The Role and Lure of Mathematics in Science

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Abstract: In this paper we investigate the legitimate and useful role of mathematics in science (and physics in particular). We also investigate the illegitimate and harmful role (or "lure") of mathematics in modern science (and theoretical physics in particular). Thanks to the obsession of contemporary scientists with complex mathematics and the wrong belief (as well as the wrong scientific values and standards) among these scientists that mathematics is the gold standard of excellent science, highly-mathematized and theoretized science (especially in modern physics) reaches these days a shocking level of irrationality and non-sensibility which often approaches the degree of delusion and hallucination. This obsession with complex mathematics and excessive theoretization inflicts serious damages to modern science and results in a huge waste of efforts and resources as well as the emergence of stray trends and bogus scientific theories inside and outside the main stream of science.

Keywords: modern science, contemporary science, modern physics, contemporary physics, over-mathematization, excessive mathematization, mathematics in science, mathematical physics, theoretical physics.

Contents

1 Introduction

The misuse and abuse of mathematics in modern science (and theoretical physics in particular) are widespread in recent times and they are becoming the norm and rule in some branches of science. It is common these days to propose and formulate bizarre theories and irrational ideas (which are supposedly scientific and hence they allegedly represent the reality of the physical world) based on very abstract mathematical concepts and models and highly theoretical and hypothetical frameworks. In many cases, it is difficult to distinguish between what is physical and what is mathematical in these theories and ideas or even to classify the related literature as belonging to physics or mathematics.

It is also common these days that when someone comes with a "novel" scientific theory or a "brilliant" scientific idea (regardless of its intuitivity or experimental support or even logical rationality and physical reality) he starts with very complicated mathematical formulation in which he spares no effort in employing all sorts of mathematical machinery in the most sophisticated and obscure forms to present and establish his theory or idea. Very often this is not associated with any effort even to present or explain his theory or idea in a few words or bother to give a brief background about its essence and motivation in an understandable descriptive manner and qualitative form. Sometimes, even the most basic concepts and ideas (which are intrinsically and naturally qualitative) are deliberately, forcibly and artificially mathematized so that the mathematical exhibition becomes thorough and complete.

This, of course, is understandable from a psychological and "sociological" viewpoint since these mathematical shows in such theatrical forms will certainly impress most (if not all) people, not just the elites of scientists who have the ability (i.e. knowledge and skill) to understand and appreciate these mathematical shows and their content. This is also understandable from the perspective of current trends and convictions (as well as the contemporary scientific standards and values) which think of mathematics as the gold standard and the absolute value for good and reliable science. However, these factors and considerations should not give, in our view, any credibility to the proposed theories or ideas from a scientific view and physical perspective.

This trend of excessive mathematization of science is relatively recent as it emerged and grew with the emergence and growth of modern physics at the start of the twentieth century (with the rise of this trend at an epidemic level in the last few decades and the rise is going on). Classical science (and physics in particular) was in general moderately and sensibly mathematized where mathematics is seen as a useful tool that should serve the

science rather than being an objective in itself in this regard. In fact, even when there was some excessive use of mathematics in classical physics the mathematics was mostly natural and intuitive and the mathematized physical models remained generally intuitive and sensible, or at least the excessively mathematized physics is kept outside the mainstream physics and generally seen as mathematical artifacts that belong to mathematicians and should be kept away of science. This is understandable from the perspective of classical science which is generally based on intuition and rational thinking noting that intuition and rationality were some of the main sources of inspiration and resources of creativity to classical scientists.

It is worth noting in this regard that the mathematical formulation of physical laws in the *Principia* (i.e. "The Mathematical Principles of Natural Philosophy" of Isaac Newton which is one of the most important books in the history of modern science) is generally limited where many of the fundamental laws and formulations (such as the famous law of gravity) were given in purely descriptive and qualitative forms. Despite this, this book and its content are seen rightly as some of the main breakthroughs and revolutions in modern science. I am not aware of any scientist who looks down to this book or belittles its stature because of this "deficiency" or "shortage" in mathematics. Many great ideas in science (as well as in its philosophy and epistemology) can be stated and expressed entirely and adequately in such descriptive and qualitative manners with no loss or deficiency (although this should not be understood as a call to get rid of mathematics in science or diminish or degrade the legitimate and essential role that it plays, and should continue to play, in science).

