WHAT ARE THE EFFECTS OF USING STRATEGIC APPROACHES TO MULTIPLE-CHOICE QUESTIONS ON THE CONFIDENCE LEVEL AND MOTIVATION OF GIFTED STUDENTS IN ADVANCED PLACEMENT CHEMISTRY?

by

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DEDICATION

This paper is dedicated to some very important people in my life. First to my sister Mary Joyce who remains by my side in the journey that is science education. My "little brothers" Michael Joseph and Joseph Robert who remind me of the value of hard work and dedication, and whose futures as excellent engineers I am fortunate to be part of. My friend Giancarlo, whose experience in multiple-choice testing inspired much of my work in this paper and most importantly, my parents Conrado and Florita for their unwavering support of all my educational pursuits.

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ABSTRACT

In this investigation various strategies were implemented with the purpose of improving students' confidence and motivation with multiple-choice tests in Advanced Placement chemistry. The effects of various interventions were examined for any impact on the confidence students had on multiple-choice evaluation and on their motivation to improve. The observed changes point to time allocation for tests as well as students' concurrent mastery of content and strategy as unforeseen variables that affected how their perception and belief impacted their actions.

INTRODUCTION AND BACKGROUND

I have been teaching Advanced Placement (AP) Chemistry for most of my career. I have observed over this time that students always had low scores on multiple-choice questions in their science courses, regardless of whether the students were identified as being gifted or they chose to be in the AP program. Likewise, the results always seemed to be the same regardless of whether the questions came from a computerized test bank or personalized by the teacher.

As I began to reflect on this situation, I realized that something needed to be done regarding improving student test scores on multiple-choice. These students will continue to encounter multiple-choice in university, as it remains a very common format for evaluation at the post-secondary level. Likewise, the fact that they are in the AP stream gives them the opportunity to challenge AP College Board exams that do have multiple-choice components that cover for the most part, 50% of the total score. Finally, it is a method of evaluation, that while it has its critics, tests not just on knowledge of the subject matter, but more importantly, its application in different contexts. Even with the increased emphasis on visualization of scientific concepts, testing student understanding of models and representations often use the multiple-choice format. This makes it even more important for students preparing for science, technology, engineering and mathematics (STEM) careers and gifted students in particular, to be able to master.

By having an increased focus on multiple-choice assessment in these classes, I explored how increased practice and exposure to multiple-choice questions and a concerted effort to emphasize strategy and method when answering these questions

affected overall student performance. It was my belief that students can learn to achieve significantly better results on multiple-choice questions when provided with practical strategic support alongside increased exposure to this type of evaluation, rather than only seeing these questions once during a unit or during a final examination for any given course.

This study was conducted in one section of AP Chemistry, over one semester, at St. Brother André Catholic High School, a Catholic secondary school in Markham, Ontario. St. Brother André is situated in suburban Toronto and has a student population of about 1400. It is one of four Catholic high schools in Markham. The school accurately reflects the demographic reality of the city of Markham, long lauded for the ethnic diversity of its population while maintaining its long-held reputation as a vibrant bedroom community with one of the highest median incomes in Ontario and Canada. A walk through the school's hallways would lead to a quick realization of the ethnic diversity that seemingly coincides with the varying academic abilities of its students. St. Brother André CHS has had a long-standing reputation for excellence in both academics and athletics for much of its thirty-one year history. It offers a wide range of courses in the STEM areas as well as in the technological education field, with classes in woodworking, automotive technology and hospitality and food preparation rounding out its course offerings. More importantly, the school is only one of four schools in the York Catholic District School Board to house the AP program for its identified gifted students. These courses employ the traditional lecture format with an emphasis on using technology in the delivery of curriculum and are predominantly taken by students in the

AP program in their senior years. These courses also tend to be one of the courses that students submit for admission purposes to the university programs of their choice.

My project focused on the effects of employing this strategy on AP Chemistry students. My project focus question was, *What are the effects of using strategic approaches to multiple-choice questions on both the confidence level and motivation of gifted students?* My project also considered whether active intervention and strategic approaches to responding to multiple-choice questions affected student performance as well. I also looked at whether an increased focus and attention on multiple-choice evaluation had any effect on my own teaching, attitudes and motivation. For the purpose of this study, motivation refers to interest to learn and being actively engaged in bettering their performance in the course.

CONCEPTUAL FRAMEWORK

The ongoing transition to guided inquiry-based learning calls for an examination of the effectiveness of multiple-choice assessments in the high school science classroom. While multiple-choice has been used as a primary means of student evaluation for a long time, and most especially in post-secondary science, technology, engineering and mathematics programs (STEM), it remains uncertain whether the collective body of knowledge accumulated thus far regarding strategies for improving multiple-choice test scores actually enhances the academic experience of high school students or motivates them to achieve at a higher level (Raina, Singh, Sood & Chader, 2016). The intensity and rigor of accelerated programs such as Advanced Placement (AP) or International Baccalaureate (IB) has led to a greater focus on multiple-choice since a significant

section of the overall score for these standardized exams is tested in this format (Brookhart 2015). Likewise, multiple-choice testing forms the basis of post-secondary evaluation, mostly characterized by various forms of these objective style questions (Hickson, Reed & Sander, 2012). These questions also prompt students to connect their conceptual understanding and apply it in other contexts, both of which pose significant challenges to students who may not otherwise have the confidence or necessary skills to be proficient in multiple-choice evaluations (Liu, Lee & Linn, et al., 2011).

There have always been differing perceptions on the difficulty level of multiple-choice formatted examinations. Anecdotal evidence from students has long suggested that they do poorly on multiple-choice tests. However, they do show significantly more favorable attitudes towards this format compared to essay type formats in terms of the most critical dimensions assessed in one study (Tozoglu, Tozoglu, Gurses & Dogar, 2004). While many students proclaim difficulties with multiple-choice questions, especially those that make use of exceptions, data presented does not support the notion that these types of multiple-choice questions are more difficult than "true" multiple-choice questions (Laprise, 2012). There is sufficient evidence to suggest that student confidence needs to be factored in to see if any correlation exists between performance and perception of the difficulty of multiple-choice questions.

Student confidence in approaching multiple-choice questions has been shown to be vital to success in this form of evaluation. Knowing what to expect before the multiple-choice exam allows students to reflect their good study habits and thinking skills, as well as the actual materials they have studied and learned. This becomes

especially significant, as this is an assessment technique very commonly levied upon them (Blackey, 2009). Likewise, these are vital to students if they are to be thoroughly prepared in various academic environments as this relates to mental preparation and building confidence in a high-stakes world once they leave formal schooling (Brookhart, 2015).

Most students tend to demonstrate varying degrees of insight and foresight when their approach to answering multiple-choice questions is analyzed. Their increased confidence was associated with more correct, fewer incorrect and fewer unsafe responses (Tweed et al, 2013). The same study also revealed a small subset of students who showed a pattern of providing unsafe responses held with high confidence. So while increasing experience improved insight in relation to correct responses and foresight in relation to incorrect unsafe responses, it becomes evident that for high ability students who had higher levels of confidence to begin with, even their unsafe responses were held in higher confidence as well (Tweed, et al., 2013). This has significant implications for AP students whose performance in multiple-choice tests tend to fall short of their own expectations (Geiger, 1996).

Proficiency in correctly responding to multiple-choice questions is not limited to anecdotal student experience. Results of a study indicate that pre-service teachers experience more difficulty in constructing best-answer-type multiple-choice items that require higher reasoning. This coincides with findings that tend to support the fact that students generally lack high-level cognitive functioning skills. The limited abilities of

both student and teacher in this area translate into a shared deficiency when it comes to dealing with multiple-choice questions (Asim et al, 2013).

Performance on multiple-choice exams also has implications for how courses are planned and for managing student expectations. These types of questions tend to elicit high-consistency and low trajectory results in terms of student performance over time (Bowen & Wingo, 2012). While it tends to assess the degree of knowledge integration, it often does not tap high levels of it, showing in part that using this form of assessment can indeed detect a wide range of student performance (Lee & Linn, 2011). The effect of using multiple-choice assessment on grades has also been studied and revealed very little differences in the grade outcomes of classes that wrote multiple-choice tests compared to those that used constructed response questions (Hickson et al, 2012). Further research will inevitably be stimulated from the lack of substantial benefits of using constructed response questions over multiple-choice questions.

The challenge to improving performance on multiple-choice type questions has always centered on whether students can correct errors and prevent further misconceptions from taking hold before the next test. Having strategies in place is important since the feedback they receive helps them maintain correct answers (Marsh et al, 2012). Not only does it narrow down the possible answers and identifies specific lures as false, it has been found to convey information to the student which has both practical and theoretical applications for their learning. Even a small amount of feedback tends to make a difference to both student confidence and performance on multiple-choice tests. It has long been established that both total feedback and partial feedback causes better

subsequent criterion test performance than will no immediate feedback (Hanna, 1976). Thus, if students gain from receiving feedback then perhaps other strategies that could improve their scores can potentially be implemented to serve that goal.

Formative assessment has always been part of traditional science instruction where students are provided exercises to practice skills and improve overall learning and not counting towards their final marks in the course. Being exposed to numerous formative assessment in the form of multiple-choice tests did not seem to have a dampening effect on student enthusiasm for courses that practice them frequently on this format (Rød et al, 2010). So when research points to older students achieving higher scores on factual and applied multiple-choice questions (Yonker, 2011), the surface approach to study that younger students tend to employ at this stage does not serve them well if they are trying to get good grades and improve overall learning at the same time.

It becomes increasingly evident that the potential for improved student performance on multiple-choice questions is predicated on various strategies that if used properly, should assist them greatly in getting better results. Students need to learn how to deal with a varying number of choices or lures on a multiple-choice test more effectively. Experiments were conducted to indicate whether increasing the number of lures on a multiple-choice test helps, hinders or has no effect on later memory. When subjects spend time comparing the lures and the target in the question, they are engaging in relational processing and associating the incorrect answer to the question stem (Butler, Marsh, Goode & Roediger (2006). This has implications on how an increased number of

lures impair students' performance on the multiple-choice test and on general knowledge as well.

Of significance, not just to AP, but all science students is the effect that technically worded options have on multiple-choice test performance. On recall multiple-choice questions, when the correct option was not technically worded, the percent of correct responses was 33% less than the average of the other three option combinations (Strang, 1980). The same study looked at interpretive multiple-choice questions and found that when both the correct and incorrect options were technically worded, the percent of correct responses was 56% less than the average of the other three option combinations. Likewise, the presence of a "none of the above" option in multiple-choice tests was found to negatively impact performance as well. Individuals were reluctant to select "none of the above" on tests and as such, less likely to correctly accept it as the answer even when it is the most appropriate response (Butler et al, 2006). It appears as if students have shown a historical bias towards selecting a response option other than "none of the above" in these situations. These findings have clear implications on the way students should be preparing for multiple-choice tests.

It is also evident that modeling how to answer multiple-choice questions strategically has real intrinsic value in the classroom. When instructors set up a "how-to" lecture where students are taught how to identify keywords and phrases within the answer choices, students showed evidence of learning how to apply information across contexts and how to analyze and interpret application-based multiple-choice questions (Holtzman, 2008).

METHODOLOGY

In order to assess whether implementing various strategies designed to help students do better on multiple-choice evaluations affected their confidence level, data was collected prior to the intervention and after the interventions. For the non-treatment component of the study, no specific preparation for multiple-choice tests were given. Students were given no prior instructions as to how to approach these questions. They just did what they have been doing previously. For the treatment component of the study, a three-pronged approach was developed to improve student confidence levels regarding multiple-choice questions. First, the treatment began with a lesson specifically devoted to developing strategies to improve student performance in multiple-choice evaluations. This lesson was presented at the beginning of the first unit that comprised the treatment phase of the study and in the form of an introductory lecture (Appendix A). The introductory lecture titled *Multiple Choice Test Taking Strategies for AP Science Students* looked at the nature of multiple-choice testing and the challenges students often encountered with this type of testing tool. It provided general advice from instructors as well as introduced a variety of strategies that students can use to practice with sample multiple-choice questions. The questions that were provided in the lecture came from units of study in the grade nine and ten science courses and thus were considered prior knowledge. Utilizing these questions as opposed to taking material from topics students learned more recently was an attempt to ensure that if students did not respond correctly to the assessment questions, it was because they were still learning the particular strategy and not due to a lack of conceptual understanding of the material.

The introductory lecture provided students with strategies to improve their performance on multiple-choice tests. These took the form of tips from academics that may have already been obvious to students in the past, such as re-reading the question, rechecking the calculations and re-evaluating the methods used to answer the questions. Students needed to be reminded that these general tips are useful not just for multiple-choice tests specifically but for preparing for any test format. Emphasizing these simple reminders forced students not just to rethink the way they tackle tests but more importantly, to be open to the idea that strategizing can be useful in test preparation. Students were also asked to pay greater attention to detail as they answer each practice multiple-choice question given in the introductory lecture. This emphasized a specific skill that proved successful in test preparation and was something that gifted students tended to be aware of for the most part.

A second component of this strategic approach featured the use of practice assessments in the form of multiple-choice clicker questions based on the concepts just learned. At least two multiple-choice clicker questions were embedded in each subsequent lecture. These clicker questions were both conceptual in nature as well as calculations-based and were chosen in part so students can respond to them relatively quickly using clickers provided to them by the instructor. Students were often advised by the instructor that these questions should not take longer than two minutes, not including the amount of time it takes to read the question fully. This allowed students to practice the various strategies they have been learning, thereby assessing their competence with the strategies simultaneously with the physical chemistry concepts. Students were given

additional time for clicker questions that required more time to read as well as those that were more quantitative in nature. The instructor also assessed how confident students were with the recently learned concept and allowed for extra time, whenever appropriate, in administering the clicker questions (Appendix B).

