the process as transparent as possible, did have some benefits. Whenever these arose, we met with the students to discuss their concerns and explained our rationale.

Worked Example
In the Appendices, we provide a sample problem (see Appendix A) to give a flavor of the process. The material was based on two recent publications [17,18]. The TRIPSE itself is fairly concise with just a single figure. The central issue is that a given chemical induces tissue swelling, and a drug given sometime later reduces the swelling markedly, in contrast to saline. Neither arthritis, nor even inflammation, had been discussed in the course. The expected answers (see Appendix B) provide, not only the crucial elements that needed to be covered, but the range of possible answers that were deemed acceptable. Students were given considerable license to frame their answers. We also show
partial answers from two students (see Appendix C). Each of them approaches the problem differently. They both list what they consider to be the crucial elements, but make different assumptions. One student looks at the mechanisms underlying the termination of responses to a signaling molecule, whereas the other considers the possibility that the drug is an activator (transcription factor) that produces a protein that reduces inflammation.

In assessing these answers, we were rigorous, but our expectations were adapted to the profile of the students, who were freshmen in their first term at university.

**Student Perspectives**

In general, the exercise was well received by the students. We asked students to rate the value of the exercise to their learning on a scale of 1–10. As can be seen from the data gathered over a 6-year period, the scores are rather high (see Fig. 2). Even though the scores span the entire range, it is comforting to see the clustering at the high end with over 518 students out of 712 giving a score of 8–10. Although we did not use MCQs in this course, the students were quite familiar with the approach and many courses at the university level use that approach, including their required freshman chemistry course. Students rated the learning value of this experience significantly higher than a standard MCQ on a 10-point scale (TRIPSEs 8.2, CI 7.7/8.3 versus Individual 8.2, CI 7.9/8.5 (n = 146).

**Variations Tested**

The procedure described here has evolved over several years. Though the process has remained essentially the same, we have tried a few minor variations, particularly with the Part 3 reassessment, which we have conducted both as a take-home exercise, or within the exam period. Though the TRIPSEs were designed to assess individual performance, we have experimented with a group exercise as well with only one cohort. All students were put into groups of 6, and given the TRIPSE to tackle as a group exercise. The procedure remained the same, though time was provided for groups to discuss their explanations and proposed tests. We had a practice session for this as well. From their perspective, the learning value of each approach was not significantly different. The scores on a 10-point scale were: Group 8.0, CI 7.7/8.3 versus Individual 8.2, CI 7.9/8.5 (n = 146).

**Appropriate Problems**

The prompts that can be used to start the process can take many forms: a table, a diagram, a narrative, or even a cartoon sketch. The prompts must be linked clearly to the content objectives of the course, but must deal with situations they have not specifically studied. It is important though, that the information provided be limited so that students can clearly recognize the elements that are provided, so that they can frame suitable hypotheses within a limited time frame. Distractors need to be minimized. As part of this course, we provide students an opportunity to write TRIPSEs themselves. These exercises (Legacy TRIPSEs), have sparked considerable enthusiasm and provided a means for the students, not only to consolidate their knowledge, but express their creativity and imagination [13–16].

**Practice Sessions**

Time needs to be set aside for practice sessions. Not only did these sessions serve to dispel anxiety, they provided students with opportunities to consolidate learning and enhance writing skills. Practice sessions work best as group exercises, in which students share ideas with peers. Two compulsory practice sessions were held, which followed the exact format of the regular TRIPSE exercises.

**Assessors**

Two instructors, and on occasion three, were able to handle the entire class. In general, each class had two TRIPSEs during the course. On one occasion, we used graduate student teaching assistants (TAs) as markers. Even though very clear guidelines were provided, we found that the
discrepancies and variations in marking lead to more discussions and complaints. This particular experience lead us to abandon the use of TAs as markers for the TRIPSEs.

One of the advantages of using the TRIPSE approach, is that it minimizes cheating and plagiarism. We feel that such behaviors are encouraged by exercises where there are single correct answers, so that those who know have an advantage over those who do not. When there are no single correct answers, and only sets of possible ones, no one student has the “correct” answer, and therefore there is no great advantage to cheat.

Generalizing this approach to other settings requires careful consideration of resources. It is important that the students get the message that there is no one prescribed answer. Students must recognize that effective problem-solving requires consideration of multiple issues, and the ability to synthesize and integrate information.