Although we do not deny the legitimacy of contemplating highly mathematical theories and ideas and conducting entirely hypothetical investigations in subjects related to the physical world and its diverse phenomena, this sort of intellectual activities should be kept away from science and physics because they actually belong to mathematics or philosophy (or whatever other discipline they aptly belong to) rather than to science and physics. At the minimum, this sort of intellectual activities should not be driving the science and physics and determining their direction and destiny (as it is actually happening in some branches of science and physics these days).

Mathematicians and philosophers (and their alike) have absolute right and they are completely free to go in their intellectual tours beyond the physical world with no right of anyone to impose limits or restrictions on their mental activities (within certain ethical rules which are not of relevance to our current discussion). However, they should not be in the driving seat of science and physics which are intrinsically and exclusively about the

physical world and hence science and physics should be restricted to the physical world and stay inside its borders.

The present paper is about the legitimate role of mathematics in physics as well as its potential role as a lure, i.e. when mathematics becomes deceptive to scientists and a handicap to science and a tool for bad physical formulations and excessive theoretization. The plan of this paper is that we discuss in the following two sections (see § 2 and § 3) the simplicity of science as a virtue and demand as well as the legitimate role of mathematics in physical sciences in general and the conditions (or recommendations) that should be observed in its use in this regard. We then discuss in the next section (see § 4) the wrong role of mathematics in the physical sciences when it becomes a lure and trap for producing nonsensical science, illusions and hallucinations. We then discuss in the following section (see § 5) the reasons behind this wrong trend in modern science where we outline and highlight its motivations and roots. We then present in the next section (see § 6) the reasons and justifications for our rejection of over-mathematization and excessive theoretization of science. We then outline in the final section (see § 7) the main results and conclusions that we presented and obtained in this paper.

2 Simplicity of Science

We argue in this section that simplicity of science should be regarded as a virtue and benefit (and hence a demand) to science in general and therefore we should always try our best to make science as simple as possible. In this regard we note the following:

1. On the theoretical side, simple science is obviously more understandable and sensible (since it is usually intuitive and conforming to common sense), and hence simplicity should achieve (or at least should be more able to achieve) the theoretical objective of science as an attempt to understand the physical world (see § 2 of [1]).
2. On the practical side, simple science is more useful since it is more practical to use and employ in dealing with the physical world and exploiting its resources, and hence simple science should achieve (or at least should be more able to achieve) the practical objective of science as an attempt to conquer the physical world and exploit its resources for the benefit of humanity and beyond (see § 2 of [1]).
3. Simple science should be more qualified to be compliant with the epistemological principles of science which are related to economy and intuitivity (see § 5.4 and § 5.5 of [1]). In fact, it should also be more qualified to be compliant with the other epistemological

principles of science (namely the principles of reality and truth and the principle of causality; see § 5.1 and § 5.2 of [1]) because simple science should be closer to reality and more consistent with the causality from theoretical and practical perspectives.

4. Sensible epistemology and interpretation of science can only be achieved with some form of simplicity. In other words, as science becomes more complex and mathematized the possibility of producing sensible epistemology and consistent interpretation of science should become harder (and possibly impossible). As we dive deeper and deeper in the abstraction and idealization of mathematics and its obscure conceptual framework and symbolic language we move further and further from knowledge and understandability which are the essence and soul of epistemology and interpretation. For example, the epistemologization and physical interpretation of a scalar theory (based on employing scalar physical quantities and parameters) is certainly easier and more achievable than a multi-dimensional tensor theory.

3 The Legitimate Role of Mathematics in Science

In our view, the legitimate role of mathematics in science is to provide concise and precise description and quantification of the phenomena of the physical world using sensible and understandable abstract models, concepts, symbols, (... etc.). So, mathematics (in the context and climate of physical sciences) is essentially a symbolic language[1] for conceptualizing and theoretizing the physical world in a compact, precise and useful form (which is usually of quantitative significance and value). At the minimum, this should be the ideal situation for the role of mathematics in science (if it is not a must).

Accordingly, we may propose imposing some conditions (or at least following some recommendations) on the legitimate use of mathematics in science (and physics in particular). The most essential of these proposed conditions (or recommendations) are outlined in the following points:

1. Because mathematics is a language for expressing and formulating the physical world (at least in one of its sides and aspects) the mathematized and theoretized science should be sensible and understandable in the sense that the models, concepts, symbols, (... etc.) which are used in the construction of mathematical science should be based on and originate from qualitatively sensible ideas and experiences whose roots come from

[1] In fact, "language" should be understood in its broad sense and within our view about human knowledge in general as a high level language and hence any epistemic system is essentially a language in this sense. For more details about this issue please refer to our book [2] and its second chapter in particular.

intuition and life experiences (where "life experiences" should include the specialized life experiences of scientists which are based on their observations and experimentations and related intuitions and insights that they gain from these experiences). This is particularly important for the epistemological and interpretational side of science and its theoretical objective (see § 2 of [1]).

