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Trivium & Quadrivium: A Systematic Exercise for Setting Structural Elements in Scientific Reports

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Abstract: Experience in thesis and peer reviewing revealed that most authors have much difficulty in presenting the structural supports of their study. This becomes evident in both their oral and written scientific reports in which little congruency or lack of it is frequently observed between title of the study, general objective (aim), and the hypothesis. Likewise, confusion is usually present when distinguishing purpose from objective when presenting the research problem. In order to aid in approaching the mentioned difficulties an exercise termed Trivium is proposed and explained. This term that designated the main subjects in scholar formation during medieval times, is used to designate the effective coupling of the above three structural elements (title, objective, hypothesis) that, properly used, confer epistemological basis to their scientific reports. Likewise, in order to reinforce this exercise a Quadrivium is recommended in which a fourth structural element is added, i.e., a premise, as the theoretical basis that precisely indicates the purpose of the study and provides immediate support to the hypothesis. Examples to illustrate these exercises are provided. Abiding by this logic may significantly aid science students and some open-minded researchers in adequately constructing their scientific reports, while avoiding frustrating experiences due to uncomfortable observations by peers on their manuscripts.

Keywords: Hypothesis, Objective, Premise, Scientific Method, Scientific Report, Scientific Research

1. Introduction

Nowadays, global society shows astonishing similarities with that of medieval times in many aspects. However, not trying to get into extensive debates on this subject, let us say that as in the latter, religious fanatism is widely extended and promoted, mainly in sport events, where athletes are unaware of their religious fanatical gestures. That is the least of the problems. On the other hand, although medieval or scholastic philosophy was theological and extremely dogmatic and repressive, it eventually gave way to actual philosophy, and later to scientific philosophy. Another similarity would be that most people take for granted technological progress without distinguishing technology from science and even less its philosophy, nor philosophy in general.

Notwithstanding, also laudable was the establishment of universities where teaching included the much earlier created Trivium that included three subjects: Grammar, Rethoric, and Logic; and the Quadrivium: Arithmetic, Geometry, Astronomy, and Music [1, 8]. These constituted the main stem of scholar training for the learned person. The practiced form of teaching persisted for centuries during the medieval long period and is deemed scholastic (authoritarian) inasmuch it relied exclusively on the word of the learned teachers, while students took notes seldomly questioning anything [14]. Consequences are of historical transcendence, and much of this still happens. So, has some of this been extended to the current training of science students? Is there an *ad hoc* system, besides the traditional (modern) curricula (with abundant) subjects based on quality textbooks that ensures an adequate understanding of what scientific research and Scientific Method consist of? Too many science students do not have access to this, and although many are successful in joining the scientific community many others fail. In either case, during their school days or as members of an academy, the limited dose of philosophical training that most science students receive is reflected in several aspects of their performance, in spite of their brilliant handling of theory and methodological techniques. Consequently the philosophical basis for understanding the concept of Scientific Method are

lacking and, as in the case of the misuse of the term observation when referring to Scientific Observation [13] and difficulty in grasping the relevance of resorting to hypothesis construction [10] it may also bring about various unsuspected consequences later in their careers, see [15]. In the present case, this is reflected in a meager knowledge of what confers structure to a scientific report, which is comprised in the concept of Scientific Method, and that corresponds with the epistemological structure of the investigation carried out.

2. Addressing the Problem in Relation to the Trivium and the Quadrivium

Experiences in thesis and peer reviewing have revealed that most authors have excessive difficulty in presenting the structural supports of their study, which becomes evident in both their oral and written scientific reports. In these, little congruency or lack of it between the title of the study, the general objective, and hypothesis is frequently observed. Likewise, confusion is usually present when defining purpose and objective. Briefly, purpose refers to generating knowledge in a particular scientific field, whereas an objective indicates precisely what especific question we are trying to answer in our study. According to this, an exercise is recommended to ensure logical structure to any scientific thesis, a Trivium. The term is used here to designate the observed three structural elements (title, objective, hypothesis) that confer epistemological basis to a scientific report. Likewise, a further exhort on the obliged resorting to hypothesis is in hand, inasmuch in many cases pseudo-argumentation is seeked to avoid the effort for constructing one [10-12], which is caused by the lack of philosophical formation for understanding what the scientific method consist of, in spite of high class denials that became quite popular on the same context [5]. On the other hand, attempts for establishing formal references on what Scientific Method is and has been historically may prove incomprehensible [6] outside a well-taught philosophy of science course. With this being stated, in order to reinforce the logical procedure of the trivium a fourth structural element is added, a premise, in which the direct theoretical basis indicate with precision the purpose of the study (thus the term Quadrivium), while revealing the epistemological (theoretical-illative) nature of the exercise.

