CHAPTER 3: HOW NON-SCIENTISTS USE THE SCIENTIFIC METHOD

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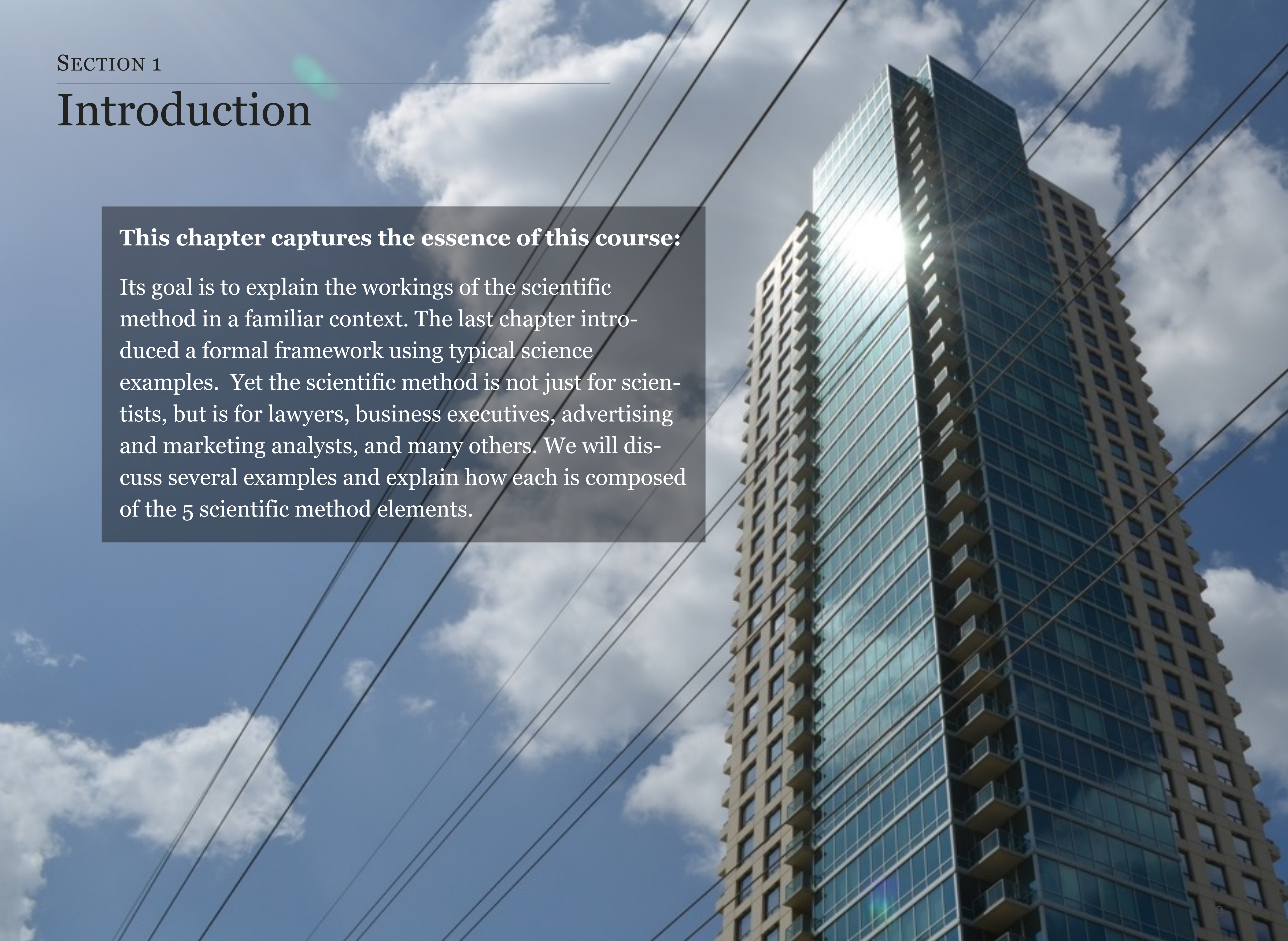
The scientific method is used unconsciously by many people on a daily basis, for tasks such as cooking and budgeting. The same elements present in traditional scientific inquiry are present in these everyday examples. Understanding how to apply the scientific method to these seemingly non-scientific problems can be valuable in furthering one's career and in making health-related decisions.