Instructors, in turn, should be prepared to reward students for giving, what may appear at first glance, to be unexpected answers. Failure to encourage this will detract from the value of the exercise. It is, thus, very important that the assessors be well versed in the subject, so they can properly evaluate the range of answers given. This is in marked contrast to problem-based tutorials, where non-expert tutors can be used quite effectively. For programs or courses that have limited faculty resources, the Group TRIPSEs may afford a more convenient assessment exercise. One can have expert instructors evaluating a limited number of TRIPSEs. However, even here, it is important to ensure that individual members of a group contribute equally to the product.

A recent report [19] analyzed the evaluation procedures used in a large number of introductory biology courses, and concluded that such courses emphasize facts more than higher-order thinking. This, as White [20] pointed out in a recent commentary, shows that faculty has low expectations of their students. Part of the problem is that grading requires time and effort. In most undergraduate courses, the lectures are given by the faculty, whereas marking and grading is done largely by TAs. We feel, based on our experiences, that faculty should be more involved in reading and marking exams, as well. This would give them a much better insight into thought processes of their learners, and help them provide more useful guidance. Recently Norcini et al. [21] have discussed good assessment practices in medical education from several perspectives (students, teachers, patients, and institutions). They note that a set of criteria may not apply equally well to all situations. However, two of the points they raise are worth considering in the context of TRIPSEs. They discuss the potential educational effects that motivate students to prepare in a manner that benefits their learning, and the catalytic effects which create, enhances and supports education, thus driving it forward. Based on some student comments, the TRIPSEs appear to have these effects on students. More importantly, they have had similar effects on instructors, as well. We have found over the years, that reading and marking TRIPSEs, though superficially arduous, has been ultimately an exhilarating experience. The instructors learnt as much as the students did, testifying to the educational value for both parties.

Coda
The information gathered over a 6-year period show that TRIPSEs can be used, even in a large class setting. These exercises provided students an opportunity to demonstrate that they had acquired a set of concepts that they could transfer to a novel situation. To be successful, they had to engage in analysis, synthesis, application and evaluation, which form the higher levels of cognitive function. Exams are often used as assessments of learning. It is also important to consider that the same exercises can be used as assessments for learning. In that regard, the students have found the TRIPSEs to be useful to them. Thus, the exercise is valuable to both learners and instructors.

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References
Appendix A: Sample TRIPSE Given to Students

These Feet Not Made For Walking

Swollen joints are characteristic of many forms of arthritis. Experimental models are widely used to explore the pathogenesis of this clinical condition and to test potential anti-arthritis drugs. Rats were injected with a specific chemical in their paws to induce swelling and inflammation. Once a significant increase in paw volume had been noted, one group of rats (shown by triangles) were administered a particular drug for a given period of time. Rats administered equivalent amounts of saline (shown by squares) served as controls (Fig. 3).

Appendix B: Expected Instructor Answers to the TRIPSE

Information Given
Changes in paw volume with time.
Specific chemical injected into paws.
Gradual swelling of paws noted (measured as increases in paw volume).

Preamble
Read the problem carefully. List all of the key elements/observations from the problem that any good hypothesis/explanation must include. If you are making any assumptions of the data, state this clearly so that we can make sense of your answers (1 page; 5 marks).

Part 1
Using the key elements/observations that you have listed on the previous page, provide two (2) possible hypotheses/explanations that can be tested (0.5 page each; 10 marks).

Part 2
Select what you consider to be your strongest explanation/hypothesis and what possible approaches would help you strengthen this explanation/hypothesis? Suggest other avenues of exploration (such as searching databases or patient charts) and/or design an appropriate experimental test (1 page; 10 marks).

Part 3
Does the new information alter your perception of the problem, and do you think the answers that you gave in parts 1 and 2 are still good ones and discuss why (1 page; 5 marks).
Once the swelling is manifest, rats treated either with saline or drug over a period of days.
Saline injection does not reduce paw volume, which continues to increase.
Drug administration produces a significant decrease in paw volume, which appears to begin within a few days after administration.
The decrease in paw volume has not yet returned to basal values but appears as though it may approach it.

Information Not Given
Nature of arthritis-inducing chemical.
Dose of the drug.
Route of administration.
Frequency of administration.
Nature of the drug.