Unfortunately, large parts of the mathematical frameworks and theoretical constructions in modern science (particularly in theoretical physics) are entirely artificial and purely hypothetical with no roots or origins in physical observations or experimentations or experiences or anything like these that belong to physical reality. In other words they are completely abstract, synthetic and hypothetic with no roots or origins in the physical world and hence they do not represent or reflect or depict the physical world or correspond to any observed or observable quantity or quality or phenomena (or ... etc.) that belong to this world. I recommend reading the literature of string theory (as an instance) to see where its conceptual framework and theoretical constructions come from and to which physical world they belong. As a purely mathematical theory, this theory is entirely legitimate and acceptable (as long as it is mathematically sensible and complies with the principles and rules of mathematics), but as a physical theory it should not (due to its alienation from the physical reality of this world). This also applies to many aspects of the theory of general relativity where the theory (or at least the consequences and implications of the theory with regard to these aspects) is completely detached from the physical reality of gravity (and related physical events and phenomena) as it is based on and deals with entirely hypothetical entities and imaginary objects.

2. Based on the previous point,[2] the (presumed) mathematical formulation of a physical theory should follow experimental and observational evidence (or at least indication) for the validity of the formulated theory. In other words, mathematical formulation should generally be on the footsteps of observation and experimentation (or at least there should be some indication from observation and experimentation to certain possibilities and directions that the formulation should follow). In short, mathematics and theory should follow observation and experimentation not the other way around.

   However, this should not mean that we are against using mathematized scientific theories to inspire scientific intuition or make legitimate contemplations as long as these

[2] Actually, this is also related to what will be discussed later on of other aspects and considerations that prompt this condition or recommendation (e.g. mathematical correctness of a theory is not a guarantee of its physical correctness or "physical reality"; see § 4.2).

inspirations and contemplations remain within (or at the border of) observation and experimentation. In fact, large parts of legitimate science (in its observational and experimental forms) come from this type of inspirations and contemplations. So, although scientific theories should be driven primarily by observation and experimentation, they can also drive observation and experimentation and hence they inspire and guide them within their domain and territory (i.e. the physical world and its observed events and observable phenomena).

4 The Lure of Mathematics in Science

We investigate in the following subsections the main reasons and aspects that can make mathematics (especially when used excessively and recklessly) a dangerous tool for conceptualizing, formulating and theoretizing science and hence it becomes a "lure" to science rather than a useful tool that plays beneficial roles in the development and advancement of science.

4.1 Mistakes in the Mathematization of Science

Errors and mistakes in the mathematization of science are very common (although they are usually hidden and hard-to-discover due to their complexity and obscurity), and this should be considered as one of the main reasons for the possibility of mathematics to become a dangerous and damaging tool to science since it can lead to serious and difficult-to-detect errors and mistakes (noting that the danger and damage should increase in gravity by excessive mathematization and theoretization).

In fact, there are many causes that can lead to errors and mistakes in conceptualizing, formulating and theoretizing the physical world by mathematics. However, we can classify these reasons into two main categories:

1. Errors and mistakes in the conceptualization and theoretization of the physical world by mathematics. In fact, there are several reasons and causes for this type of errors and mistakes. For example, the physical world does not necessarily follow our mathematical models and formulations even when they are absolutely correct and rational from a mathematical and theoretical perspective (see for instance § 4.2) and hence the conceptualization and theoretization of its events and phenomena may not reflect the reality of the physical world or capture its hidden facts. Moreover, the high level of abstraction in mathematics makes committing mistakes in representing the physical phenomena by

our mathematical models and formulations highly probable especially with the excessive use of abstraction which can be a natural reason for the divergence from the reality of the physical world.