SECTION 1

Introduction



This chapter captures the essence of this course:

Its goal is to explain the workings of the scientific method in a familiar context. The last chapter introduced a formal framework using typical science examples. Yet the scientific method is not just for scientists, but is for lawyers, business executives, advertising and marketing analysts, and many others. We will discuss several examples and explain how each is composed of the 5 scientific method elements.

Section 2

Trial and error

In the simplest terms, common uses of the scientific method involve trial and error. Consider automobile repair. Every weekend handyman, and every high school student with a passing interest in autos knows about the method of trial and error. Your car is starting to run poorly, and you take matters into your own hands in an attempt to fix it. The first step is to guess the nature of the problem (your model). Acting on your hunch, you proceed to exchange a part, adjust a setting, or replace a fluid, and then see if the car runs better. If your initial guess is incorrect and the car is not improved, you revise your guess, make another adjustment, and once again test the car. With patience and enough guesses, this process will often result in a operable car. However, depending on one's expertise, quite a few trials and errors may be required before achieving anything remotely resembling success.

The methods scientists use to evaluate and improve models are very similar to the method of trial and error, and are the subject of this chapter. You may be reluctant to think that the bungling process of trial and error is tantamount to the scientific method, if only because science is so often shrouded in sophistication and jargon. Yet there is no fundamental difference. It might seem that scientists start with a more detailed understanding of their problem than the weekend car mechanic, but in fact most scientific inquiries have humble and ignorant beginnings. Progress can occur just as assuredly via trial and error as in traditional science, and the scientist isn't guaranteed of success any more than is the handyman: witness the failure to develop a vaccine for AIDS. One of the themes of this book/course is that the scientific method is fundamentally the same as these simple exercises that most people perform many times in their lives.

Cooking From A Recipe

Another activity familiar to all of us is cooking. Although the microwave oven has reduced our dependency on preparing food for ourselves, many of us still face the need to perform rudimentary culinary skills. The preparation of most dishes begins with a recipe - a list of ingredients and instructions for mixing and cooking them. However, rare is the chef, whether budding or accomplished, that follows the recipe to the letter and does not taste and modify the dish during the cooking process. Modifications are attempted until the preparation meets the cook's approval, whence the food is served. Any significant alterations to the recipe may be adopted as permanent modifications, to become part of the recipe itself in the future.

Although it is likely that all of us can identify with this example, it may be less obvious how this example bears on our scientific method template. Returning to our template of 5 elements, we may dissect this example as follows:

SCIENTIFIC METHOD TEMPLATE	
GOAL	To prepare a food dish
MODEL	The Recipe
DATA	Tastings during preparation or when served
EVALUATION	Decisions on how it tastes
REVISION	Changes to the recipe

Let's consider each of these elements again. In the cooking example, the goal is to prepare a specific kind or quality of food dish. The model is simply the recipe you use. It is a model because it is an abstraction of the actual process used in preparing the food; it is essential, because you could not plan to prepare a specific kind of food dish without some guidance based on previous preparations. Here, the data are simply your tastings of the dish before or after it's finished. Evaluation is performed when you compare the actual taste (the data) to your idea of how the food should taste. If it tastes better (or worse) than you expect, you then try to figure out how to revise the recipe accordingly. These revisions may be short-term (how you modify the recipe on this particular occasion) or permanent changes to the written recipe.

The recipe example was chosen because it is commonplace. Yet it is extremely apt. The procedures that scientists use may be slightly more stereotyped and formal than those of the ubiquitous household chef, but the way you work with a recipe, garment pattern, and any of a number of other daily experiences are not fundamentally different than the way a career scientist operates. Lab chemistry and molecular biology is filled with just as many miserable failures as are our nations kitchens, and in both cases the mistakes are used to foster improvements for the future.

SECTION 4

Writing a News Story

A newspaper article about a murder starts as scribbled notes in the reporters notebook (first version of the model), then progresses to a rough draft (second version of the model), which is read by the editor and rewritten by the reporter to become the published article (third version of the model).

Using our template:

SCIENTIFIC METHOD TEMPLATE	
GOAL	Improve sales
MODEL	Current and modified ads
DATA	Responses to each ad in trials
EVALUATION	Deciding which ad most closely achieves your goal in numbers of responses
REVISION	Adopting an ad for general distribution

Progress occurs as new drafts are written, in response to the reactions of the author and others (the data), and according to the author's intended responses (evaluation).