Cellular Signaling Perspective
Based on the framework provided in the course, many possible explanations are likely:
If the increase in paw volume induced by the chemical is due to an unknown messenger molecule, then the drug could work at any one or more of the following levels:
Production of the molecule (interfering with synthetic process)—applies to both pre-formed and de-novo synthesized molecules
Storage/Release (if it is a molecule that is preformed)
Recognition (interference with binding to the receptors)
Transduction/amplification (interference with any of the signal transduction pathways)—many possibilities exist at this stage (including effects on gene transcription)
Stimulating or enhancing destruction by activating enzymes/uptake mechanisms, etc.
The drug could simply destroy or inactivate the chemical that starts the process. This is a weaker explanation, since that chemical is given just once and the drug is administered several days later after the paw volume has shown a significant increase.

Gene Expression Perspective
Based on the information given, there are many perspectives in which to analyze the data. The disease focus is arthritis and symptoms manifested and measured are indicators of inflammation.
We have covered information regarding gene expression from stimulus to protein production. Therefore hypotheses may include key players such as extracellular stimuli, receptors, transcription factors, promoters, mRNA and/or protein.
Below are nine hypotheses; however an almost infinite number of possibilities exist.

1. The drug is a protein, which stimulates anti-inflammation genes.
2. The drug is an inhibitor of inflammation stimuli.
3. The drug is an activator of anti-inflammation stimuli.
4. The drug is an inhibitor of activators (GRPs) of inflammation genes, prevents them from translocating to the nucleus.
5. The drug prevents activators (GRPs) of inflammation genes from binding to their GRSs.
6. The drug induces repressors (GRPs) of inflammation genes.
7. The drug directly inhibits products of inflammation genes “inflammation proteins.”
8. The drug is an siRNA for “inflammation genes.”
9. The drug is an siRNA for activators (GRPs) of “inflammation genes.”

Appendix C: Sample Student Answers to the TRIPSE

Cellular Signaling Perspective

Preamble
A chemical is used to induce swelling and inflammation in rat paws
It is only injected once, at the beginning
This chemical directly or indirectly causes swelling; histamine may be involved
Both drug and nondrug (saline) groups begin at 0.5 mL of paw volume before specific chemical was added
Both groups increase in a similar manner (slope of ~0.5 mL day\(^{-1}\)) after specific chemical was added
After the drug/saline was added, the drug group’s paw volume began to decrease in a roughly linear trend, after a small delay of about 2 days
The saline group continues to increase
It is assumed that the drug group’s paw volume decrease is due to the drug itself, and not any other variable, as change is only noticed after addition of the drug
Similarly, it is assumed that saline had no effect on the nondrug group
Same amounts of drug and saline administered from day 4 onwards
Assuming that drug was regularly administered (per day)
The effects of the specific chemical are localized to the rat paw (effects are not systemic)
Let the specific chemical inducing swelling be known as chemical X
Let the drug be known as drug D
Assessor’s comments: Essential elements were listed. You picked up on the changes of paw volume. You made several assumptions (amount of chemical drug, regularity, and local rather than systemic effects). All justifiable. Point form, but clear.
Assessor’s marks: 4.3/5
Hypothesis/Explanation
Assume an enzyme exists that is continuously degrading an endogenous chemical that induces joint swelling (arthritis). When rats are injected with an exogenous chemical that induces arthritis day –6 (day negative six), this enzyme is inhibited. This inhibition prevents the degradation of the endogenous chemical that induces swelling. Higher levels of endogenous arthritis-inducing chemical lead to higher paw volume. The injection of anti-arthritic drug stimulates the degrading enzyme. This stimulation leads to the restored degradation of endogenous arthritis-inducing chemical, and therefore decreases paw volume.

Assessor’s comments: You had an endogenous molecular t- that could induce arthritis being kept in check by a degrad- ing enzyme. This was inhibited by the chemical leading to an increase in paw volume, and with the inhibition reverse- d by the drug. This was a bit convoluted, but given that yo- u had little prior knowledge about arthritis or inflamma- tion, you made an attempt to apply the principles learned to this situation. I gave you credit for that. Would have helped had you given some hypothetical names to your mole- cules and drawn a diagram.
Assessor’s marks: 7.5/10

Experiments
Because the anti-arthritic drug is stimulating (activating) the degrading enzyme, the levels of endogenous arthritis-inducing chemical are expected to decrease. To test this hypothesis, the levels of the endogenous arthritis-inducing chemical must be measured over the treatment regime. Initially, upon injection of the exogenous arthritis-inducing chemical day –6 (day negative six), the enzyme would be inactivated. This would lead to higher levels of the endoge- nous chemical and greater paw volume. Upon administra- tion of the anti-arthritic drug, the degrading enzyme is reactivated. This would lead to decreasing levels of the endogenous arthritis-inducing chemical, which could also be measured. This can be shown as in Fig. 4.