Finally, the frequency of multiple-choice testing was increased to provide more opportunities for students to be exposed to this type of evaluation. In the pre-treatment phase, students only saw multiple-choice on a test at the conclusion of a unit. During the treatment phase, all subsequent quizzes and tests included a multiple-choice component or consisted solely of multiple-choice questions. The multiple-choice questions were taken from a wide-array of test banks from university-level general chemistry textbooks and not teacher-constructed. This set a more standard level of difficulty on which to base the assessments. The topics considered for non-treatment and treatment followed the traditional order that topics are covered based on the course syllabus and textbook chapters for the course. Topics were covered in such a way that it provided the necessary scaffolding and foundation for future concepts so it was not seen as having made significant differences in the level of difficulty for the non-treatment versus the treatment sections of the study. Concepts covered later in the course were not necessarily more difficult than those covered earlier in the course, which tended to have been part of the non-treatment section of the study.

The non-treatment part of the course covered units in quantum theory and atomic structure, chemical bonding and intermolecular forces and solutions. This covered roughly the first six weeks of the course. The treatment part of the course covered units

on solutions and phase changes, thermochemistry, chemical kinetics, chemical equilibrium, acid-base equilibria and electrochemistry. The treatment section of the study lasted until the final examination was written at the end of the semester. Considering that the method of delivering curriculum and the pedagogy remained identical for both treatments, it was not seen as casting doubt on the results of the study even if the topics and concepts are not identical in the non-treatment and the treatment components of the study.

Selection of multiple-choice questions used for each evaluation followed methods traditionally used by the department which involved using mostly conceptual-based questions that test knowledge of the topic. Multiple-choice questions that involved calculations were chosen so that these did not take a lengthy period of time to complete. This often took the form of questions that involved no more than one or two steps. Gifted students tend to spend a lot of time on the multiple-choice questions and more often than not, fail to appropriate their time to the rest of the questions in the test. Ensuring that no multiple-choice question, whether it takes too long to read or requires more complex mathematical calculations, eats up too much of the student's time in one part of the test allowed for a more objective view of student performance.

In addition, an increased emphasis on modeling and visual representation of scientific concepts in the AP curriculum also allowed for diversification in the nature of these multiple-choice questions. Having a certain number of questions that tested a student's ability to articulate conceptual understanding through analyzing graphs, pictures or visual patterns ensured that no single evaluation was too easy or difficult. Given that

topics in the pretreatment and post-treatment parts of the project already had varying levels of difficulty, this allowed an appropriate level of consistency and continuity (Appendix C).

The final unit test in the treatment phase took the form of a partial-credit multiple-choice evaluation. In this particular test, students are given credit not for choosing the correct answer from the choices provided but for the number of choices that they successfully eliminate from the question, thereby leaving the correct response intact. This particular strategy was implemented at the end of the treatment phase in part to assess how students felt about using the various strategies that they have been taught (Appendix D).

The Multiple-choice Test Proficiency and Confidence Level Survey was administered prior to the interventions to ascertain the confidence level of students as they went through multiple-choice questions ((Appendix E). Students were then asked to respond to the same survey at the end of semester, which coincided with the end of the treatment period. The survey asked students to respond to a variety of questions and statements on how confident they are or have been previously when dealing with multiple-choice evaluation. Students responded to prompts that dealt with preconceived notions of the multiple-choice test format as well as those that inquired upon their confidence in various established strategies for improving performance.

They were also asked to answer a shorter questionnaire regarding their own sense of how they perceived their confidence level changed as far as multiple-choice evaluation is concerned. The initial question in this Overall Change in Confidence Level survey was

administered immediately after students submitted their final examinations on the last day of the course. The remaining questions were administered about a week later when students returned to review their examination results. The questions students responded to ranged from how they felt about the multiple-choice component of the final examination to whether or not they feel confident going forward in their post-secondary careers with the various strategies they learned in the course (Appendix F).

After the post-treatment surveys were conducted and the final grades for the course released, interviews were conducted with selected students in order to get a more definitive snapshot of whether their performance in multiple-choice questions correlates with their performance in short answer or free response questions, allowing for a determination of an effects of the intervention on how they perform on multiple-choice. These interviews were conducted outside of regularly scheduled class time with selected students based on their academic performance in the course so far. At least one high, average and low achieving student was interviewed. Interviewing students armed with data collected both from multiple-choice and short answer/free-response evaluations was important in determining whether further intervention was necessary for improving student performance in multiple-choice questions which tends to be the component of tests that most students do poorly on, even if they do quite well on the short answer component. This also proved crucial to determining whether the intervention could be used on a wholesale basis or it was better used for individual students on a case-by-case basis.

Throughout the study, I made observations and took notes regarding student motivation and confidence, particularly their reaction to having more frequent assessments and evaluations using the multiple-choice format. I also conferenced regularly with the school's AP Coordinator who has a science background and has previous experience in crafting her own multiple-choice questions, as well as colleagues who are teaching AP science courses concurrently. A self-evaluation reflection consisting of various questions was drafted to assess my own motivation and confidence throughout the treatment process as well as after each particular strategy was unveiled and implanted. I also posed various questions to assess how I felt overall once the treatment process was completed and how this affected my own teaching. These reflection questions can be found in Appendix G.

Twenty-two AP Chemistry students participated in this project. The course met every day for a 76-minute period during the first semester of the 2015-2016 academic year which ran from September to January. The majority of the students were 16 to 17 year old males representing roughly two thirds of the course population and females accounting for a third. A unique characteristic of this group was that 40% of these students are identified gifted students, having gone to a designated elementary school where an accelerated and enriched gifted program was delivered from Grade 5 to Grade 8 prior to entering secondary school. The remaining members of the class were students who applied for admission to the program based on their above-average performance in elementary school as well as test scores on an aptitude test used for admission.

Instruction and data collection for the project took place when the course ran during the first semester of the 2015-2016 academic year. The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained. (Appendix I).

The triangulation matrix shown in Table 1 outlines the sources of data that were identified for each subquestion. Triangulation of data helped to provide a more accurate conceptualization regarding the effects of the various intervention means employed in the study. It also eliminated the possibility of misconstruing any single source of data. Interviews at various points in the study allowed for increased reliability of survey data. Since gifted students are very much highly motivated by their grades, discussing their course marks as part of interviews added more credibility and authenticity to determining whether the intervention affected their motivation and confidence in multiple-choice evaluations (Table 1).

The data that was collected in this study were both qualitative and quantitative in nature. This combination hoped to provide a more accurate depiction of the effects of my intervention more than what statistics from a small sample can provide. Any differences regarding the motivation and confidence of students in approaching multiple-choice test questions and how they actually performed in tests were assessed through interviews with this information on hand. Since most of these students were identified as gifted and had a lot of experience with being tested in an academic setting, the descriptive angle of the data provided needed insight on whether the strategic approach to answering multiple-choice questions benefited them.

Table 1
Triangulation Matrix

Research Questions	Data Source		
	1	2	3
Motivation and Confidence of student	Pretreatment survey	Interviews	Post treatment survey & interviews
My teaching and attitude	Teacher journal	Self-evaluation	Peer conferencing

DATA AND ANALYSIS

The results of the Multiple-choice Proficiency and Confidence Level survey indicated that students were not satisfied with their general performance in the course, with a drop in the satisfaction level in the post-treatment survey (N=22). Thirty-six percent of students expressed satisfaction with how they performed in the course after the study, dropping from 41% at the beginning of the study.

Students were not satisfied with their performance on the multiple-choice part of their tests, with a slight uptick in students that are more satisfied with their performance after the treatment. Seventy-three percent of students had adverse feelings about their multiple-choice performance prior to the interventions with 64% remaining dissatisfied after.

Students were asked to reflect on how they have performed on multiple-choice tests in other science courses and on previous years as well. Their historical performance, as far as their own reflections on their performance, did not change much before and after the interventions.

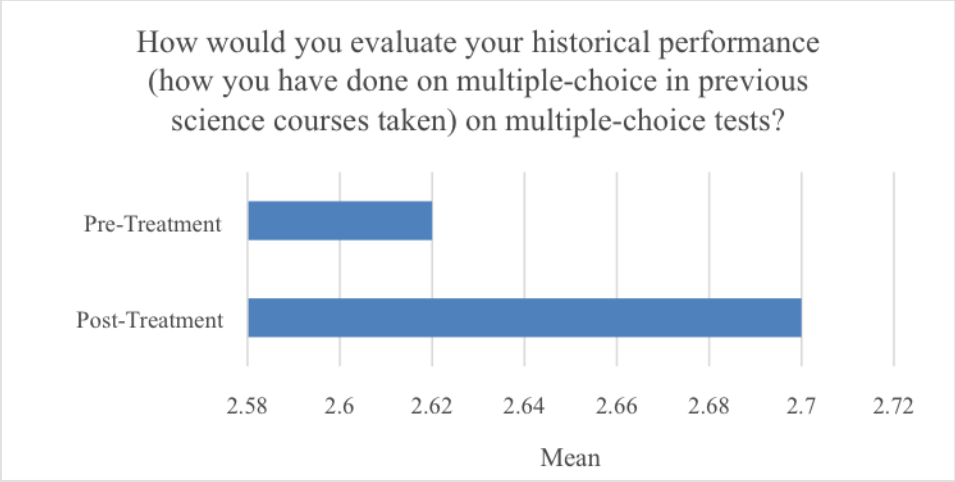


Figure 1. Multiple-choice proficiency and confidence level survey, (*N*=22).

While fewer students overall made an extra effort to study for the multiple-choice components after the interventions, slightly more students felt that they have a strategy in place that helps them do better on this type of test. The number of students who responded that they do little to no extra work to study for multiple-choice tests grew slightly from 55% to 59%. One student said, "I feel that multiple-choice is a crap shoot so why bother? I get the same mark all the time anyway." A majority of students already feel they have a strategy in place to improve their performance with 64% of them expressing this sentiment compared with 59% at the beginning of the study.

When asked prior to the interventions, to evaluate the most recent and consistent outcome of their multiple-choice tests in terms of marks, a majority of students (68%) felt that they were performing poorly in this regard. After the interventions, most students (59%) now expressed feeling good about their marks.

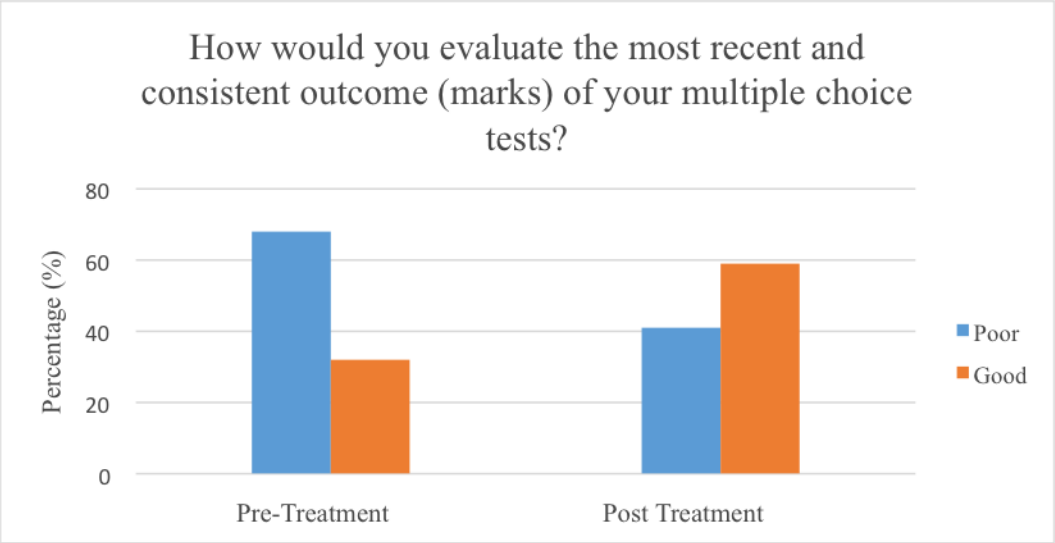


Figure 2. Multiple-choice proficiency and confidence level survey, (*N*=22).

There was almost no change in how students evaluated their own learning outcome from the multiple-choice tests even after the interventions. About a third of students surveyed felt that they learned very little from their multiple-choice tests, with 36% feeling this way even after the strategies were introduced.

The static nature of their responses when asked whether they were confident of doing well on multiple-choice upon completing each test reflected little to no change in their perception of their own learning from this type of evaluation. Sixty-eight percent of students said they were not confident of being able to achieve well at the multiple-choice component of the test, both before and after the implementation of the strategies.

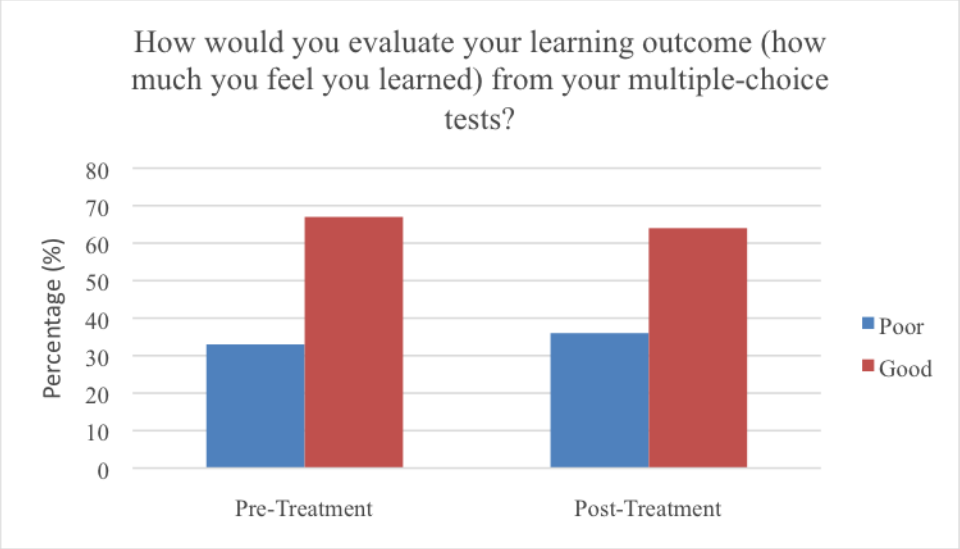


Figure 3. Multiple-choice proficiency and confidence level survey, (*N*=22).