2. Errors and mistakes in the mathematical formulation itself (i.e. regardless of its relation to the physical world). As indicated already, the high level of abstraction in mathematics and its complex nature make committing mistakes in our mathematical practices and activities commonplace. This factor is present in employing mathematics in general regardless of using it as a tool for conceptualizing and theoretizing the physical world or not. Although mathematics is generally a precise and rigorous language (and hence it may seem less likely to be prone to errors and mistakes), it is also very tricky and difficult to follow and hence committing mistakes in the conceptualization and applications of mathematical formulations and models is very likely despite its preciseness and rigor. The extent and seriousness of this danger obviously increase as we overuse mathematics and dive deeper in its complexities and abstractions.

   Anyone who is in the habit of reading the scientific literature critically and skeptically[3] should know that errors and mistakes in mathematics (and in the mathematized science in particular) are commonplace and this problem seems unrecognized by scientists (or at least its gravity is underestimated by them). We should also mention that history tells that even great mathematicians can make silly and serious mistakes especially in the early stages of developing novel mathematical concepts or models or ideas or theories (or ... etc.) where the picture is still hazy and incomplete (and this actually is the nature of mathematized science in the research stage which dominates the literature of modern science).

   In short, mistakes and misconceptions are commonplace even in the scientific work and writing of experts in their fields of expertise where these mistakes and misconceptions are generally hidden behind the complexity of these subjects and their highly technical nature (and the complexity of mathematics in particular).[4] In fact, the mere existence

[3] Actually, I refer in particular to the reviewers of research papers submitted to scientific journals (and the respected journals in particular). From my previous personal experience as a reviewer, I have many examples and instances of committing mathematical blunders by respected academics and researchers (and sometimes even by leading experts in their fields). These blunders include, for instance, using wrong forms of equations, using formulations that do not satisfy their stated assumptions and axiomatic frameworks, mixing symbols and terminologies and confusing their meanings, conceptualizing and interpreting the mathematical formulations wrongly and drawing wrong or excessive conclusions from them, (... etc.). In fact, the list of examples is very long and hence it cannot be recorded here in detail.

[4] They are also hidden behind the glitter of "great scientists" which blinds the eye of the public (of the scientific community) to see the hidden garbage. In fact, even nonsense and absurdities are usually met

of huge differences and contradicting views among these experts should be an indication to the existence of such mistakes and misconceptions (of highly technical nature) because at least some of these experts should be wrong in their formulations which their views are based on or represent.

So, we should always put question marks on large parts of these mathematical formulations (especially the very novel and excessively complicated ones) from a mathematical viewpoint (as well as from other viewpoints) due to the delicacy and obscurity of mathematical concepts and the ease of falling victim to illusions and misconceptions at this high level of abstraction and theoretization. Moreover, we should not be influenced by the naive view which naturally emerges when we see a highly mathematized and theoretized piece of scientific literature or fall under the effect of overwhelming admiration (and even "intimidation") to believe that this piece of literature must represent a great scientific work. In fact, some of these masterpieces of mathematical complication and theoretical sophistication are no more than pieces of nonsense and absurdity (at least from a scientific perspective) and they do not belong to science or any sort of rational knowledge.

4.2 Inner Consistency and Outer Consistency

One of the reasons for mathematics to become a "lure" is the mix and confusion between "inner correctness" (which originates from subjective or intrinsic or logical consistency) and "outer correctness" (which originates from objective or extrinsic or physical consistency). In brief, mathematical correctness of a scientific theory is not a guarantee of its physical correctness. This is because for any theory (or proposition in general) to be correct it must be intrinsically correct (by being compliant with the rules of logic) and extrinsically correct (by being compliant with the rules of physical reality).[5] What mathematical correctness actually do is to establish "inner correctness" (due to the fact that mathematics is essentially a form of specialized logic and is ultimately based on the general rules of logic although this partially reflects the reality and essence of mathematics).

However, what a scientific theory needs to be correct is "outer correctness" (in addition, of course, to "inner correctness") by being compliant with the facts of observation and the results of experimentation. So, in a sense a supposedly scientific theory that passed the test of mathematical correctness is a potential scientific theory, but it is not real and actual

with acceptance and admiration when they come from these "great scientists".

[5] For more details about these issues we refer the readers to [1–3].

scientific theory until its "outer correctness" is established or (at least) until its "outer correctness" can *in principle* be established, i.e. the theory is capable of being verified and proved to be correct or incorrect physically and by observational and experimental means.