Assessor’s comments: Here the diagram helped. Though yo- ur hypothesis was complex, this was not a bad test, as you

focused on the levels of the endogenous molecule that led t- o joint swelling. If you knew what the degrading enzyme w- as, you could have measured its activity directly in vitro. Needed controls!
Assessor’s marks: 8/10

Gene Expression Perspective

Preamble
The graph shows the swelling (indicated by paw volume → y-axis) over time (x-axis) when rats were injected with (1) saline (control) and (2) drug (experiment). The overall trend was that rats administered with saline’s paws increased in volume over time. Thus saline had no effect on paw growth. Paw growth increase thus made the arthri- tis condition worse. That is paw growth/volume continued to increase with saline injection. The drug on the other hand decreased paw volume over ti- me. This decreases arthritis over time as well. From day –6 (day negative six), –2 (before drug or saline was given to rats), the graph went up showing that with no treatment paw growth increases and arthritis gets worse. Only with drug administration, the arthritis got better.

A good hypothesis should include how or why the drug was able to decrease arthritis growth. What part of the body di- d the drug act on to decrease arthritis? By what mecha- nism did the drug work? Did it inhibit certain processes in- volved in causing arthritis? Or active certain processes involved in stopping arthritis?

Assumptions:
TFA is known
The drug is a protein that can act as an activator during g- ene expression

Assessor’s comments: This answer clearly identifies all of the points in the data that need to be addressed. Focused on the key issue of the mechanism of drug on arthritis. Assumptions are valid given the lack of knowledge on arthri- tis and inflammation.
Assessor’s marks: 4.5/5

Hypothesis/Explanation
The drug is an activator (transcription factor), TFA, which binds to GA involved in the production of a protein (PA) that is somehow involved in decreasing the rate of arthritis. Only with TFA in the mechanism shown above with the transcription process be able to occur because only when TFA binds to GA can transcription occur. Without trans-cription (production of mRNA), translation cannot occur either. This results in no PA eventually being produced.

Note: the mechanism shown above skips many intermedi- ate steps between TFA binding to GA, producing mRNA, w- hich undergoes translation to produce PA. It simply shows GA → PA the actual process is GA → mRNA → translation → PA.
Experiments

1). To prove that with drug a TFA binds to GA using the EMSA
   (a). Carried out using electrophoresis apparatus and 3 lanes: 1) cell extract without drug (TFA), 2) cell contents and the drug, and 3) the antibody should be known to bind specifically to TFA. Lane should be cell extract + drug + antibody.
   (b). A gel with 1) no band, 2) mid band, and 3) high band
   (c). If hypothesis is correct, the above results should occur. In the 1st lane there should be only free probe because there is no binding without the drug. In the 2nd lane should be a higher band representing the TFA bound to GA. It is heavier because of the binding thus higher up, because it moves slower. In the 3rd lane should be a very heavy thick band representing antibody + TFA + GA, verifying that it is in fact TFA that binds to GA.

2). To prove that mRNA is being produce with drug using the test RT-PCR
   (a). In 2 chambers 1) add contents from cells culture + drug 2) cell culture without drug. In each chamber:
   (b). Carry out RT first → all mRNA is converted to cDNA (because only double-stranded DNA versus single stranded mRNA can be seen during electrophoresis).
   (c). Carry out PCR → magnitude and amount of cDNA multiplies and the respective amounts of cDNA in cell cultures with and without drug can be measured. → corresponded to relative amounts of mRNA in each
   (d). If hypothesis is correct, without drug, RT-PCR should show thin or no bands because no/very little mRNA is produced. With drug, electrophoresis will show thick bands proving that with drug high amounts of mRNA are produced.