Student behavior regarding how they dealt with multiple-choice questions showed modest change after the interventions, with the exception of making an effort to ask for feedback. Almost all students surveyed appeared not to be making much effort in this regard.

As a result of the interventions, most students have begun moving away from guessing at the answers to multiple-choice tests (mean of 2.4 from 2.6), and from changing their original answers often (mean of 2.55 from 2.33). Likewise, more students now seriously consider “none of the above” and “all of the above” as viable responses on multiple-choice tests.

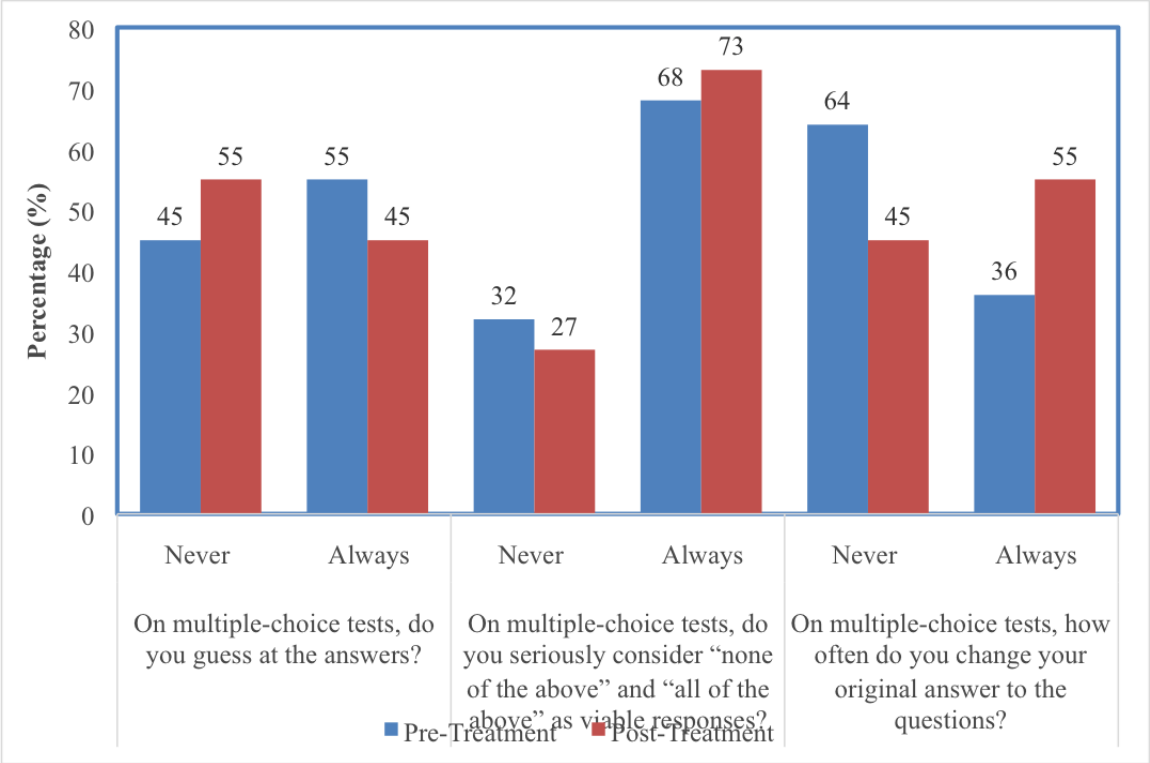


Figure 4. Multiple-choice proficiency and confidence level survey, (*N*=22).

Having access to more time appeared to go along with student confidence levels, with some change in those who believe that they can get a higher score on the test if they were given more time just for the multiple-choice. Asked at the beginning of the study, 41% of students felt they do not have enough time to do multiple-choice tests with a high degree of confidence. After the strategies were implemented, this sentiment increased with 64% of students who admitted to feeling that way.

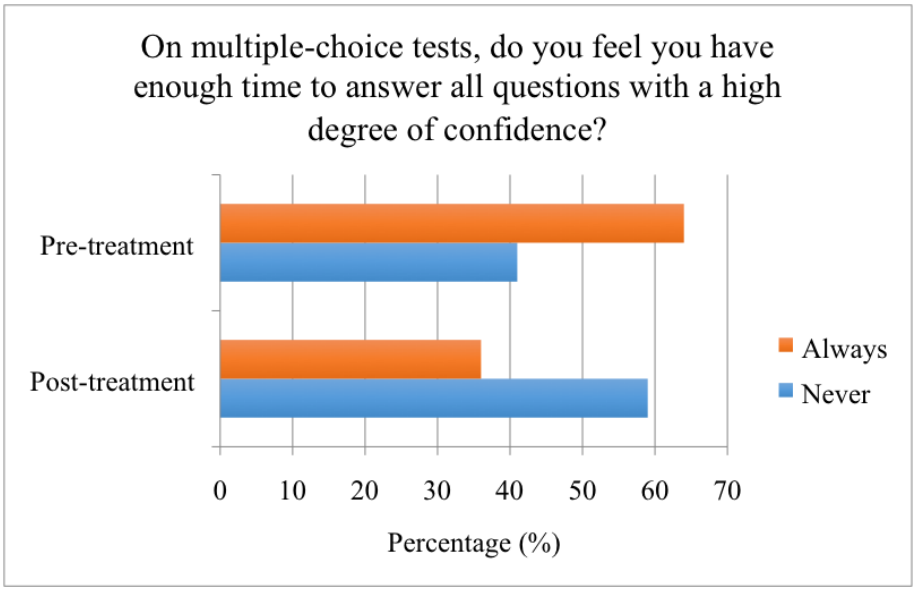


Figure 5. Multiple-choice proficiency and confidence level survey, (*N*=22).

The other questions in the Multiple-choice Proficiency and Confidence Level survey dealt with parameters that involve students' own perception and understanding of the multiple test structure.

The interventions did not do much to alter the perception that multiple-choice tests are difficult and challenging. More students thought this way after the treatment than before. Eighty-six percent of students agreed to the notion that it is difficult to do well on multiple-choice tests. The number of students who felt this way increased to 90% after the interventions.

Similarly, when compared to short-answer questions, the idea that multiple-choice questions are harder was perceived by more students after the interventions. A majority of students (55%) agreed with this idea prior to the study and the number only increased (59%) once the strategies were introduced.

The concept of time and student confidence in answering multiple-choice questions is raised once again when asked whether they feel they have enough time to respond properly and be confident of doing well. Students solidified their perception that there is not enough time to do so as more students felt that time was an issue. Fifty-two percent of students agreed that they can score higher on tests if given more time on the multiple-choice. Fifty-five percent remained in agreement after implementing the interventions.

The perception of time appeared to be linked to students' confidence in the structure of multiple-choice as a means of testing that benefits them academically. There was no change reported in their perception after the intervention, with most students feeling that they will not do much better if most of the testing in the course is done in this format.

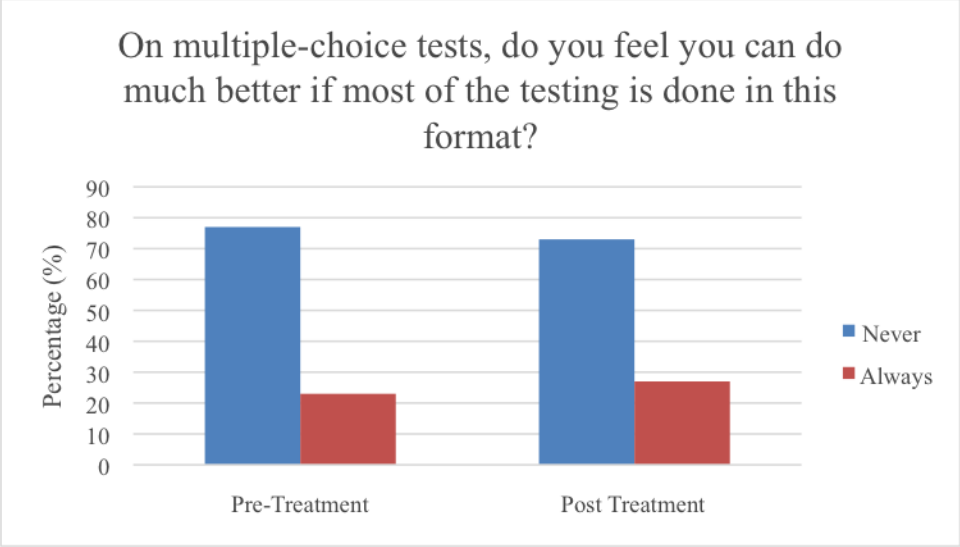


Figure 6. Multiple-choice proficiency and confidence level survey, (*N*=22).

The perception that some multiple-choice questions are inherently more difficult and challenging than others gained ground as well, with more students believing this is

the case after the interventions. Those who agreed with this sentiment grew from 86% of respondents at the beginning of the study to 90% after.

If ever students perceived that multiple-choice questions that did not involve numerical calculations are easier than those that did, the post-treatment data suggested otherwise. Prior to the study, 62% of students felt that having to do calculations made for more difficult multiple-choice questions. Only 23% of students felt that way after the study. More students felt after the interventions that factual and conceptual-based multiple-choice questions are no easier than quantitative-based ones.

Table 2
Pre and Post-treatment Survey Analysis, (N=22)

"Multiple-choice questions dealing that are mostly factual and conceptual in nature are easier than questions requiring numerical calculations."		
	Pre-treatment	Post-treatment
Mean	2.00	1.85
Mode	3	2

There appeared to be little to no change in the perception that high levels of confidence were linked to being adequately prepared for tests. The averages of student responses before and after the study did not change in this regard with most respondents (mean of 3.05) remaining in agreement or strongly in agreement.

In the Multiple-choice Test Proficiency and Confidence Level Survey, students were asked to respond to a couple of statements that attempted to define what "doing well" on multiple-choice tests is about. More students agreed with the notion that success in multiple-choice tests is about mastery of content, as opposed to having a strategy in place. These perceptions solidified after the interventions with more students

moving towards equating success in multiple-choice with solid understanding of the concepts and moving away from the notion that having a strategy helps them do better.

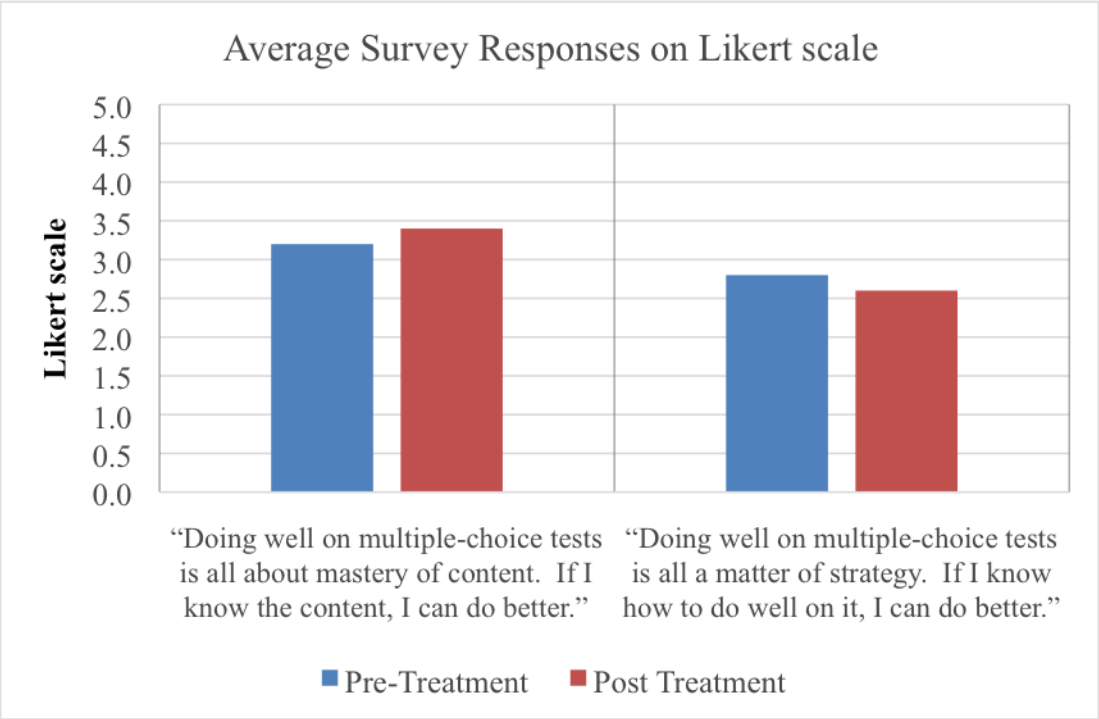


Figure 7. Multiple-choice proficiency and confidence level survey, (*N*=22).

The Overall Change in Confidence Level questionnaire administered after the final summative evaluation in the course reported perceived confidence levels among students for both the short-term and long-term future.

Table 3
Overall Change in Confidence Level Questionnaire Analysis, (N=22)

Confidence level assessment for multiple-choice component of final exam		
	Upon completion of the multiple-choice component of the final exam	Upon reviewing results of the multiple-choice component of the final exam
Not confident	13.6%	21%
Somewhat not confident	40.9%	47.4%
Somewhat confident	40.9%	31.5%
Extremely confident	4.5%	0%

When asked how confident they were that they did well on the multiple-choice component of their final examination, students were evenly split. Upon reviewing the results though, students expressed less confidence in their overall test taking abilities. Sixty-eight percent of students felt that their multiple-choice test taking skills were lacking upon reflecting on their final examination results.

Furthermore, when asked at the end of the end of the semester to gauge their level of enthusiasm each time a new strategy was unveiled or continued, 15 out of 22 respondents reported being optimistic to a minimal extent. One student said, "It might help me boost my confidence level so I'm willing to give it a try." Six out of the 22 expressed minimal pessimism, agreeing that the strategies might not help them boost their confidence level but they are willing to give it a try. With the exception of one student who expressed great optimism, none of the students admitted that the strategies were useless as far as boosting their confidence levels are concerned.

