This workshop will describe a general approach that students should consider when taking math based problem-solving courses such as Calculus, Chemistry, statistics, physics, or engineering. Before we begin, I would like to acknowledge that the University of Manitoba campuses are located on original lands of Anishinaabeg, Cree, Oji-Cree, Dakota and Dene peoples. And on the homeland of the Metis nation. We respect the treaties that were made on these territories. We acknowledge the harms and mistakes of the past, and we dedicate ourselves to move forward in partnership with indigenous communities in a spirit of reconciliation and collaboration. Let's take a moment to complete a thought experiment. Please think of a personal skill outside of school that you have developed throughout your life. Some examples could include hobbies or extra curricular activities, such as playing an instrument, dancing, playing sports, or performing a task at a high level. Now if I asked you to explain how you develop that particular talent, how would you respond? When asked this question, most people will say that they develop their talents through many hours of repetitive practice. Learning how to solve problems and perform at high level for math, chemistry, or physics is very similar. It involves cumulative, repetitive, and regularly scheduled practice, much like learning how to play an instrument or perform a sport at a high level. Athletes and musicians do not become successful by cramming for sporting events or performances. They practice a little bit every day in order to solidify their talents and skills. This is important because some students do not know how to practice for problem-solving courses. One common mistake that people make is to spend too much time reviewing their textbooks, notes or previously solved problems without doing any practice themselves. This can create what might be referred to as an illusion of competence where students falsely believe that they have mastered a concept. It is easy to assume that we understand a concept when the answer is directly in front of us. True mastery, however, needs to be tested through practice and application. Another problem is that some students might jump right in and try to solve problems without having an adequate understanding of the basic concepts that are required to complete those problems successfully. It is therefore important to spend some time reviewing concepts before trying to tackle difficult problems. Students should review their course outlines, textbooks and notes with a focus on developing a basic understanding of foundational concepts. Learning the required procedural knowledge or their specific steps that need to be followed in order to solve a problem. Making informed decisions about which practice problems will provide the best preparation. Start by reviewing previously solved problems, but then identify a variety of problems for further practice. Let's have a look at a really simple example. If you tried to calculate practice questions related to the five-number summary used in statistics without knowing what it refers to, you wouldn't get very far and you would be forced to return to your notes or textbook. Therefore, it does make sense to spend some time reviewing the concepts involved before doing practice questions right away. For starters, what exactly are the features of a five-number summary? The minimum, the first quartile, the median, the third quartile, and the maximum. You should know what these are and have a general sense of what these things mean. Next, what are the steps required to calculate a five-number summary? Your data should be in order from smallest to largest. From there you can identify the minimum and maximum. Your median can be calculated with the formula n plus one divided by two. From there you can identify the quartile to the left of the median and the quartile to the right of the median, which will give you the required values for a five-number summary. Finally, you should review your syllabus notes or the textbook to find some problems scenarios that allow you to practice calculating a five-number summary. Let's have a look at another example. If you tried to draw Lewis structures without knowing what you were doing, you would probably get frustrated. It would be important to know some of the conventions before starting. For example, can you identify the number of valence electrons? How do you represent single bonds? Double bonds? Triple bonds or non-bonding electrons? When drawing Lewis structures. Your textbook might even outline some important steps to keep in mind. And reviewing the steps would be useful before trying to solve problems related to Lewis structures. Once you have reviewed the required steps and feel