The first structural element in a scientific report is the title. Why? Because it is intended to present the problem for the research on which it is being informed or reported [4]. The problem is the catalizer of any scientific research, inasmuch it represents a new scientific idea [2], it derives from the critical and analytical study of the current theoretical basis available for a certain field or discipline of knowledge [9-11] that models how nature manifests itself. It is a question derived through the inferential nature of observing [13], and indicates that something is missing from the analyzed theory and we aim to discover it. It is dependent also on creativity and intuition, non-logical ways of thinking that mingle with the inductive and deductive (logical) inferential techniques that get going when studying a theory. This constitutes an individual/original way of thinking that distinguishes a given scientist [13]. Overlooking the above poses the risk of underestimating the true scientific contribution by omitting the actual addressed problem in the title, which frequently happens. However, other factors may and actually preclude said creativity from reaching the title in which it is advertised, e.g., aesthetical temptation from complex techniques or sophisticated writing (or cliches) that displace the main contribution. This has to be rescued. Moreover, accepted titles can be either thematic (indicative, topic) or informative (conclusive, descriptive). The former on the one hand may also be aesthetically attractive but otherwise uncompromising, and precludes relating with precision the other structural elements. The latter on the other hand compromises with either the aim or objective of the study (descriptive), or the outcome from testing the hypothesis, i.e., conclusive [4]. This should be always the recommended one, and although is actually difficult to achieve, it is an intellectual challenge that we are obliged ethically to undertake. Albeit, in reality most authors elect otherwise.

The second structural element is the objective (or aim). Why? Because an objective consists on answering the posed scientific question, i.e., solving the problem. Let us recall that an epistemological characteristic of science is its objectivity [3]. So referring to the objective within the title using the adequate syntax rescues the actual pretended contribution of the scientific paper or report. As a precaution, any objective should be rewritten changing syntax into the form of a question, which has to be concise in order to delimit a plausible, inferentially predicted answer according to the structural logic of the related theory.

Consecquently, the third element is the hypothesis. Why? Because it is the predicted answer to the scientific question, which we derive through abduction. It is an inferential technique of deductive nature that gathers creativity based on the way that theoretical basis are interpreted, on what can be logically expected to be a plausible answer but requiring corroboration or contrast with facts (data) or reality. So, there can not be a hypothesis if there is no question first [9]. Albeit, inferential leaps are very frequent, especially of common deductive nature, i.e., when jumping to conclusions, or abductive when launching hypothesis without examining the correspondent question it will answer, although it is there, and it haunts science students and established researches alike. It is a tendency to synthetic thinking, and it is problematic to scientific performance. A hypothesis, besides guiding scientific research, serves to weight the degree to which the theoretical basis are mastered. Hence, it can be an autocritical reference when having difficulty to construct one. On the other hand this can be just a lack of ability to write that can be properly salvaged resorting to this exercise.

In synthesis, the structural elements of a trivium gather logical and non-logical thinking and studying techniques that

constitute a reliable source for generating new epistemologically (sound) knowledge, methodology pending which is rigorously conditioned by a solid trivium.

The Quadrivium contemplates a fourth element which is recommended to be propperly identified, the premise which consists of an outlined position induced from the theoretical frame that compiles the necessary background, traditionally obtained from the works of other investigators, that can be deemed an induction principle [7]. That is, an illation process using conclusive results from other studies, that leads to establish a statement having axiomatic transcendence. It thus serves as a reliable platform to abduct hypothesis within a logically structured theoretical frame. Thus, the premise combined with the elements of the trivium through its logical support for abducting hypothesis forms the Quadrivium.