When asked to assess how their confidence level changed over the period of the study as a result of exposure to the various test-taking strategies, half of the students

surveyed reported that their confidence level improved more times than it deteriorated. About a third reported the opposite, with a small number sharing a great level of deterioration as it pertains to their confidence level.

Finally, the Overall Change in Confidence Level questionnaire asked students to gauge their optimism on their own abilities to perform well on multiple-choice evaluations as they prepare for post-secondary studies. Ninety-five percent of respondents agreed that they felt confident that they will do just as well or better in future university-level multiple-choice examinations.

Table 4
Overall Change in Confidence Level Questionnaire Analysis, (N=22)

"Given more exposure to test-taking strategies and mastery of the content, I feel confident that I will do just as well or better in future university-level multiple-choice examinations." (1=strongly disagree, 4= strongly agree)	
Percentage of respondents who "somewhat agree"	81.8%
Percentage of respondents who "strongly agree"	13.6%
Mode	3

INTERPRETATION AND CONCLUSION

Several themes emerged from analyzing the data. Confidence levels as far as how my AP chemistry students exhibit it appeared to involve more variables than originally anticipated. An important variable that needed to be considered was time. Students did not necessarily feel that strategies and interventions would work unless they had enough time to go through the multiple-choice adequately. One student said, "I was always more concerned about finishing the test than anything else…. I never have enough time to go

back and check my previous answers so whatever I shade on the *Scantron* is pretty much it." The notion of time appeared to be linked to their confidence level.

Mastery of content appeared to be linked with time as well. If the feeling is that there is never enough time to do multiple-choice adequately to begin with, then it did not really matter what kind of strategy they are taught, it likely will not help improve scores or increase confidence in the entire system. Test preparation and high level of confidence in answering multiple-choice questions appeared to go hand-in-hand in this regard. Student responses did not point to any change from pre-treatment to post-treatment. One student who scored very high on the multiple-choice of the final examination said, "I honestly think I did well because I studied, I studied for the course and not really thinking about the stuff we learned about how to do better on multiple-choice." Another student whose score on the multiple-choice component of the final exam was below the class average agreed, "If you stop believing that the teacher is out to trick you with impossible multiple-choice questions, it just boils down to whether you studied enough of the material or not."

The perception that multiple-choice testing is inherently difficult did not change even with the implementation of strategies, and even when most students were enthusiastic about trying them out. Student confidence level in multiple-choice test performance did not appear to be intricately linked not just to the implementation of strategies, but also to the types of strategies themselves.

Confidence level seemed to differ depending on the "risk" involved or the importance of the piece of evaluation. In the Overall Change in Confidence Level

questionnaire, students were asked to assess the overall change they perceived in their own confidence level over the period of the study as a result of exposure to various test-taking strategies. The strategies mentioned were the low risk activities implemented in the study that aimed to raise their confidence level in multiple-choice. The multiple-choice in the final examination though, constituted a significant portion of their final examination mark, with the exam mark accounting for 30% of the course grade. Students in the AP program in the district get a 1.05% multiplier appended to their final grades in recognition of the higher level of inquiry and instruction set forth in the AP curriculum. Students often experience tremendous pressure to make up for any poor marks in the term. A final mark boosted by a high final exam grade makes the 1.05% multiplier potentially accentuates this advantage further. Ensuring that they benefited from this is something that these students, who are within months of getting official acceptances to the university of their choice, were very concerned about. Therefore, the multiple-choice component of their final exam made it "high risk" and their confidence level appeared to have tanked along with the perceived threat of not doing well.

The Overall Change in Confidence Level questionnaire pointed to an even split among students who reported that their confidence level deteriorated more times than it improved over the span of the study, and those whose confidence level improved more times than it deteriorated. A telling number from this data is that not a single student in the survey suggested that the improvement in their confidence level is to a "great extent". Even when prefaced with assessing their confidence level through the lens of a

macroscopic view of test taking strategy that was exposed to them, students appear not to be buying into the notion that any kind of strategy is useful.

A different picture emerged when two variables are combined: exposure to test-taking strategies and mastery of the content. An overwhelming majority of students agreed that they will feel more confident of future success in university-level multiple-choice examinations. There appeared to be more of a willingness to consider the strategic approaches but only if the mastery of content is there. Likewise, there appeared to be a deeply ingrained connection between confidence level and mastery of content, and not necessarily about having the strategies needed to be successful in multiple-choice. But having strategies was perceived to be enhancing whatever the benefits that a solid content of the concepts had.

A significant insight that came out of the study was how perception of the nature of multiple-choice testing was so deeply-entrenched as far as gifted students were concerned. AP chemistry is a course at the core of this strongly held belief. It was very difficult to change such long-standing beliefs especially when previous experience has been otherwise. It did not help that this format of evaluation remains the most prevalent form of testing at the post-secondary level, particularly in the STEM fields that a majority of these students will be pursuing shortly. One of the first tasks that I wanted to get done in this action research project was to find some kind of a barometer for my students' confidence level as far as performance on multiple-choice tests were concerned. Of particular interest to me was whether the strategies that I have introduced, implemented and convinced them to try were successful in increasing their motivation and confidence

level. As evidenced by little to no change in the way they perceived the nature of multiple-choice testing itself as well as their own confidence that they can be successful at it, my AP chemistry students appeared to have little confidence that any particular kind of strategy will work.

However, using particular strategies to try to improve confidence levels of gifted students in multiple-choice questions did have some impact on how the students approached this particular type of evaluation. It gave them pause to think that there might be a way to improve. One student said, "At times, I found myself simply choosing an answer because it seemed the most correct, without actually reading what it said, because I was afraid to devote too much time to it. On the other hand, more time can sometimes make me unsure of my answers. I may overthink the wording and misinterpret the options, then change my answers that were previously correct." Most students were interested in the lecture and took to looking at the strategies mentioned, although some doubted right off the bat. Another student said, "I didn't really think I found anything useful in the lecture, mostly because I've already been practicing a lot of the stuff that was being mentioned." There was some vocalization of apathy about learning the strategy, appearing more like skepticism that any strategy would work. Most though were willing to give the strategies a try since I was trying it. One student remarked, "I had nothing to lose by trying it out and see if it would work, since the teacher seems to think it can, then why not?" I did see positive behaviors including some encouraging signs from some students that perhaps they might find a strategy that will work, but this was seen in the minority of students and mostly with the students that tended to have high

confidence in their abilities to begin with. One student noted, "I felt confident about how I'm doing since I already was practicing those strategies so it didn't really affect me."

The frequency of multiple-choice assessments also affected the students. Most students hated the idea, as they were pretty vocal about hating multiple-choice to begin with. One student said "I really didn't like how frequently we now had multiple-choice since it might be a simple idea but to me, multiple choice is just mostly right or wrong and it is a lot of work trying to find an answer that might be wrong." Those that did not shy away from the idea that this was going to be a more frequent occurrence in the classroom, more or less tried to open themselves to the idea that the strategies might work.

I was not sure if knowing ahead of time that the quiz was going to be all multiple-choice was changing the way they studied or whether this was not a factor in how they studied. There was not a lot of whining and complaining about having to do this pretty much for much of the semester. I was never completely sure about whether this was about the multiple-choice itself or whether they are sensing that it is not working. Part of this may be due to their very nature themselves. Gifted students often gravitate to natural tendencies to do as they are told, and considering that this might be something that could work, went ahead and participate wholeheartedly. There were some students though that did feel apprehensive, perhaps knowing that they do poorly on multiple-choice to begin with and that since this is an important year academically for them with university applications, perhaps the timing was not the most ideal.

Time is indeed a variable, even for the study itself. A semester with less than 93 days is simply not enough to dispel any myths about the nature of multiple-choice testing, to master any strategies that are being tested, and then, more importantly, to buy in to the idea that perhaps doing better on multiple-choice is not only possible but can actually be something to work for. There was no time for any changes in perception, either through personal experience in the course or through their own intuition to evolve into something tangible in the data.

Confidence level is only one small piece of the whole gifted student identity. Gifted students pride themselves in their intellectual capacities, their ability to master content and to be proficient at material that most students their age would struggle in. Hence their confidence level is closely linked to their mastery of content and not necessarily through plotting out strategy—which is what I am basically trying to get them to do. These students have seen success for most of their lives so there seems to be a hesitance to try anything new. Trying to alter something as abstract and emotionally-based as confidence level or motivation is a monumental task, and if it is even possible, not an expedient one. One student noted, "More time to learn the strategy would definitely help. You build habits from grade 9 or younger that you use and those habits carry over. Suddenly when you re far into your education and you're introduced to a new idea, it's not always as easy to adapt to it and you don't believe it's going to work, because high school is about marks. As much as we don't want it to be, it is, and we're scared that if we change to these new ideas, it will negatively affect our marks."

The quality of the research could be improved further by implementing a number of changes. The focus on one AP chemistry class limited the sample size. Depending on the homogeneity and the skill level of the students, the results could potentially skew in one direction or another. Getting a bigger and more diverse sample could be accomplished by extending the scope of the research beyond the last year of the AP program and perhaps starting with the Pre-AP students in grade 9. Confidence level could may well be very strikingly different at the beginning of high school than it is at the culmination of their secondary school career, and this information could lead to a greater understanding of how and when new pedagogical strategies should be implemented. One student reflected, "It's not a good feeling to see yourself crashing and burning after having so much success, and if preventing that includes starting this multiple choice training as early as possible, then it must be done."

Putting together the profile, both of the gifted science learner and what constitutes confidence level is something that needs to be explored further at a time when previously held conceptions of either can so easily be altered.

VALUE

The study has value for a number of reasons. It opened up a conversation about confidence and motivation, one of the needs of the gifted learner that is somewhat underappreciated. Performing poorly on one particular method of testing does not necessarily ring alarm bells in the education community especially for a group of students that otherwise does better than the average student so looking at their confidence level allowed for a deeper understanding of its merit to a young person.

The action research-based study allowed the class to move away from their comfort zone to try something new. It pushed them to reflect upon their own capabilities as students at the end of their high school career, the things that they have always done and either succeeded or failed at, and how much of their own perceptions about themselves mirrored their accomplishments.

As the divisional program teacher for PACE (Program for Academic and Creative Extension), the gifted program for my school district and AP Science, I oversee the AP science program and provide support to my colleagues both across the hall from me as well as across the district. This action research enabled me to embrace the value of critical thinking and enhance my own abilities in integrating it in every activity in the classroom. As a teacher in the Catholic school system in Ontario, I feel I have done my part in putting the vision that my school district has for our community. The vision statement of the York Catholic District School Board states that "Our students will become creative and critical thinkers who integrate Catholic values into their daily lives, as socially responsible global citizens." I feel that being involved in this project added another dimension to my work as a teacher and kept me in line with the moral and spiritual core of my calling as a catholic school educator.

Being successful at multiple-choice testing has evolved into not just about being able to do well at rote memorization but more about being able to problem solve and analyze. This is a critical skill for students to have, one that I, as the teacher, felt I had both a professional and moral obligation to provide. I also felt that I have grown as a teacher as a result of the action research, not just as a more effective science instructor

but also as a more reflective practitioner. I was able to step back, look at a situation that I foresaw as a potential problem, lean in and make reasonable attempts to solve it, and take a final step back to accept what the data told us.

It allowed me to further explore various aspects of twenty-first century teaching and interdisciplinary learning, two areas of which I have been strongly involved in at both the school and district level. The very nature of the teaching profession has changed significantly from my days as a high school student. I realized that I have to change as well, and that this does not have to be a bad thing nor did it have to be challenging and difficult. I learned to be open not just to any potential new strategies that can change status quo but to unforeseen variables as well.

My involvement in the action research process led me to think that as a result of what I learned in this study, there were indeed implications for the way we as science teachers, particularly those that teach the gifted learner, need to change our practice. I have long been convinced that science does not exist in isolation and neither should the way we go about communicating it to our students. I realized that there are always other things that factor in to the equation as far as gifted learning is concerned. The microscopic view is just as important as the macroscopic, the specific just as relevant as the general. More importantly, I learned to appreciate the value of every student for the whole human person that they are, one whose complete story is told beyond what mere numbers can suggest.

Upon further reflection of the numerous challenges I encountered in the process of completing this project, I focused on my difficulties justifying the relevance of what I

was doing. I realized how important it was from a theoretical standpoint. This was an important skill that students need to know. I was also dealing with gifted students that have thrived and survived this far academically with a certain level of confidence in their academic abilities. But somehow, I was not seeing any effects that my strategies were having on moving them forward. My relationship with these students also became part of my reflection on this whole exercise. I started out thinking that I wanted to help them perform better, especially on an important time in their academic careers. Upon realizing that my strategies may not have any positive effects, I became even more apprehensive as to the goals of my entire capstone. "What am I doing?" is a question I asked myself repeatedly, mostly upon seeing results that were nowhere different than what we normally had even before any interventions were implemented. The idea that I was wasting precious time and perhaps playing Russian roulette with the academic lives of the strongest students in the school was a thought that crossed my mind more times than I could remember. Thinking that nothing positive was coming out of it was one thing, the possibility that I may be harming them emotionally and hurting their confidence level was something I found difficult to take. Compounding this were my own difficulties completing the capstone. Somehow I could never quite have enough time to get everything done, with my professional and personal obligations constantly getting in the way of giving the project the time it deserves. I realized that I was in the same boat as many of my students. We were all trying our best to be proficient at a skill that supposedly is something that we could all be good at, but somehow never completely buying in to the idea that this was achievable. While I was analyzing how to properly

gauge the confidence level of my students when it came to performing better on multiple-choice tests, my own confidence level on accomplishing the project with what I perceived as acceptable results was declining. For the duration of the capstone, I never felt that I was going to be able to succeed. There were too many variables that I am juggling in my own personal and professional lives that I constantly felt overwhelmed. I felt too overwhelmed to even consider how my own students were feeling. To what extent were they overwhelmed as well with trying to find something positive to feel good about with multiple-choice? To what extent was I in denial about my goals for the capstone, and how far did my own denial extend to the confidence level of my students?