SECTION 5

Designing Advertisements

Advertising agencies use the scientific method explicitly to improve the effectiveness of the ads they compose. Ads are models that manipulate consumer behavior, and they are designed with a great deal of scientific input. Each ad has many dimensions that need be considered in detail, such as what headline to use, what size type to use, whether to use pictures, and how large the ad should be. All these questions can be answered using the principles of model evaluation and improvement.

The most useful evaluation of ads comes from mail order returns. To determine whether an ad with a picture sells more gizmos than one of the same size with only text, one simply has to gather some data: place one ad in half the copies of the February issue of a magazine, and the alternative ad in the remaining copies. Put different 800 phone numbers or P.O. Box numbers in the two ads, so you will know which ad generates more responses. The evaluation in this example comes when you compare the responses generated by the two ads, and the progress (model improvement) comes when future ads are changed to reflect the ad that generated the most responses. Again, in template form:

SCIENTIFIC METHOD TEMPLATE	
GOALS	Improve sales
MODEL	Current and modified ads
DATA	Responses to each ad in trials
EVALUATION	Deciding which ad most closely achieves your goal in numbers of responses
REVISION	Adopting an ad for general distribution

SECTION 6

Corporate Finances

Tangible examples of the scientific method also abound in business. Consider a corporation's financial planning. The most basic goal of the corporation is to survive economically. This goal requires a complicated, formal business plan, to control and monitor the company's finances. Data accumulate during the year in the form of actual revenues and expenditures, and these data are compared to the model (the model is evaluated) to determine whether further changes (revisions) are warranted:

SCIENTIFIC METHOD TEMPLATE	
GOAL	Increase profits
MODEL	A plan showing anticipated revenues and expenses
DATA	Actual revenues and expenses
EVALUATION	Comparison of plan to data
REVISION	Modifications of the plan in response to the evaluation

Demonstrations

In-class examples: (1) Lamp switch; (2) Wheel of Fortune

The scientific method template can be applied to any trial-and-error problem. The demonstrations used in class are but two of countless examples that can be offered. (You must attend this lecture to obtain the information.)

SECTION 8

Is THIS Science?

A shortcut to decide if something is science:

Is the use of evidence paramount?
Do the rules keep improving?

The template we have given has 5 components. You can get a good sense of whether a system obeys scientific methodology from two criteria. First and foremost is a strict and ruthless adherence to the evidence. If evidence is not used, is used selectively and sparsely or is downplayed, you can be sure that it's not strict science. Second is turnover of the accepted models – nearly everything in science undergoes change because new evidence and new ideas are continually introduced. You can think of this criterion as ongoing refinements. The changes may be few and slow of course. In many of our non-traditional examples above, the goal has a defined endpoint, so the turnover ends when the goal is met. (For example, writing a news story ends when the story is published.) So the 'continual turnover' criterion applies to problems large in scope but not necessarily small ones.

If an example fails on evidence or turnover, it's not good science. However, an example that passes this preliminary test may still fail on other criteria. Evidence and turnover merely provide a convenient first pass.

Use of the 5 Elements by Various Institutions

It may be useful to understand how science works by considering institutions where it is used properly versus used improperly or not at all.

Criminal Trials:

These come close to fulfilling all 5 elements. The jury has the goal of discovering whether the defendant is guilty or not guilty. This is the goal of deciding between the model advocated by the defense, and the model advocated by the prosecution. Data are presented by the defense and prosecution during the trial, and the jury evaluates the two models based on that evidence. The verdict (guilty or not guilty) is the jury's evaluation of which model best fits the data, with the proviso that in order to return a guilty verdict, the jury must find that the data presented supports this model "beyond a reasonable doubt."

Criminal trials are weak on the strict use of evidence and on revision. Although trials routinely present evidence, critical evidence is sometimes excluded from the jury by the court; proper science would let the jury decides its relevance. And the jury is free to ignore evidence in reaching its decision, which apparently happens commonly (lawyers often appeal to a jury's emotions, an indication that evidence is not paramount). Revision is also weak, though not absent. The appeals process provides for limited revision. However, the types of model revision permitted on appeal are somewhat restricted. For example, after a defendant has been found guilty, it is very difficult to obtain a new trial and introduce into court factual evidence that exonerates him/her. Conversely, the prohibition against double jeopardy prevents the prosecution from reopening a case after a "not guilty" verdict has been returned, even in light of new and compelling data suggesting that the defendant was actually guilty. A strict scientific use of revision would mean that the verdict can be revisited (and potentially reversed) at any time based on new data or new analysis.