So, we can say that a theory (or proposition) whose "outer correctness" is virtually impossible to establish and verify should not be considered a scientific theory (regardless of its "inner correctness") even though it is "scientific in shape" by being about the physical world and synthesized and conceptualized in physical terms and forms. When mathematical abstraction and theoretization reach a certain high level, mathematical formulation becomes virtually impossible to verify from the perspective of "outer correctness" even though the formulation is absolutely right from the perspective of "inner correctness" and even though the formulation is "scientific in shape".

Now, the danger of such theory when it is mingled (and compete) with truly-scientific theories and classified as a piece of scientific work (thanks to its supposed "inner correctness" as well as its synthesis and conceptualization in physical terms and forms which make it "scientific in shape") is that it brings to science many harmful effects (such as being a source of illusions and fantasies or being a cause for loss of efforts and waste of time in deliberating on its meaning and significance or contemplating on its imaginary implications and non-verifiable consequences).

In fact, this is the state of considerable parts of modern science (especially in theoretical physics) where highly mathematized theories are treated as scientific theories (by virtue of their supposed inner correctness as well as being synthesized and conceptualized in physical terms and forms) regardless of their capability to be validated (or invalidated) from the perspective of "outer correctness" (and sometimes despite their obvious incapability of being verified from this perspective). As indicated earlier, such theories should be expelled from science and classified as mathematical speculations or philosophical contemplations (or whatever they actually belong to) to relieve science of their heavy burden and high cost and get rid of their harmful effects and consequences. At least, these theories should not be classified as serious scientific theories or treated like ordinary scientific theories, i.e. they should be classified as scientific peculiarities or science fiction contemplations (or something like these) and treated as "luxurious" theories or curiosities that to be handled by those "scientists" who have plenty of leisure time.

4.3 Dangers of Excessive Mathematization

One of the reasons that can make mathematics a "lure" to science is that it contains or implies some hidden dangers and potential risks (especially when it is used excessively and recklessly). The following list gives some typical and common examples of these dangers and risks:

1. Delusions and hallucinations: one of the potential dangers of mathematization of science (and over-mathematization and excessive theoretization in particular) is that it can lead to illusions and fantasies since mathematics is full of artificial artifacts and abstract objects that do not correspond or belong to physical reality. For example, it is common to get from our mathematized scientific theories things like non-physical solutions, imaginary quantities, singularities, infinities, senselessly-negative entities, (... etc.). However, this type of mathematical artifacts is the obvious and visible part of these non-physical objects and imaginary entities that we can get from our mathematized science. In fact, this obvious and visible part may represent the "innocent" part and the tip of the iceberg (what is hidden may be greater in quantity and more sinister in quality). So, even if a mathematized (or rather over-mathematized) scientific theory is generally correct (in the sense that it correctly reflects the physical reality to a certain degree) it could still be dangerous from a theoretical perspective since it can lead to illusory results about the physical world. In fact, we can see this in reality where some of the dominant scientific theories (particularly in theoretical physics) have generated and incubated many fantasies, hallucinations and false scientific implications and consequences thanks to their heavily mathematized and excessively theoretized nature.
2. Absurdities and paradoxes: we can find many inconsistencies (in the form of absurdities and paradoxes) in over-mathematized scientific theories where most of these inconsistencies originate from the over-mathematized nature of these theories and their use of highly hypothetical and abstract mathematical frameworks in modeling the physical world and depicting its phenomena and events. Typical examples of such inconsistencies can be found, for instance, in the literature of general relativity (we refer the reader for instance to the absurdities and paradoxes related to black holes and the nonsensical results and paradoxical scenarios that general relativistic formulations lead to in modeling and describing their physics).

Apart from the theoretical harms that these dangers and risks can cause (such as leading to wrong convictions and steering the academic and research activities in wrong directions), they can be a source for draining huge amounts of precious resources in activities related

to these delusions, hallucinations, absurdities, paradoxes and so on. Also see § 6.

At the end of this section we should note that there are countless mathematical formulations of contradicting physical theories in the literature of modern science which are impossible to be correct at the same time. This should imply that either modern science is full of mathematical and theoretical mistakes (as discussed in § 4.1) or mathematical correctness does not mean physical correctness (as discussed in § 4.2). More realistically and logically, we should expect to have a mix of both these possibilities (i.e. we have at the same time many erroneous formulations and many non-physical formulations).

5 The Reasons for Excessive Mathematization in Modern Science

In the following subsections we discuss the main reasons behind the wrong trend in modern science of obsession with over-mathematization and excessive theoretization of science and highlight some of its motives and roots.