I began to feel that teaching with a focus on getting students to be more confident in multiple-choice took a page out of any coaching handbook. It felt part scientific and logical, but more emotional and psychological. I felt comfortable with the scientific and logical ("if you do things a certain way, you will get certain results a certain way") but never quite with the emotional and psychological. There was a part of me that realized from the very beginning that it was going to be a hard sell, much more than if I had done the project with honors level students who I feel were more open to new ideas and new ways of doing things than AP students who are set in their ways. In a way, it was difficult for me to challenge their worldview. They have been successful for so long subscribing to the kinds of beliefs and strategies that they were taught or have been comfortable with. I was never really sure whether I was fully vested in what I perceive to be success for the project or whether I felt my focus was too forced on finding an answer. With little to no change in my students' confidence level after implementing my

strategies, I felt I should have taken more steps to counter preconceived notions pertaining to how my students view academic success. Clearly, success in multiple-choice tests is seen as a black-and-white issue for most of them. In retrospect, I realized that there was more I could have done to meet the students where they are, rather than assume that I can get them to move forward on something that they may not be quite ready to accept.

When one student mentioned that the more frequent opportunities for multiple-choice may be a bit "too much" considering it is already a stressful year for them to begin with, I took pause as if to try to see whether I am doing more harm than good. The response I ended up having is to address the idea that backing off of learning to strategize when it came to raising the bar on multiple-choice performance is akin to sticking your head down in the sand and continuing to remain in denial about it. As practitioners of science, at the very least, we should always be welcome to new ideas of doing things, and as future practitioners of science, so should the students. I found that their reaction, however much in the minority, was more of a reflection of the confidence level that they do have. This was happening nearer to the beginning of the intervention and in retrospect, I should have related that particular response as an indication of their confidence level. Perhaps they knew that nothing was going to change, and maybe even change more towards the negative side.

After having done the interventions, it became clear that student confidence level as it pertains to multiple-choice does not exist in a vacuum. Assuming that it operates in isolation, and thus can be manipulated as such, is perhaps something that I need to

reconsider the next time I delve into this. And there will be a next time.

I have come to think that this particular endeavor is something that is indeed worthy of further examination. Unless there is a massive paradigm shift that occurs in the way post-secondary institutions evaluate students, and for as long as multiple-choice remains a staple of standardized testing, which educational institutions find themselves more and more subjected to, this is a skill that students need to be proficient at. It is, and always will be, a survival skill in the academic world. As educators, we are now also more concerned about the mental and emotional well-being of our students as they move from K-12 to post-secondary, and having the confidence to achieve at a proficient level on this type of evaluation is a much valued tool in their arsenal of survival skills in 21st century learning. Everyone involved is a stakeholder in this process and as such, we all have something to gain from making the right choices here.

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APPENDICES

APPENDIX A

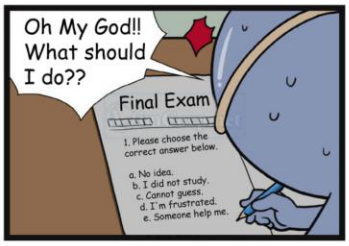
INTRODUCTORY LECTURE – MULTIPLE CHOICE TEST TAKING STRATEGIES FOR AP SCIENCE STUDENTS

Multiple Choice Test Taking Strategies:

A Primer for AP Science students

A.J. DINGLASAN
DIVISIONAL PROGRAM TEACHER – PACE/AP SCIENCE
YORK CATHOLIC DISTRICT SCHOOL BOARD

Multiple Choice





Studying for Multiple Choice Tests

- Studying for a multiple choice test (or a multiple choice section of a test) requires you to prepare differently from a short-answer format
- Multiple choice tests ask a student to recognize a correct answer among a set of options that include 3 or 4 wrong answers (called *distracters*), rather than asking the student to produce a correct answer entirely from his/her own mind.

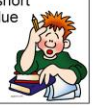
So it's easier then?

- The correct answer is guaranteed to be among the possible responses. A student can score points with a lucky guess.
- Mostly tends to emphasize basic definitions or simple comparisons, rather than asking students to analyze new information or apply theories to new situations.
- Usually contains many more questions than short answer section so each question has a lower point value and thus less risky.



It's actually harder?

- Contains many questions, so students forced to be familiar with a much broader range of material than short answer section.
- Usually expects students to have a greater familiarity with details-- Students cannot easily "b-s" on the multiple choice section.
- Much more difficult for a teacher to write good multiple choice questions than to design short answer questions so riskier for students due to **unintended ambiguity**.



General Tips from the Pros

The answer is already there. Use that fact to your advantage!

So what if your answer is not one of the choices…..

General Tips from the Pros

The answer is already there. Use that fact to your advantage!

So what if your answer is not one of the choices…..

-RE-READ the question carefully

General Tips from the Pros

The answer is already there. Use that fact to your advantage!

So what if your answer is not one of the choices…..

-RE-READ the question carefully

-RE-CHECK your calculations

General Tips from the Pros

The answer is already there. Use that fact to your advantage!

So what if your answer is not one of the choices…..

-RE-READ the question carefully

-RE-CHECK your calculations

-RE-EVALUATE your method

General Tips from the Pros

Examine the answer choices.

General Tips from the Pros

Examine the answer choices.

May need to consider each choice separately

General Tips from the Pros

Examine the answer choices.

May need to consider each choice separately

May need to see a relationship between the choices that will help you find the answer more quickly.

General Tips from the Pros

Examine the answer choices.

May need to consider each choice separately

May need to see a relationship between the choices that will help you find the answer more quickly.

May help to work backward from the choices, but be careful, as it may take you longer than simply reasoning it out

General Tips from the Pros

For questions that require calculations, scan the answer choices to see if you can approximate

In other questions, too, it may be helpful to scan the choices briefly before solving the problem to get a better sense of what the question is asking.

If computations are involved in the solution, it may be necessary to carry out all computations exactly and round only your final answer in order to get the required degree of accuracy.

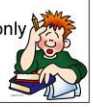
In other questions, you may find that estimation is sufficient and will help you avoid spending time on long computations.

So how do I score better on multiple choice?

Make sure that you identify and understand thoroughly everything that your instructor emphasized in class.

- fundamental terms, concepts & definitions
- descriptions and examples
- mathematical steps and "plug & play" calculations

These are the items that most commonly appear on the multiple choice section



Sample Question #1

The gold foil experiment performed in Rutherford's lab _____.

~~A) confirmed the plum-pudding model of the atom~~

B) led to the discovery of the atomic nucleus

~~C) was the basis for Thomson's model of the atom~~

D) utilized the deflection of beta particles by gold foil

E) proved the law of multiple proportions

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~~E) proved the law of multiple proportions~~

Sample Question #2

When the reflection of an object is seen in a flat mirror, the image is:

A. real and upright
B. real and inverted
C. virtual and upright
D. virtual and inverted

Sample Question #2

When the reflection of an object is seen in a flat mirror, the image is:

A. real and upright
~~B. real and inverted~~
C. virtual and upright
~~D. virtual and inverted~~

Image is not inverted!

Sample Question #2

When the reflection of an object is seen in a flat mirror, the image is:

A. real and upright
~~B. real and inverted~~
C. virtual and upright
~~D. virtual and inverted~~

What's real vs. virtual?

Sample Question #2

When the reflection of an object is seen in a flat mirror, the image is:

~~A. real and upright~~
~~B. real and inverted~~
C. virtual and upright
~~D. virtual and inverted~~

Watch out for absolutes

- Be mindful whenever you see "always" or "never"
- Requires an extra layer of consideration to be able to eliminate as a correct option

Sample Question #2

Which one of the following statements concerning speed is true?

a) Speed is always a positive number.

b) Speed can be a positive or negative number.

c) Speed is always a negative number.

d) The direction of the speed is directed from the starting point of motion to the ending point.

e) The average speed is always the same as the instantaneous speed.

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RTFQ2X

Read The FULL Question 2X

- Know what the question is actually asking you to do
- Do not get distracted by what you think the question is asking
- It's not a trick question if you did not do what it asked you to do!

Sample Question

When the following equation is balanced:
$K_3PO_4 + CaCl_2 \rightarrow Ca_3(PO_4)_2 + KCl$
the sum of the coefficients of the products would be:

A. 6
B. 7
C. 11
D. 12
E. 5

Sample Question

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A. 6
B. 7
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E. 5

"Correct" vs. "Incorrect"

- Easy to get confused with what the question is asking you to eliminate
- Use the same elimination strategy as practiced before, but make sure you are eliminating what you need to FOR THAT QUESTION



Sample Question

Which of the following statements concerning the elements and the periodic table is **incorrect**?

A. The modern periodic law may be stated as: *Properties of elements are periodic functions of their atomic numbers.*
B. There are more non-metallic elements than metallic elements.
C. There are a few elements that have properties intermediate between those of metals and nonmetals.
D. Hydrogen can be considered to be a member of more than one group.

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Sample Question

Choose the INCORRECT statement.

A) Potential energy is energy in action.

B) Heat is energy transferred as a result of a temperature difference.

C) Kinetic energy is the energy of motion.

D) Pressure volume work is calculated by $w = P \cdot V$.

E) Heat moves from a warmer body to a colder one.

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Choose the INCORRECT statement.

A) The surroundings are the part of the universe that is studied.

B) Thermal energy is energy associated with random molecular motion.

C) Work is done when a force acts through a distance.

D) Chemical energy is associated with chemical bonds and intermolecular forces.

E) Energy is the capacity to do work.

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Choose the INCORRECT statement.

A) Temperatures of two bodies are equal when the average kinetic energies of the two bodies become the same.

B) Most metals have low specific heats, as metals can be heated quickly.

C) The specific heat is the heat capacity for one mole of substance.

D) The law of conservation of energy can be written: $q_{system} + q_{surroundings} = 0$.

E) The heat capacity is the quantity of heat required to change the temperature of the system by one degree.

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Choose the INCORRECT statement.

A) Radioactivity is the emission of ionizing radiation.

B) Gamma rays are emitted from a nucleus in an excited state.

C) An alpha particle is the nucleus of a helium-4 atom.

D) A positron is like a beta particle but with a positive charge.

E) A beta particle is a neutron.

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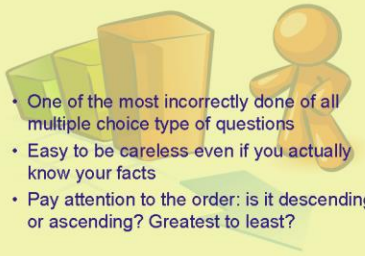
B) Gamma rays are emitted from a nucleus in an excited state.

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Ranking Questions



- One of the most incorrectly done of all multiple choice type of questions
- Easy to be careless even if you actually know your facts
- Pay attention to the order: is it descending or ascending? Greatest to least?

Rank this!

Light is refracted at the interface between two liquids.

In each drawing, the incident ray is in liquid A and strikes the interface at the same angle of incidence.

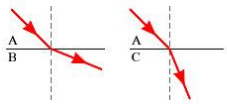
In one case the ray is refracted into liquid B, and in the other it is refracted into liquid C.

The dashed lines denote the normals to the interfaces.

Rank this!

Rank the indices of refraction of the three liquids in descending order (largest first).

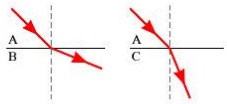
A. n_A, n_B, n_C
B. n_A, n_C, n_B
C. n_C, n_A, n_B
D. n_B, n_A, n_C
E. n_C, n_B, n_A



Rank this!

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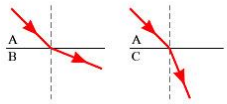
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C. n_C, n_A, n_B
~~D. n_B, n_A, n_C~~
~~E. n_C, n_B, n_A~~



Calculations

- Scan the options– eliminate the outliers
- Watch for signs (+ or -) and units
- Check if you can approximate for faster number crunching

Sample Question

$2\ NOCl(g) \rightarrow 2\ NO(g) + Cl_2(g)$ $\Delta H° =$ +75.56 kJ
$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g)$ $\Delta H° =$ -113.05 kJ
$2\ NO_2(g) \rightarrow N_2O_4(g)$ $\Delta H° =$ -58.03 kJ

Compute $\Delta H°$ of
$N_2O_4(g) + Cl_2(g) \rightarrow 2\ NOCl(g) + O_2(g)$ in kJ.

A) -246.65
B) +95.52
C) +246.65
D) -95.52
E) none of these

Sample Question

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Sample Question

Which of the following (with specific heat capacity provided) would show the smallest temperature change upon gaining 200.0 J of heat?

A) 50.0 g Al, CAl = 0.903 J/g°C

B) 25.0 g Au, CAu = 0.128 J/g°C

C) 50.0 g Cu, CCu = 0.385 J/g°C

D) 25.0 g granite, Cgranite = 0.79 J/g°C

E) 25.0 g Ag, CAg = 0.235 J/g°C

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"Multiple" answers and Combos

- Scan all the options and pick out the one or two options that you are (100%) sure about
- Eliminate the choices that DO NOT HAVE those options as part of the answer
- Quick elimination gives time to verify correctness of your choice

Sample Question

Which of the following are thermodynamic state functions?

I) heat
II) volume
III) temperature
IV) enthalpy
V) density

A) I, II, IV, V

B) I, III, V

C) II, III, IV, V

D) II, IV

E) I, II, III, V

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D) II, IV

E) I, II, III, V

More than one correct answer?

- May or may not be the case
- Be keenly aware as you go through the question

Sample Question

A 10-L flask and a 1-L flask each contain two moles of ideal diatomic gas (but not the *same* gas) at 25°C. Which of the following statements about these gases *must* be true? (There could be more than one correct choice.)

A) The molecules in the larger flask have the same root-mean-square speed as those in the smaller flask.

B) The internal (thermal) energy of the gas in both flasks is the same.

C) The internal (thermal) energy of the gas in the smaller flask is greater than the internal (thermal) energy of the gas in the larger flask.