3. An Example on Trophic Marine Ecology

Conclusive (bold) Title: "Non-selective *in situ* feeding of benthic diatom species by pink abalone juveniles". It shows conclusion backing up the hypothesis.

Objective or aim: To determine whether or not diatom species are consumed selectively by pink abalone juveniles *in situ*.

Hypothesis: Pink abalone juveniles consume diatom species non-selectively *in situ*.

This prediction requires determining the available diatom taxa *in situ* and those present in the gut contents of the juveniles for comparing them.

Indicative (*typical*) *title*: "Feeding habits of pink abalone juveniles at Tortugas bay". In terms of Scientific Method this title has several flaws: 1) First, it refers to a locality even though biogeographical connotations are irrelevant, because it has to be mentioned in the methods section anyway. Second, it is aesthetically appealing, so the author will try to hang on to it. And third, and most important though, is that in this way an objective could address various questions but it does not indicate which or what type, e.g., behavioral, strategic, preferential or selective habits. That, is usually mentioned in the objective, albeit confusion occurs, and the research problem remains clouded. An inferential compromise is avoided and, consequently, a hypothesis (if any) will not be reflected in the title.

An adequate premise for the former, which could be used to correct the latter could be: Pink abalone young are recruited in the rocky environment where adults thrive feeding in a diversified way on benthic diatoms and macroalgae that proliferate on the rocky substrate, but preferentially on the latter. However, what is known on early juvenile feeding habits is restricted to laboratory conditions in which they are fed diatoms films that grow on culture trays after filtering the supplied seawater. The rearing success of the juveniles suggests that they are feeding on whatever diatoms are growing on the trays and thus that their feeding is non-selective, as is expected to be *in situ*.

This premise adequately fits the first case (Trivium: title, objective, hypothesis), and should serve to be a guide in the second case for choosing an objective that permits a suitable hypothesis, and thus to construct a title that reflects the actual contribution of the study.

Thus, the corresponding exercise for the quadrivium would look somewhat (abridged) as follows:

(Premise) The young of pink abalone inhabit the rocky environment where they feed on diatoms that they scrape off from the rock (epilithic forms), but mainly on macroalgae covering the rocky substrate, and whose thalli harbour also many epiphytic diatoms.

1) Objective: To determine whether epiphytic diatoms of macroalgae are preferentially consumed by pink abalone young *in situ* over diatoms living directly attached on the rocky substrate. i.e., are ingested epiphytic diatom species more diverse and numerous than the ingested epilithic forms?
2) Hypothesis: More species and abundance of epiphytic diatoms of macroalgae than epilithic forms will be found in the gut contents of pink abalone young collected *in situ*.
3) Title (conclusive): "Non-preferential ingestion of epiphytic and epilithic diatoms by pink abalone young". It shows conclusion rejecting the posed hypothesis.
4) While the indicative, uncompromising not recommended title could read: "The *in situ* trophic ecology of pink abalone from Asunción bay, Mexico". Same observed flaws stand out.
5) Source for example [16].

4. Conclusion

It has to be kept in mind that working strictly on the four elements during an investigation and in the elaboration of the respective report are part of the Scientific Method. And so is submitting said report to rigorous critic by peers before and during editorial process. This constitutes a quality filter that assesses scientificity in the report, thus having a saying on the reliability and plausibility of the generated knowledge. Whether many researchers are conscious or not, what is being observed is the epistemological basis of any given study which corresponds with the scientific logic characterizing these four elements and their coupling. Thus, abiding by the logic underlying the trivium and quadrivium exercise may significantly aid science students and some open-minded researchers in adequately constructing their scientific reports, while avoiding frustrating experiences due to uncomfortable observations by thesis and peer reviewers on their manuscripts.

5. Updating Remark

For the sake of being fair it has to be said that recently, at least in domestic presentations, students from the graduate

programs, e.g., at Cicimar-IPN, are resorting to using a premise to support their hypotheses, but only after being criticized and advised on the matter. Notwithstanding, they focus mainly on their objectives, both general and particular, systematically improving their presentations, but still showing deficiency in constructing their hypothesis and even more when constructing their title.

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