5.1 Dominance of Highly Mathematized Scientific Theories

The dominance of highly mathematized and theoretized scientific theories like general relativity and quantum mechanics (and their extensions and generalizations in particular such as quantum electrodynamics and quantum gravity) is a major factor for the excessive use of mathematics in science and the emergence of extreme trends of mathematization and theoretization especially in modern theoretical physics. This factor demonstrates its effect and influence in two main sides:

1. On one side (which may be classified as "theoretical"), these theories are seen as the role models for science and hence their content and style in over-mathematization and excessive theoretization are intentionally imitated and followed by modern scientists in their views, ideas, models, formulations, theories (... etc.) so that they get some of the "glitter", "magnificence" and "glory" of these theories. These dominant theories also contain (or imply) mathematical artifacts and theoretical defects, (such as fantasies, absurdities and similar types of artifacts and defects) and hence these artifacts and defects are naturally transferred to the views, ideas, models, formulations, theories (... etc.) which are built on them. This process of consumption and recycling of mathematical artifacts and theoretical defects is repeated and hence its products and

byproducts are magnified and exacerbated generation after generation.

2. On another side (which may be classified as "practical"), due to the dominance of these "great" theories they dominate the mainstream trends in research and publication and hence any scientist who does not want to be left behind and ignored (or even excluded and "excommunicated") by the scientific community he must follow these theories in their contents and orientations as well as in their styles and methodologies. This means that any acceptable type of research in respectable research and academic institutes and any publishable literature in the respectable scientific media must be heavily mathematized and excessively theoretized (similar or even "better" in content and style than these "great" theories); otherwise it will be seen as trivial and minor and hence it will be neglected and ignored. For example, this type of research will not get any fund from the funding bodies; moreover any publication related to this type of work will not be published in high impact journals and hence it will not be noticed or cited by respectable academics and researchers. This, of course, means complete ruin to the career and livelihood of any academic or researcher who dares to challenge the establishment and takes this "wrong" route.

Overall, over-mathematization and excessive theoretization should be seen these days as the trend and fashion of modern science (thanks, in large part, to the dominance of these highly mathematized and theoretized scientific theories), and hence anyone who does not follow this trend and simulate this fashion in his academic and research activities will be seen (in the eye of the dominant scientific circles and communities) as a poor or incompetent scientist (if he is seen as a scientist at all and not classified as "crackpot").

5.2 Values and Standards in Modern Science

Another major factor for the excessive use of mathematics in modern science and the emergence of extreme trends of mathematization and theoretization is the wrong values and faulty standards that dominate modern science and are adopted by contemporary scientists. For example, mathematics is seen as the gold standard for high-quality and reliable science, and hence any science that is not mathematized (or rather heavily mathematized and theoretized) is belittled and ignored and seen as trivial and marginal. Also, the literature of this type of "trivial science" is commonly classified as "general literature" (rather than technical and specialized literature) of science or put in the category of "popular science" or "science popularization". This means that this sort of science and literature will not be inspected or taken seriously by respectable academics and researchers and

hence it will not be followed or cited by them. The logical consequence is that this type of science and literature has no chance to survive or compete with the mainstream (and heavily mathematized and theoretized) science and literature and hence it will die in its infancy and become forgotten.

We believe that the history of modern science is full of examples of respectable (and even great) theories which died in their infancy because of this factor (or similar factors) although they have all the scientific qualities and potentials that entitle them to survive (and compete or even take the place of the surviving "great theories" especially if they were improved and developed further). This is one of the many aspects and forms of injustice in the history (as well as the present and future) of science (and even beyond science of other aspects of human life and history).

Anyway, there are many other examples of wrong values and faulty standards as well as many reasons for the emergence and adoption of these wrong values and faulty standards (e.g. the dominance of highly mathematized and theoretized scientific theories which determine the values of modern science and put its standards; see § 5.1). However, this is beyond the scope and size of the present paper and hence we do not investigate these issues further (hoping that they will be investigated in more details in our future publications).

5.3 Psychological and "Sociological" Factors

There is a strong psychological factor that motivates over-mathematization (as well as legitimate mathematization) which is the satisfaction that is generally felt by scientists for being "mathematicians" (and seen as such) due to the high respect and reputation of mathematics as the most abstract and intellectual mental activity, and hence mathematics is generally considered as the language and tool of the intellectual elites of human beings. This seemingly originates from the general desire among scientists (as well as ordinary people) to be (and be seen) as "sophisticated" and "meticulous" where these qualifications are regarded as a sign of intelligence and knowledge (noting that mathematics generally meets these qualifications and criteria).