3). Western blot used to prove that with drug high amounts of PA produced.
   (a). Antibody tagged to PA after carrying out electrophoresis with cell extract 1) with and 2) without drug
   (b). In hypothesis is correct, with drug thick bands will show up on electrophoresis apparatus; without drug (TFA activator) no/very little PA will be produced.

Appendix D: Students Comments on the TRIPSE

"TRIPSEs - I feel that more worked examples before writing the evaluated TRIPSE would have been helpful. Having more opportunities for practice TRIPSEs would also be helpful, because it requires one to learn to think in a different way."

"The TRIPSEs were great, and I would suggest that students receive more individual practice TRIPSEs, which would allow them to familiarize themselves with the assessment expectations and build confidence in their abilities."

"I think there could also be more feedback and practice as far as the TRIPSEs in term one went so we could get a better feel of how to approach them."

"I would have also liked to do more practice individual TRIPSEs, since we only did practice group TRIPSEs."

"I really liked the group TRIPSE, but I think it’s also important to have individual TRIPSEs."

"While the practice TRIPSE’s were nice, I think it would have been better to feedback on them on a more individual scale. The reason being is that even though we practiced writing and thinking with a TRIPSE state of mind, we didn’t know what mistakes we made and therefore we had a high chance of making them again."

"I think I learned the most from the TRIPSE. This is where I learned the most about experimental methods."

"TRIPSEs are weird!"

"TRIPSE provided a good application for this knowledge, though I felt that due to its ‘general’ nature, a lot of the material in the lectures were ignored."

"I feel that the tutorials in first term could be improved if there were more practice TRIPSEs that we could discuss, perhaps even using three consecutive sections to do each part as a group so that we can see what is to be expected of us, in terms of which observations to make, etc."

"The TRIPSEs, that required an understanding of the material, were too difficult. If a student has a good understanding of the concepts, he/she should be able to succeed in a course."

"I felt that I did not learn anything properly until I had to do the TRIPSEs. I think that the TRIPSEs were great! Preparing for them meant learning the basics of everything we had covered. I think that they really helped me understand and remember some of the material."

"What I liked: TRIPSEs!!! I had trouble with them at first, but they are very logical and a great way to show that you really understand the material."

"I also enjoyed applying the knowledge I gained from lectures and research articles to other projects and TRIPSEs. This application of knowledge was very valuable and consolidated my own understanding of concepts and ideas."
“The TAs also were very subjective: My TA, for example, was really hard on the students for TRIPSE in comparison to other TAs. This discouraged me from studying at all for the TRIPSE because I felt that my effort had gone to waste.”

“Although I may have struggled with many of the evaluation methods and group assignments, I have come to recognize their value. I would encourage the further use of TRIPSEs.”

“More evaluations such as TRIPSEs should be given. Especially for TRIPSEs, the first TRIPSE allows students to develop the proper techniques, then the second allows them to apply them. More should be given so that students can hone their skills further.”

“I, personally, am not a huge fan of the TRIPSEs, but this is probably due to the fact that I lack thinking abilities and therefore found this to be really challenging.”

“I personally feel that the TRIPSEs are excellent tools to consolidate knowledge of lab techniques learned in class.”

“The TRIPSEs allowed for very unique and dynamic learning that I am glad I was able to experience.”

“TRIPSEs were an assessment I actually enjoyed doing—I feel that the knowledge I gained from them was incomparable.”

“All in all, TRIPSEs were an amazing learning experience and greatly contributed to expanding my knowledge in cellular and molecular biology. More frequent TRIPSEs would have been ideal in my opinion.”

“I really liked the group TRIPSE, but I think it’s also important to have individual TRIPSEs.”

“Group TRIPSEs worked well in terms of group dynamics and ability to synthesize answers.”

“I liked having the Group TRIPSEs first especially since that gave me a chance to bounce ideas off each other. Also my group had people who were knowledgeable in different areas and through TRIPSEs we were able to learn things from others that were needed for our Individual TRIPSEs. I personally didn’t know how to apply any of the laboratory techniques until after applying it with help from group members in the Group TRIPSE.”

“I found the Group TRIPSE much more effective than the individual one, as we fed off of each other’s ideas and I learned more from my peers when I worked with them as opposed to when I did the Individual TRIPSE on my own.”

“I wish there would have been more Group TRIPSEs spread out throughout the year (or at least term 1). Perhaps use smaller groups (3–4 people). They were a valuable and excellent educational tool; highly appreciated.”