Astrology:

Astrologers (psychics) claim to have ways of forecasting the future, if only in vague terms. There are books that specify how predictions are to be made (the models). A rigorous adherence to the scientific method would involve comparing predictions with outcomes, evaluating whether the predictions did better than random, and developing new predictors based on successes and failures of older predictors. Needless to say, those types of tests are not part of astrology, and the very suggestion of asking how often astrology predictions are held up is anathema to many astrologers. So the example of astrology contains goals and models, but the other elements are absent.

Government Agencies:

Nearly all government agencies are established with some specific (often lofty) goal. They are also provided with a set of rules (a model) of how that goal should be pursued. But there is rarely a formal procedure for evaluating whether the goal is achieved, and there is almost never a procedure for implementing a new model when the old one is deemed inadequate. Elected officials can and so sometimes bring about change, and the political climate now is more demanding of government accountability than in the past, but agencies generally are not established with the kind of built-in self-improvement system that underlies the scientific method. The federal and state constitutions DO specify how to implement a new model - via amendments.

Yet some agencies that are charged with making decisions do adhere to the scientific method rigorously. The FDA (Food and Drug Admin) is a good example. That agency is charged with approving new drugs and monitoring for problems with prior drugs. To obtain approval for a drug, a company must submit results of extensive (and often expensive) trials that are well documented and meet all the criteria of good science. The FDA is actually rigorous in its evaluation, although the submitting company does not have to provide all relevant data, and the FDA may thus receive biased information. The fact that the FDA continues to monitor for complications of approved drugs (some of which have been recalled) indicates Revision.

Religion:

Religion is not science, nor does it pretend to be. Most religions are based on specific doctrines and codes of conduct that followers agree to accept. There is no attempt to "improve" religion by changing the mores every few years and assessing the impact. (An exception applies to the Hawaiian ruler Kamehameha II, who in 1819, abolished the nation's traditional religion, apparently partly in response to the changing economic and cultural conditions in Hawaii brought about by trade with Europeans and the influx of missionaries.)

An example in which the scientific method cannot be used:

Consider the difference between a gambler playing a card game versus a slot machine. Use of the slot machine is strictly random, a fully automated process of pulling a lever or pushing a button, it does not allow revision in how the game is played. That is, there is no alternative strategy possible in how the game is played (except in not playing the game). In contrast, the method one uses to plays cards does admit the scientific method because there is a lot of strategy that can be adopted and altered by the player.

SECTION 10

Science is not the end-all, be-all in making decisions

This class will focus on how to apply and interpret the scientific method as a way of making rational decisions. It should not be construed that a strict adherence to scientific principles should be the sole criterion in reaching a decision. There are many factors that are relevant to our well being. An idealized view of the role of the scientific method in decisions of a societal level is:

issues	®	evidence & scientific conclusions	®	social, political, legal, and ethical consequences of alternative decisions	®	policy

Thus, science is (and should be) used to inform decisions, but there is no intent that it be the sole criterion. For example, ethical considerations may override the science, as has been the case with stem cell research in the U.S.

History abounds with examples in which science was ignored in reaching policy, and the policy was not made in the best interest of the people. A spectacular one was the Soviet suppression of genetics in the 1940s into the 1960s, leading to major agricultural failures. Genetics was at odds with the communist ideology that everyone was equal (recall the book Animal Farm), and T. D. Lysenko was given the authority to suppress Soviet research on genetics, which included imprisonment and eventual death of several prominent geneticists. (There is a UT connection here, in that Hermann Muller, who first showed that radiation caused heritable, genetic damage while he was at UT, moved from UT to the Soviet Union to show his support for communism. The reality of the Soviet regime led him to escape and ultimately return to the U.S., where he resided when he won a Nobel Prize for his earlier UT work.)

In general, scientific considerations may be overruled (or even ignored) due to a variety of factors:

- *political ideology*
- *financial interests*
- *religion*
- *legal precedents*
- *various alternatives: superstition, instinct, hunches*

Even when science is considered in making decisions, these factors can have a larger influence than they should.

The fact that science should not be used as the sole criterion in setting a policy or reaching a decision is fundamentally NOT the same as relying on poor science in reaching a decision. Poor science can give you the wrong answer (e.g., a dangerous drug appears to be safe). We need quality science to decide how the science should be used.