comfortable, draw some diagrams for various compounds while slowly increasing the level of difficulty. Once again, review your syllabus notes or the textbook to find some problems, scenarios that allow you to practice in an appropriate way. As we have already discussed, when it comes to finding practice problems, a good place to start is your syllabus or course outline. Often instructors will provide recommendations regarding practice questions within the course outline itself. If they don't, consider approaching your professor or TA during office hours to get advice on how to practice for the course. In this course outline for chemistry, the instructor makes very specific suggestions about which practice questions to complete from the textbook. In general, most textbooks will contain a variety of questions and problems to solve at the end of each chapter, try doing some of the questions that specifically relate to the concepts that have been taught in your class. The bookstore may contain older textbooks or other materials that have practice problems related to your course. Ask at the bookstore if they can make recommendations regarding additional resources for practice. Archived exams are sometimes provided by the instructor or they can be accessed through some of the help centers on campus. Ask around to see if there are any old exams that your instructor is allowing students to look at for review purposes. Ask the instructor, ask your TA, asked the tutors at the Help Center or ask some of your classmates about the resources that they are using. If you're having trouble finding practice problems, your notes may contain some sample problems that were solved in class or used for iClicker practice. Try resolving some of those problems without looking at the answers. See if your solution matches how the instructor solved in class. Also, if you're having trouble finding problems, you can resolve some of your homework problems for added practice. But ideally, you should try to find new problems that you have never seen before. Here are some general suggestions on how to go about the problem-solving process. Problem-solving courses tend to be cumulative. For this reason, it is important to do some practice problems every day or every couple of days. Keep up with the course material by doing problems related to the content being covered in class. A good time to practice is right after class while the information is still fresh. Do your best to solve the problems from beginning to end without using the answer key or solutions manual. Occasionally, it's helpful to do a series of problems while giving yourself a time limit in order to simulate the exam environment. Ensure that you understand the process or method that has been explained in class by doing a variety of problems. Avoid trying to memorize as many practice problems as possible. Focus instead on the application of methods to unique circumstances. Identify the gaps in your understanding by making a list of problems that had been previously answered incorrectly. After completing a practice test, this particular student highlights all of the questions that are answered incorrectly. She then writes down the names of chapters and concepts related to the especially challenging questions. After reviewing the content, she makes a point of redoing any highlighted problems at a later date in order to ensure mastery of troublesome concepts. Going into the exam, she also makes a series of personal notes related to past mistakes and reminders regarding tricks for solving difficult problems. Interleaving refers to the practice of alternating your exposures to different types of problems. That practice with one concept is periodically followed by practice with a completely different concept. There is a growing body of evidence to suggest that working in this way will help students to produce better test scores because it improves one's ability to discriminate between similar principles. Practicing in this way might be more time-consuming and it could produce more errors, but in the end, it has been shown to increase competency because it more accurately simulates an actual test. To illustrate this example, one study used batting practice for baseball players. If batters want to learn how to hit different types of pitches, a fastball, a curveball, and a change-up. It worked better for them to practice these pitches in a random order, in order to simulate an actual game experience. If they exclusively practice hitting fast balls in one setting, they will know what type of pitches coming and may become good at hitting the fastball. But this will lead to an illusion of competence that makes them less prepared for a real game. The same principles has been demonstrated

through studies involving math acquisition. For example, a large number of algebra problems involve the instruction solve for x, but there are multiple strategies that can be employed. Students need to be able to distinguish between situations that require the quadratic formula and other situations that may necessitate the use of factoring. Becoming proficient at solving problems means knowing how to solve problems. But interleaving help students to identify which strategies to use in specific situations. Typically, students will practice a concept by doing a series of textbook questions related to a chapter that they have just completed. For example, one might be learning how to use different types of equations for a Math course such as linear equations, polynomial equations, cubic equations, and quadratic equations. Using a blocked practice would involve doing a series of problems related to the first type, followed by a series related to the second type, and so on and so forth, much in the same way that the information might be presented in the textbook or in class. This would certainly be a good way to start when first learning concepts. However, over time, it would be advantageous to start interleaving problems in a more random fashion, as illustrated in this example. Instead of doing a series of problems related to practicing linear equations exclusively, consider splitting things so that you can do one of each type of problem while ensuring that the other linear equations that you did not end up getting to practice are distributed into later study sessions. In the long term, this will make it easier for you to distinguish between the various scenarios. While doing practice problems after a while, you should also begin to notice some patterns or situations regarding the more difficult types of problems that you may have encountered. It is helpful at this point to begin anticipating some of these so-called special cases so that you're prepared for them on tests or exams. Create a list of reminders for yourself as the exam approaches so that you can be prepared for some of the trickier types of problems that you're likely to see on a test. Some common situations to be prepared for might include questions where the information is hidden or at least not provided explicitly. For example, you may be expected to use some formulas or constants that may not have been identified. Questions where you are required to convert units in order to obtain the correct answer. Situations where reversing the sequence or order of steps may be necessary. For example, using tables to calculate z-scores in a statistics course. Problems where there is extraneous or distracting information. Lastly, problems where preliminary steps are required before proceeding to the final calculation. In her book, a Mind for Numbers, how to excel at math and science, Barbara Oakley outlines. Two different types of neural states. In the focused mode, your brain is highly attentive and engaged in learning the details required for analyzing a math problem, which is crucial for learning. The diffuse mode is more of a resting state when your brain is working in the background. The diffuse mode allows us to gain new insights on problems and to see the big picture. According to Oakley, both modes are important for studying math and science. And students who want to be successful need to find ways to switch back and forth between these modes. Sometimes we get stuck on a problem because we're too focused on particular solutions and finite details. In those cases, taking a mental break can help us to get unstuck and allow us to find other solutions through new and creative insights. Some suggestions at these times might be to go for a walk, play an instrument, play a sport, or to have a nap. Returning to the problem a little later with a fresh set of eyes might provide some understanding on how to move forward. This is one of the reasons why short study sessions are usually considered more effective. The human brain cannot focus for long periods of time. Taking breaks increases efficiency and provides time for memories to consolidate. If you find yourself repeatedly getting stuck on problems, you may need to get outside help in order to move forward. Whenever you do approach a professor TA help center or a tutor for assistance, make sure to formulate specific questions in advance related to practice problems. It is easier for someone to provide you with timely and accurate assistance if they know more specifically what you are confused about. Remember, you are not alone and help is available. The academic Learning Center's mission is to support U of M students in the development of their skills in learning, writing, studying and researching.

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