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APPENDIX B

SAMPLE ASSESSMENT QUESTIONS – CLICKER LECTURE QUESTIONS



Which one of the following statements does not describe the equilibrium state?

A) Equilibrium is dynamic and there is no net conversion to reactants and products.

B) The concentration of the reactants is equal to the concentration of the products.

C) The concentration of the reactants and products reach a constant level.

D) The rate of the forward reaction is equal to the rate of the reverse reaction.



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Molecular hydrogen can be made from methane gas by the reaction below. How is the rate of disappearance of CH_4 related to the rate of appearance of H_2?

$$-\frac{\Delta[CH_4]}{\Delta t}, = ?$$

CH_4 (*g*) + H_2O (*l*) → CO (*g*) + $3H_2$ (*g*)

A) $+\frac{\Delta[H_2]}{\Delta t}$

B) $+\frac{1\Delta[H_2]}{3\Delta t}$

C) $+\frac{3\Delta[H_2]}{\Delta t}$

D) none of these



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D) none of these



Which of the following gases has the lowest average speed at 25°C?

A) CH_4
B) H_2S
C) NH_3
D) O_2

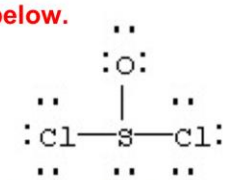


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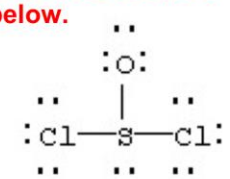
Assign formal charges to each atom in the resonance form for $SOCl_2$ given below.



A) 0 for Cl, 0 for S, and 0 for O
B) 0 for Cl, +1 for S, and -1 for O
C) -1 for Cl, +4 for S, and -2 for O
D) -1 for Cl, -2 for S, and -2 for O



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APPENDIX C

SAMPLE MULTIPLE-CHOICE QUESTIONS ON QUIZZES AND TESTS

SCH4UY-A
AP CHEMISTRY II
Thermochemistry

Quiz – Thermochemistry Intro

Level

KNOWLEDGE: _____

10



Take no more than ten (10) minutes for this quiz!

1. A system that does ***no*** work but which receives heat ***from*** the surroundings has:
   A. $q < 0, \Delta E > 0$
   B. $q > 0, \Delta E < 0$
   C. $q = \Delta E$
   D. $q = -\Delta E$
   E. $w = \Delta E$

2. A system receives 575 J of heat and delivers 425 J of work. Calculate the change in the internal energy, ΔE, of the system.
   A. -150 J
   B. 150 J
   C. -1000 J
   D. 1000 J
   E. 575 J

3. A system expands from a volume of 1.00 L to 2.00 L against a constant external pressure of 1.00 atm. The work (w) done by the system, in J, is:
   A. 1.00 J
   B. 2.00 J
   C. 1.01×10^2 J
   D. 1.01×10^5 J
   E. None of these choices is correct.

4. Which one of the following relationships is ***always*** correct?
   A. potential energy + kinetic energy = constant
   B. $E = q + w$
   C. $\Delta E = \Delta H - P\Delta V$
   D. $H = E + PV$
   E. $\Delta H = q_v$

5. Which of the following is ***not*** a state function?
   A. internal energy
   B. volume
   C. work
   D. pressure
   E. enthalpy

6. Ethylene glycol, used as a coolant in automotive engines, has a specific heat capacity of 2.42 J/(g-K). Calculate ***q*** when 3.65 kg of ethylene glycol is cooled from 132°C to 85°C.
   A. -1900 kJ
   B. -420 kJ
   C. -99 kJ
   D. -0.42 kJ
   E. -4.2×10^{-6} kJ

7. When two atoms form a covalently-bonded diatomic molecule, the distance between the nuclei at which the potential energy is at a minimum is called
   A. the bond energy.
   B. the bond length.
   C. the molecular diameter.
   D. the covalent radius.
   E. the covalent diameter.

8. Select the strongest bond in the following group.
   A. C—S
   B. C—O
   C. C=C
   D. C≡N
   E. C—F

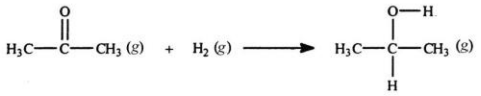
9. Nitrogen and hydrogen combine to form ammonia in the Haber process. Calculate (in kJ) the standard enthalpy change $\Delta H°$ for the reaction written below, using the bond energies given.

   $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$

Bond:	N≡N	H—H	N—H
Bond energy (kJ/mol):	945	432	391

   A. -969 kJ
   B. -204 kJ
   C. -105 kJ
   D. 204 kJ
   E. 595 kJ

10. Acetone can be easily converted to isopropyl alcohol by addition of hydrogen to the carbon-oxygen double bond. Calculate the enthalpy of reaction using the bond energies given.
    A. -484 kJ
    B. -366 kJ
    C. -48 kJ
    D. +48 kJ
    E. +366 kJ



Bond:	C=O	H—H	C—H	O—H	C—C	C—O
Bond energy(kJ/mol):	745	436	414	464	347	351

SCH4UY-A
AP CHEMISTRY
Chemical Equilibrium

Name_____

QUIZ – Le Chatelier's Principle

MULTIPLE CHOICE. Choose the one alternative that best completes the statement or answers the question.

1) The following reaction is exothermic. Which change will shift the equilibrium to the left? 1) ____

$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g)$

A) removing O_2
B) raising the temperature
C) adding SO_3
D) all of the above
E) none of the above

2) Consider the following reaction at equilibrium. What effect will adding 1 mole of Ar to the reaction mixture have on the system? 2) ____

$2\ H_2S(g) + 3\ O_2(g) \rightleftharpoons 2\ H_2O(g) + 2\ SO_2(g)$

A) The reaction will shift to the right in the direction of products.
B) The equilibrium constant will increase.
C) The equilibrium constant will decrease.
D) No effect will be observed.
E) The reaction will shift to the left in the direction of reactants.

3) Consider the following reaction at equilibrium. What effect will adding more SO_3 have on the system? 3) ____

$SO_2(g) + NO_2(g) \rightleftharpoons SO_3(g) + NO(g)$

A) The equilibrium constant will decrease.
B) The reaction will shift in the direction of reactants.
C) No change will occur since SO_3 is not included in the equilibrium expression.
D) The reaction will shift in the direction of products.
E) The reaction will shift to decrease the pressure.

4) Consider the following reaction at equilibrium. What effect will removing H_2O have on the system? 4) ____

$2\ H_2S(g) + 3\ O_2(g) \rightleftharpoons 2\ H_2O(g) + 2\ SO_2(g)$

A) The reaction will shift in the direction of products.
B) The equilibrium constant will decrease.
C) The equilibrium constant will increase.
D) The reaction will shift to the left.
E) No change will be observed.

5) Consider the following reaction at equilibrium. What effect will adding some C have on the system? 5) ____

$CO_2(g) + C(graphite) \rightleftharpoons 2\ CO(g)$

A) No effect will be observed since C is not included in the equilibrium expression.
B) The reaction will shift to the right in the direction of products.
C) The reaction will shift to the left in the direction of reactants.
D) The equilibrium constant will increase.
E) The equilibrium constant will decrease.

6) Consider the following reaction at equilibrium. What effect will reducing the pressure have on the system? 6) ____

$C_3H_8(g) + 5\ O_2(g) \rightleftharpoons 3\ CO_2(g) + 4\ H_2O(l) \qquad \Delta H° = -2220\ kJ$

A) No effect will be observed.
B) The equilibrium constant will increase.
C) The reaction will shift to the left in the direction of reactants.
D) The equilibrium constant will decrease.
E) The reaction will shift to the right in the direction of products.

7) The pink and blue species below form a violet colored mixture at equilibrium: 7) ____

$[Co(H_2O)_6]^{2+}(aq) + 4\ Cl^-(aq) \rightleftharpoons [CoCl_4]^{2-}(aq) + 6\ H_2O(l)$
(pink) (blue)

If the concentration of $[Co(H_2O)_6]^{2+}$ is increased, what happens to the solution?

A) The solution becomes colorless.
B) The concentration of $[CoCl_4]^{2-}$ increases.
C) The concentration of $[CoCl_4]^{2-}$ decreases.
D) No color change is observed.

8) The enthalpy for the following reaction is **136 kJ**. If the reaction takes place in a closed container, which one of the following reaction conditions will **not** decrease the concentration of water vapor? 8) ____

$$2\ NaHCO_3(s) \rightleftharpoons Na_2CO_3(s) + CO_2(g) + H_2O(g)$$

A) cool the container
B) remove some $NaHCO_3$
C) decrease the volume of the container
D) add CO_2

9) A crude type of disappearing ink is based on the following endothermic equilibrium: 9) ____

$$[Co(H_2O)_6]Cl_2\ (aq) \rightleftharpoons [CoCl_2(H_2O)_4]\ (aq) + 2\ H_2O\ (l)$$

(colorless) (blue)

If the reactant solution is used to write on a piece of paper and the paper is allowed to partially dry, what can be done to bring out the colored handwriting?

A) decrease the volume
B) put the paper in an oven
C) add water
D) put the paper in a freezer

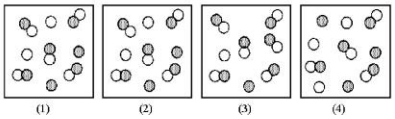
10) What effect will a change in temperature have on the value of K_p? 10) ____

A) The value of K_p will decrease or increase with an increase in temperature, depending on whether the reaction is exothermic or endothermic.
B) The value of K_p always increases with an increase in temperature.
C) The value of K_p always decreases with an increase in temperature.
D) It will have no effect on the value of K_p.

11) A catalyst increases the rate of a chemical reaction by providing a lower-energy mechanism for the reaction. When this occurs, which one of the following is **not** affected? 11) ____

A) rate of the reverse reaction
B) activation energy for the reverse reaction
C) activation energy for the forward reaction
D) equilibrium constant

12) Picture (1) represents the equilibrium mixture for the gas-phase reaction A + B ⇌ 2 AB at 298 K. If the volume of the equilibrium mixture is decreased, which picture **(2)-(4)** represents the equilibrium at the reduced volume? 12) ____



A) picture (2)
B) picture (3)
C) picture (4)
D) None of these

13) In a reaction at equilibrium involving only gases, a change in pressure of the reaction mixture shifts the position of equilibrium only when: 13) ____

A) the reaction is exothermic as written
B) the collision rate increases
C) the gases are impure
D) heat is absorbed by the reaction proceeding to the right
E) the moles of gas are not equal on the two sides of the equation.

14) Choose the correct statement about a container in which the chemical equilibrium is established: 14) ____

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) + \text{heat}$$

A) A decrease in the volume will decrease the amount of SO_2 present.
B) An increase in amount of O_2 will increase the amount of SO_2 present.
C) A decrease in temperature will increase the amount of SO_2 present.
D) A decrease in the amount of SO_3 present will increase the amount of SO_2 present.
E) A decrease in amount of O_2 will decrease the amount of SO_2 present.

15) For the reaction; $N_2(g) + 3\ H_2(g) \rightleftharpoons 2\ NH_3(g)$, the equilibrium amount of NH_3 will be increased by: 15) ____

I) increasing the pressure
II) adding H_2
III) removing N_2
IV) decreasing the pressure

A) II, IV
B) I, III
C) II, III
D) I, II
E) III only

SCH4UY-A
AP Chemistry II
Properties of Solutions

UNIT TEST – Properties of Solutions

KNOWLEDGE: (20 marks)

Choose the best answer to the following and shade in your response on the appropriate space in the Scantron Card. You ***may*** write on these sheets.

1) Choose the statement below that is TRUE. 1) ____
A) A solution will form between two substances if the solute-solvent interactions are small enough to be overcome by the solute-solute and solvent-solvent interactions.
B) A solution will form between two substances only if the solvent-solvent interactions are weak enough to overcome the solute-solvent interactions.
C) A solution will form between two substances if the solute-solute interactions are strong enough to overcome the solvent-solvent interactions.
D) A solution will form between two substances if the solute-solvent interactions are of comparable strength to the solute-solute and solvent-solvent interactions.
E) None of the above are true.

2) Which definition is INCORRECT? 2) ____
A) mole fraction = moles of solute/moles of solution
B) volume percent=volume of solute/volume of solution
C) weight percent = grams of solute/100 grams of solution
D) molality = moles of solute/kilogram of solvent
E) molarity = moles of solute/liter of solution

3) A solution is called "ideal" when: 3) ____
A) all intermolecular forces of attraction are the same, resulting in no net enthalpy change when the solution is formed from its components.
B) the forces of attraction between solute and solvent molecules are somewhat smaller than between solute-solute molecules or solvent-solvent molecules.
C) the forces of attraction between solvent molecules exceed those between solute and solvent molecules.
D) the forces of attraction between solute molecules and solvent molecules are *much smaller* than between solute-solute molecules or solvent-solvent molecules.
E) the forces of attraction between solute molecules exceed those between solute and solvent molecules.

4) The principal reason for the extremely low solubility of NaCl in benzene (C_6H_6) is the _____. 4) ____
A) hydrogen bonding in C_6H_6
B) strength of the covalent bond in NaCl
C) strong solvent-solvent interactions
D) increased disorder due to mixing of solute and solvent
E) weak solvation of Na^+ and Cl^- by C_6H_6

5) Which of the following statements is <u>false</u>? 5) ____
A) The weaker the attraction between the solute and solvent molecules, the greater the solubility.
B) The solubility of gases in water decreases with increasing temperature.
C) Substances with similar intermolecular attractive forces tend to be soluble in one another.
D) Nonpolar liquids tend to be insoluble in polar liquids.
E) The solubility of a gas increases in direct proportion to its partial pressure above the solution.

6) A solution is formed at room temperature by vigorously dissolving enough of the solid solute so that some solid remains at the bottom of the solution. Which statement below is TRUE? 6) ____
A) The solution is considered saturated.
B) The solution is considered supersaturated.
C) The solution would be considered unsaturated if it were cooled a bit to increase the solubility of the solid.
D) The solution is considered unsaturated.
E) None of the above are true.

7) Which of the following statements is generally TRUE? 7) ____
A) The solubility of a solid is highly dependent on both pressure and temperature.
B) The solubility of a solid is highly dependent on pressure.
C) The solubility of a solid is not dependent on either temperature or pressure.
D) The solubility of a solid is highly dependent on temperature.
E) None of the above.

8) KBr does not dissolve well in nonpolar solvents because 8) ____
A) solute-solvent interactions are similar to solvent-solvent and solute-solute interactions.
B) solute-solute interactions are much larger than solvent-solvent or solute-solvent interactions.
C) solute-solvent interactions are much larger than solvent-solvent or solute-solute interactions.
D) solvent-solvent interactions are much larger than solute-solvent or solute-solute interactions.

9) When a particular solid begins to dissolve in water, the temperature rises dramatically. For the dissolving of this solid in pure water 9) ____
A) ΔH_{soln} is always negative and ΔS_{soln} may be negative or positive.
B) ΔH_{soln} is always positive and ΔS_{soln} may be negative or positive.
C) ΔH_{soln} is always positive and ΔS_{soln} is always positive.
D) ΔH_{soln} is always negative and ΔS_{soln} is always positive.

10) Which of the following is **not** an application of colligative properties? 10) ____
A) melting snow by application of salt
B) adding silver to mercury to lower the vapor pressure of mercury
C) reduced boiling points of pure liquids at increased altitudes
D) desalinating sea water by reverse osmosis

11) At a given temperature the vapor pressures of benzene and toluene are 183 mm Hg and 59.2 mm Hg, respectively. Calculate the total vapor pressure over a solution of benzene and toluene with $X_{benzene} = 0.600$. 11) ____
A) 110 mm Hg B) 242 mm Hg C) 121 mm Hg D) 133 mm Hg

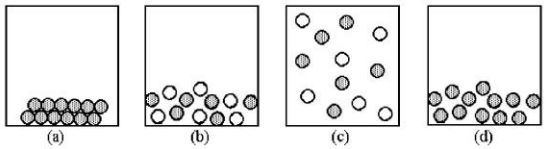
12) When 2.36 g of a nonvolatile solute is dissolved in 100 g of solvent, the largest change in freezing point will be achieved when the solvent is 12) ____
A) chloroform, $K_f = 4.70$.
B) camphor, $K_f = 37.8$.
C) benzene, $K_f = 5.07$.
D) All are expected to have the same freezing point.

13) A 0.50 *m* solution of which solute has the largest van't Hoff factor? 13) ____
A) $LiCO_3$ B) $NaNO_3$ C) $CaCl_2$ D) K_3PO_4

14) Chloroform has a boiling point of 61.1°C and dichloromethane has a boiling point of 40.0°C. When 0.100 mol of dichloromethane is added to 0.900 mol of chloroform, the resulting solution will have a boiling point 14) ____
A) between 40.0°C and 61.1°C, but closer to 61.1°C.
B) greater than 61.1°C.
C) between 40.0°C and 61.1°C, but closer to 40.0°C.
D) less than 40.0°C.

15) Two aqueous solutions, A and B, are separated by a semipermeable membrane. The osmotic pressure of solution A immediately begins to decrease. Which of the following statements is true? 15) ____

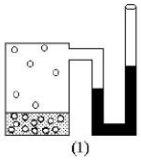
A) The initial osmotic pressure of solution B is greater than that of solution A.
B) Solvent molecules are moving from solution B into solution A.
C) The solvent molecules are moving from the solution of higher osmotic pressure to that of lower osmotic pressure.
D) Both B and C are true statements.

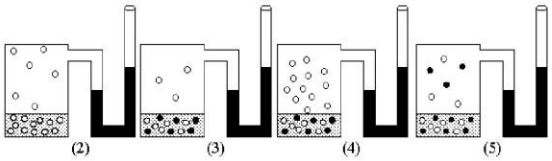


16) Which drawing above represents the system with the **lowest** entropy? 16) ____

A) drawing (a) B) drawing (b) C) drawing (c) D) drawing (d)

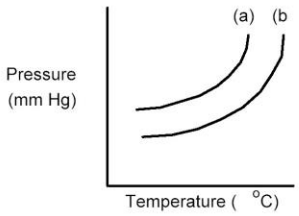
17) Drawing (1) shows the equilibrium vapor pressure of a pure liquid. Which drawing (2)-(5) represents the equilibrium vapor pressure when a nonvolatile solute is dissolved in the liquid? 17) ____





A) drawing (2) B) drawing (3) C) drawing (4) D) drawing (5)

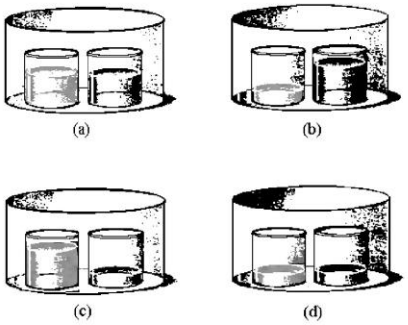
The following diagram shows a close-up view of the vapor pressure curves for a pure solvent and a solution containing a nonvolatile solute dissolved in this solvent.



18) Which curve is the solvent and what happens to the boiling point when the solute is dissolved in the solvent? 18) ____

A) Curve (b) is the solvent and the boiling point decreases.
B) Curve (b) is the solvent and the boiling point increases.
C) Curve (a) is the solvent and the boiling point increases.
D) Curve (a) is the solvent and the boiling point decreases.

19) Two beakers, one with pure water (light gray) and the other with an aqueous solution of KBr (dark gray), are placed in a closed container represented by drawing (a). Which of the drawings (a)-(d) represents what the beakers will look like after a substantial amount of time has passed? 19) ____



A) drawing (a) B) drawing (b) C) drawing (c) D) drawing (d)

20) Henry's Law states that: 20) ____

A) the solubility of a gas increases as the gas pressure is increased
B) a concentrated solution increases the boiling point of a solution
C) the solubility of a gas decreases as the gas pressure is increased
D) a concentrated solution lowers the freezing point of a solution
E) a supersaturated solution is unstable

SCH4UY-A
AP CHEMISTRY II
Chemical Kinetics

UNIT TEST – Chemical Kinetics

MULTIPLE CHOICE: (KNOWLEDGE) [15 marks]
Answer the following questions by recording the appropriate letter that corresponds to the most correct response on the Scantron Card provided.

1. The rate constant for a reaction is 4.65 L $mol^{-1}s^{-1}$. What is the overall order of the reaction?
   A. zero
   B. first
   C. second
   D. third
   E. More information is needed to determine the overall order.

2. When the reaction A → B + C is studied, a plot of $\ln[A]_t$ vs. time gives a straight line with a negative slope. What is the order of the reaction?
   A. zero
   B. first
   C. second
   D. third
   E. More information is needed to determine the order.

3. The reaction X → Y is first-order overall and first-order with respect to the reactant X. The result of doubling the initial concentration of X will be to
   A. shorten the half-life of the reaction.
   B. increase the rate constant of the reaction.
   C. decrease the rate constant of the reaction.
   D. shorten the time taken to reach equilibrium.
   E. double the initial rate.

4. An increase in temperature increases the reaction rate because
   A. a greater fraction of the collisions have the correct orientation of molecules.
   B. the activation energy of the reaction will increase.
   C. the activation energy of the reaction will decrease.
   D. temperature acts as a catalyst in chemical reactions.
   E. more collisions will have enough energy to exceed the activation energy.

5. What would happen if the kinetic energy of the reactants were not enough to provide the needed activation energy?
   A. The rate of the reaction would tend to increase.
   B. The reactants would continue to exist in their present form.
   C. The activated complex would be converted into products.
   D. The products would be produced at a lower energy state.
   E. The products would form at an unstable energy state.

6. Reaction intermediates differ from activated complexes in that
   A. they are stable molecules with normal bonds and are frequently isolated.
   B. they are molecules with normal bonds rather than partial bonds and can occasionally be isolated.
   C. they are intermediate structures which have characteristics of both reactants and products.
   D. they are unstable and can never be isolated.
   E. all reactions involve reaction intermediates, but not all have activated complexes.

7. A catalyst accelerates a reaction because
   A. it increases the number of molecules with energy equal to or greater than the activation energy.
   B. it lowers the activation energy for the reaction.
   C. it increases the number of collisions between molecules.
   D. it increases the temperature of the molecules in the reaction.
   E. it supplies energy to reactant molecules.

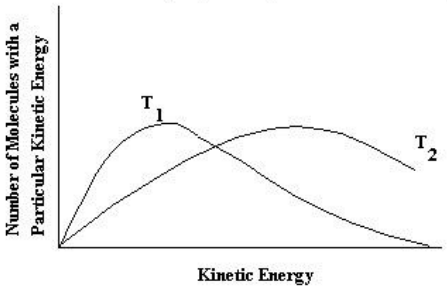
8. When a catalyst is added to a reaction mixture, it
   A. increases the rate of collisions between reactant molecules.
   B. provides reactant molecules with more energy.
   C. slows down the rate of the back reaction.
   D. provides a new pathway (mechanism) for the reaction.
   E. None of these choices is correct.

9. Which of the following statements is **incorrect**?
   A. The slow step in a mechanism generally involves a three-particle collision.
   B. After the addition of a catalyst, the collision rate between molecules is still the same.
   C. Most collisions between reactant molecules do not lead to a product.
   D. Chemical reactions involve collisions between the participating molecules.
   E. A three-particle collision is less likely than a two-particle collision.

10. A catalyst is only effective if it
    A. is present in large quantities
    B. is added before the reactants come in contact with each other
    C. is specific to the particular reaction
    D. is heated before it is added to the reaction
    E. all of the above

11. If for the reaction $aX + bY \longrightarrow products$, the rate law is determined to be $r = k[X]^1[Y]^0$, then
    A. the order of the reaction is 0
    B. increasing the concentration of Y will have no effect on the rate
    C. increasing the concentration of X will have no effect on the rate
    D. increasing the concentration of Y will increase the rate of the reaction
    E. there is no way to determine the value of k

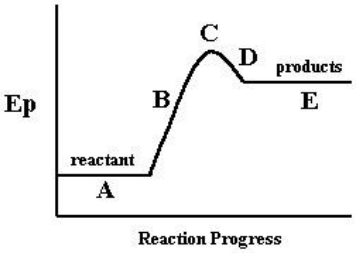
12. The following diagram represents a kinetic energy distribution at two temperatures.



In comparing the two temperatures, it is obvious that

A. $T_1 > T_2$
B. $T_2 > T_1$
C. $T_1 \propto T_2$
D. $T_1 = T_2$
E. it cannot be determined

13. In the following diagram, the letter which represents the position of the activated complex is:



A. A
B. B
C. C
D. D
E. E

14. Which of the following statements is **always** true?

A. Exothermic reactions have lower activation energies than endothermic reactions.
B. The rate of a catalyzed reaction is independent of the concentration of the catalyst.
C. The rate for a reaction depends on the concentrations of all the reactants.
D. The rate constant is independent of the concentrations of the reacting species.
E. The rate law can be determined from the stoichiometric equation.

15. The theoretical effect of the chemical nature of the reactants can be explained in terms of collision theory because it affects

I. the collision geometry involved in the reaction
II. the total number of collisions that occur
III. the fraction of collisions that are effective
IV. the required activation energy for a reaction

A. both I and IV
B. I, II and III are true
C. both II and III
D. both III and IV
E. II only

SCH4UY-A
AP CHEMISTRY II
Chemical Equilibrium

MULTIPLE CHOICE: (KNOWLEDGE) [15 marks]
Answer the following questions by recording the appropriate letter that corresponds to the most correct response on the Scantron Card provided.

1. When a chemical system is at equilibrium,
   A. the concentrations of the reactants are equal to the concentrations of the products.
   B. the concentrations of the reactants and products have reached constant values.
   C. the forward and reverse reactions have stopped.
   D. the reaction quotient, Q, has reached a maximum.
   E. the reaction quotient, Q, has reached a minimum.

2. A chemical reaction has an equilibrium constant of 2×10^6. If this reaction is at equilibrium, select the one correct conclusion that can be made about the reaction.
   A. The forward and back reactions have stopped.
   B. The limiting reactant has been used up.
   C. The forward and reverse rate constants are equal.
   D. The forward and reverse reaction rates are equal.
   E. None of these choices is correct.

3. Which of the following has an effect on the magnitude of the equilibrium constant?
   A. removing products as they are formed
   B. adding more of a reactant
   C. adding a catalyst
   D. increasing the pressure, in a gas-phase reaction
   E. change in temperature

4. In order to write the correct mass-action expression for a reaction one must
   A. know the kinetic rate law for the reaction.
   B. know the mechanism for the reaction.
   C. have a properly balanced chemical equation.
   D. have values for the concentrations of the reactants.
   E. know the limiting reactant.

5. The two equilibrium constants for the same reaction, K_c and K_p, will always equal one another when
   A. all of the reactants and products are gases.
   B. in the reaction equation, the number of moles of gaseous products equals the number of moles of gaseous reactants.
   C. in the reaction equation, the number of moles of gaseous products is greater than the number of moles of gaseous reactants.
   D. in the reaction equation, the number of moles of gaseous products is smaller than the number of moles of gaseous reactants.
   E. in the reaction equation, the total number of moles of reactants equals that of the products.

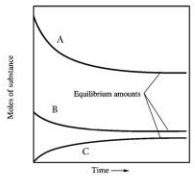
6. For the reaction $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ at 750°C, what is the relationship between K_c and K_p?
   A. $K_c = K_p$
   B. $K_c = K_p(RT)^{-1}$
   C. $K_c = K_p = 1.0$
   D. $K_c = K_p(RT)^{¾}$
   E. $K_c = K_p(RT)^{1}$

7. The reaction quotient for a gas phase reaction has a value of 2000. If the number of moles of reactants in the reaction equation is equal to that of the products, which of the following statements is definitely true?
   A. The reaction must proceed to the left to establish equilibrium.
   B. The reaction must proceed to the right to establish equilibrium.
   C. When the system is at equilibrium, the concentrations of the products will be much larger than the concentrations of the reactants.
   D. The concentrations of the products are generally larger than the concentrations of the reactants.
   E. None of these choices is correct.

8. When gaseous carbon monoxide and hydrogen are combined in a sealed vessel and heated they will eventually form an equilbrium mixture of reactants and products according to the balanced chemical equilibrium below.

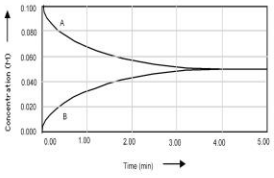
$$\mathbf{CO(g) + 3H_2(g) \rightleftharpoons CH_4(g) + H_2O(g)}$$

In one such reaction 3 moles of one reactant were combined with 1 mole of the other reactant in a fixed volume vessel and heated to 1200 K. Analysis of the reaction mixture at various times gave the results below. Which component of the reaction mixture is represented by curve B?



   A. carbon monoxide
   B. either methane or water
   C. hydrogen
   D. either hydrogen or carbon monoxide
   E. not enough information to decide

9. Shown below is a concentration vs. time plot for the reaction A ⇌B. For this reaction the value of the equilibrium constant is



   A. $K_C < 1.$
   B. $K_C = 0.$
   C. $K_C = 1.$
   D. $K_C > 1.$

10. What is the balanced equation for the following equilibrium expression?

$$K_P = \frac{(P_{SO_3})^6}{(P_{O_2})^3 (P_{SO_2})^6}$$

A. $6SO_2(g) + 3O_2(g) \rightleftharpoons 6SO_3(g)$
B. $6SO_3(g) \rightleftharpoons 6SO_2(g) + 3O_2(g)$
C. $6SO_3(aq) \rightleftharpoons 6SO_2(aq) + 3O_2(aq)$
D. $6SO_2(aq) + 3O_2(aq) \rightleftharpoons 6SO_3(aq)$
E. $SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$

11. Which of the following is/are true concerning equilibrium constants?

1. *When an equilibrium constant is very large, the equilibrium mixture contains more reactants than products.*
2. *When an equilibrium constant is very small, the equilibrium mixture contains more products than reactants.*
3. *When an equilibrium constant is neither large nor small, the equilibrium mixture contains approximately equal amounts of reactants and products.*

A. 1 only
B. 2 only
C. 3 only
D. 1 and 3
E. 1, 2, and 3

12. The reaction quotient for a system is 3.4×10^3. If the equilibrium constant for the system is 1.5×10^4, what will happen as the reaction mixture approaches equilibrium?

A. The equilibrium constant will increase until it equals the reaction quotient.
B. There will be a net gain in both product(s) and reactant(s).
C. There will be a net gain in product(s).
D. There will be a net gain in reactant(s).
E. The equilibrium constant will decrease until it equals the reaction quotient.

13. Consider the following equilibrium:

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g);\ \Delta H = -92\ kJ$$

The concentration of PCl_3 at equilibrium may be increased by

A. decreasing the temperature.
B. adding Cl_2 to the system.
C. adding PCl_5 to the system.
D. increasing the pressure.
E. adding a catalyst.

14. When cobalt chloride is added to pure water, the Co^{2+} ions hydrate. The hydrated form then reacts with the Cl^- ions to set up the equilibrium shown here:

$$\underset{\text{(pink)}}{Co(H_2O)_6^{2+}} + 4Cl^- \rightleftharpoons \underset{\text{(blue)}}{CoCl_4^{2-}} + 6H_2O$$

Which statement accurately describes the change that the system will undergo if water is added?

A. The color will become more blue.
B. The equilibrium will shift to the right.
C. More water will be produced.
D. More chloride ions will be produced.
E. There will be less of the hydrated cobalt ion at the new equilibrium position.

15. Consider the following system at equilibrium: $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$; $\Delta H° = -92.94$ kJ

Which of the following changes will shift the equilibrium to the ***right***?

I. increasing the temperature
II. decreasing the temperature
III. increasing the volume
IV. decreasing the volume
V. removing some NH_3
VI. adding some NH_3
VII. removing some N_2
VIII. adding some N_2

A) II, III, V, VIII
B) I, III, V, VII
C) I, VI, VIII
D) I, IV, VI, VII
E) II, IV, V, VIII

APPENDIX D

PARTIAL CREDIT MULTIPLE CHOICE

INSTRUCTION COVER SHEET

ST. BROTHER ANDRE CATHOLIC HIGH SCHOOL
Science Department

SCH4UY-A
AP CHEMISTRY II

A.J. Dinglasan, OCT

UNIT TEST
Electrochemistry

Name: _____ **KNOWLEDGE:** _____ **Level** _____

40

Date: _____

Instructions:

1. **PARTIAL CREDIT MULTIPLE CHOICE:**
   Answer these questions by leaving out the correct answer and completely crossing out the incorrect choices.

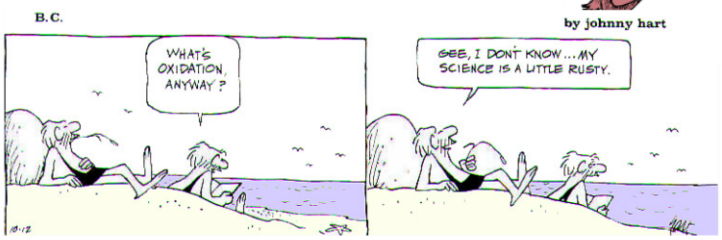
   Each incorrect choice that is crossed out is given a mark of **¼** with a **full mark given to all four incorrect responses stricken out and the correct choice left intact**.

   Should the correct choice be stricken out as incorrect, **no marks** will be awarded.

   Should three or less of the incorrect choices are stricken out, **only that fraction of the mark** will be awarded.

2. All responses are to be recorded in the preceding sheets.

3. Initial the Mole's sheet (at the end of this statement) to confirm that you understand this particular method of multiple choice testing.



APPENDIX E

MULTIPLE-CHOICE TEST PROFICIENCY AND CONFIDENCE LEVEL SURVEY

Multiple Choice Test Proficiency and Confidence Level Survey

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or standing in any way.

How satisfied are you, in general, with your test performance in this course?
(1 = not satisfied, 4= very satisfied)

1	2	3	4

How satisfied are you, specifically, with your performance on your multiple-choice question performance in this course?

1	2	3	4

Do you find that the multiple-choice questions in this course are challenging and difficult?
(1=not at all, 4=yes indeed)

1	2	3	4

Do you make an extra effort to study for multiple-choice components of tests?
(1=not at all, 4=yes indeed)

1	2	3	4

Do you find that multiple-choice test questions are generally harder than short-answer questions?
(1=never, 4=always)

1	2	3	4

Do you feel you have a strategy in place that helps you do better on multiple-choice tests?
(1=not at all, 4= yes indeed)

1	2	3	4

How would you evaluate your historical performance (how you have done on multiple-choice in previous science courses taken) on multiple-choice tests?
(1=very poor, 4=very good)

1	2	3	4

How would you evaluate the most recent and consistent outcome (marks) of your multiple-choice tests?
(1=very poor, 4=very good)

1	2	3	4

How would you evaluate your learning outcome (how much you feel you learned) from your multiple-choice tests?
(1=very poor, 4=very good)

1	2	3	4

Upon completion of each test, are you confident that you will do well on the multiple-choice component of the test?
(1=not confident at all, 4=extremely confident)

1	2	3	4

Upon receipt of the results of each test, do you make an effort to ask for feedback about the multiple-choice component of your test?
(1=never, 4=always)

1	2	3	4

On multiple-choice tests, do you guess at the answers?
(1=never, 4=always)

1	2	3	4

On multiple-choice tests, do you seriously consider "none of the above" and "all of the above" as viable responses?
(1=never, 4=always)

1	2	3	4

On multiple-choice tests, how often do you change your original answer to the questions?
(1=never, 4=always)

1	2	3	4

On multiple-choice tests, do you feel you have enough time to answer all questions with a high degree of confidence?
(1=never, 4=always)

1	2	3	4

On multiple-choice tests, do you feel most of the questions are "tricky" by nature?
(1=never, 4=always)

1	2	3	4

On multiple-choice tests, do you feel you can do much better if most of the testing is done in this format?
(1=not at all, 4=yes indeed)

1	2	3	4

"Some multiple choice questions and tests are inherently more difficult and challenging than others."
(1=strongly disagree, 4=strongly agree)

1	2	3	4

"Multiple choice questions dealing that are mostly factual and conceptual in nature are easier than questions requiring numerical calculations"
(1=strongly disagree, 4=strongly agree)

1	2	3	4

"I have a high level of confidence answering multiple-choice questions when I feel I am adequately prepared for the test"
(1=strongly disagree, 4=strongly agree)

1	2	3	4

"Given more time just for the multiple-choice, I can get a higher score on the test"
(1=strongly disagree, 4=strongly agree)

1	2	3	4

"Doing well on multiple-choice tests is all about mastery of content. If I know the content, I can do better."
(1=strongly disagree, 4=strongly agree)

1	2	3	4

"Doing well on multiple-choice tests is all a matter of strategy. If I know how to do well on it, I can do better."
(1=strongly disagree, 4=strongly agree)

1	2	3	4

APPENDIX F

OVERALL CHANGE IN CONFIDENCE LEVEL SURVEY

Overall change in confidence level questionnaire

Upon completion of the multiple choice component of the final exam, how confident were you that you did well on that part of the exam?
(1=not confident at all, 4=extremely confident)

1	2	3	4

Upon reviewing your results for the multiple choice component of the final exam, how confident are you of your current, overall multiple choice test taking skills?
(1=not confident at all, 4=extremely confident)

1	2	3	4

Assess the overall change in your confidence level over the two-semester period of this study as a result of exposure to various test-taking strategies (*such as increased frequency of tests, test-taking strategies lecture, using partial credit/other forms of multiple choice etc.*,)

1-	my confidence level deteriorated to a great extent
2-	my confidence level deteriorated more times than it improved
3-	my confidence level improved more times than it deteriorated
4-	my confidence level improved to a great extent

Gauge your level of enthusiasm each time a new strategy was unveiled or continued

1-	I was pessimistic to a great extent (*it definitely won't help boost my confidence level*)
2-	I was pessimistic to a minimal extent (*it might not help me boost my confidence level but I'm willing to give it a try*)
3-	I was optimistic to a minimal extent (*it might help me boost my confidence level so I'm willing to give it a try*)
4-	I was optimistic to a great extent (*it definitely will help boost my confidence level for future multiple choice evaluations*)

"Given more exposure to test-taking strategies and mastery of the content, I feel confident that I will do just as well or better in future university-level multiple choice examinations."
(1=strongly disagree, 4=strongly agree)

1	2	3	4

APPENDIX G

TEACHER REFLECTION QUESTIONS

TEACHER REFLECTION ON USING STRATEGIES FOR CONFIDENCE ON MULTIPLE-CHOICE TESTING

Weekly (or per activity) Summary of reflection as it pertained to the strategies implemented:

1. What impact did having this particular type of strategy have on the students? Positive behaviors observed in students during the process…

2. How did the frequency of multiple-choice assessments affect the students?

3. How did the focus on multiple-choice evaluation impact my role as the teacher?

4. What criteria did I articulate that will show where change, if any, is happening?

5. How could this have been a benefit and detriment to my teaching?

6. Did this (focus) benefit student learning? How so? If not, why not?

7. Were there any surprising results/observations today as students worked on multiple choice tests (or got their evaluations back)?

8. As a result of today, would I change anything about this treatment?

Overall Teacher Reflection:

1. How relevant was what I was trying to discover or implement, to the lives of my students? To my own life as a professional? Did I implement this strategy in a way that helped them to understand more of the chemistry and did it help them to learn the concepts that they needed to gain that insight?

2. What are the best things that happened in implementing these strategies? Why were those things "the best?" What are some things that I should revisit or change before I make any attempts at these kinds of strategies again? How could I make those changes?

3. How do I feel about teaching with a focus on getting students to be more confident in multiple choice? Is this something that I feel like I am fully vested in, or is it too forced? How can I make sure it doesn't end up being forced?

4. What were some things that my students have said that made me take pause? Why did they make me react the way that they did?

5. What evidence do I have that my students' confidence levels are changing as a result of this intervention? If I do not have evidence, what can I make sure I am doing to have evidence?

6. Would this particular endeavor be one that I would feel comfortable sharing with my department head, principal or parent of one of my students? Would any of the stakeholders of my project be able to recognize the learning that is taking place?

APPENDIX H

STUDENT POST-TREATMENT

INTERVIEW QUESTIONS

POST-TREATMENT INTERVIEW QUESTIONS

1. What were your honest impressions about what we were trying to do regarding multiple-choice? If it did nothing to change your confidence level, why do you think that was? If it did change your confidence level, what do you think made that happen?

2. What did you feel about:
   a) the increased frequency of multiple-choice?
   b) having to learn through a lecture how to do well on multiple-choice?
   c) using new types of multiple-choice like partial credit multiple-choice?

3. Address the issue of time. Would you have been able to do better on multiple-choice if you actually had more time devoted to it? (more time to do the test in the literal sense as well as more time to actually learn the strategy) Had we started you off in grade 9 with this as opposed to grade 12, do you think it would have made a difference?

4. Take this opportunity to comment on anything else that you would like to address regarding multiple-choice and your confidence level.

APPENDIX I

IRB EXEMPTION

2015

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
FWA 00000165

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MEMORANDUM

TO: Allan Dinglasan and John Graves

FROM: Mark Quinn Mark Quinn CTJ

DATE: March 10, 2015

RE: *"The Effects of Using Strategic Approaches to Multiple Choice Questions on the Understanding and Academic Performance of Advanced Placement Science Students" [AD031015-EX]*

The above research, described in your submission of **March 10, 2015**, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

_X_ (b) (1) Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

_X_ (b) (2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.

____ (b) (3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.

____ (b) (4) Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.

____ (b) (5) Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.

_____ (b) (6) Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.