We can similarly (and for the same reasons, as indicated already) say that there is a strong "sociological" factor that motivates over-mathematization in order to get respect among scientists and scientific communities as well as among the general public since such public image and reputation bring admiration and respect among the scientific communities and the wider communities. In fact, the psychological and sociological factors that we are investigating in the present subsection are partly (and intimately) linked to the

issue of "values and standards in modern science" which we investigated in the previous subsection (see § 5.2).

To conclude, mathematics is seen (wrongly!) as the ultimate form and the perfect manifestation of human intelligence and hence almost every individual (whether in the general public or in the scientific communities) likes to become and be seen as a "mathematician" (which is a quality or trait that is supposedly equivalent to being highly intelligent and sophisticated person). This is one of the drives for the excessive use of mathematics in science since mathematization means "intelligence" (as well as knowledge, expertise, skill, etc.) and excessive mathematization means "higher intelligence" (and higher personal qualities in general).

5.4 Desire to be Precise and Accurate

There is a strong motivation among contemporary scientists to use mathematics (even excessively) for the sake of attaining preciseness and accuracy, and hence they generally try to maximize the use of mathematics in expressing, formulating and communicating their ideas and theories. This is because of the reputation of mathematics as the most precise and accurate language for expressing and formulating concepts and ideas especially in the scientific subjects and disciplines. Although we agree that the language of mathematics is generally more precise and accurate (especially from the perspective of its quantitative character and quantification power) than the ordinary language we must note the following remarks:

1. It is not always the case that mathematics is precise and accurate. In fact, obscurities and ambiguities can infect the mathematical language and conceptions (like ordinary language and conceptions) and hence affect and tarnish these qualities. Historically, many mathematical concepts, models, theories (... etc.) have been subject to misconceptions and illusions and proved to be imprecise and inaccurate (and even wrong). This also applies to the application of mathematics in science where impreciseness and inaccuracies (and even incorrectness) were discovered in many mathematized scientific concepts, ideas, models, theories (... etc.). This issue was indicated earlier in this paper (see for instance § 4.1).
2. It is not always the case that mathematics is more precise and accurate than the qualitative and descriptive (ordinary) language in expressing, formulating and communicating scientific ideas and theories (as well as general ideas and theories). In fact, qualitative terminology and (ordinary) technical language can be more accurate and precise (as

well as more meaningful and comprehensible) than the symbolic (and usually abstruse) language of mathematics.

3. Committing mistakes and falling victim to misconceptions and misunderstandings are sometimes more likely to occur in communicating with highly mathematized and theoretized symbolic language than in communicating with (ordinary) technical language (due to the reasons that we discussed earlier), and this should be another reason and motive for being more cautious and conservative in using mathematics in favor of using (ordinary) technical language. At least, this factor should be considered seriously in our evaluation and assessment of mathematics and its actual and potential roles and utilizations in science.

5.5 Malicious Intents

It sounds strange, but it seems to me when I read some of the recent literature of theoretical physics (which is the natural home of typical and ideal instances of over-mathematization and excessive theoretization of science) that some "scientists" are deliberately and maliciously attempting to degrade and mock modern science by presenting it in a shabby and laughable manner as a collection of crazy ideas and fantasies expressed and formulated in nonsensical symbolic forms with no much meaning or objective (if any).

Some "scientists" may also grant themselves the freedom of producing this type of "easy science" to hide and compensate for their lack of original scientific substance and authentic scientific ability (noting that producing this sort of "nonsensical science" is relatively easy). Similarly, some "scientists" may use these theatrical mathematical shows to draw the attention to themselves and create a fuss about their "great scientific theories" or magnify the trivial substance of their theories and hide defects and flaws. In fact, there are many other potential forms and motivations for "malicious intents" and these are just a few examples.

To conclude, malicious intents could be another reason for over-mathematization and excessive theoretization in modern science and hence they should not be ruled out completely when assessing some of the "masterpieces" of mathematized science (or rather "mathematized nonsense") although this reason should be considered only in very exceptional circumstances and cases and with very strong and substantiated suspicions.

6 The Rejection of Over-Mathematization of Science

We give in the following list some reasons and supporting arguments for our rejection of over-mathematization and excessive theoretization of science and why science should rely primarily on observation and experimentation and hence it should be ruled and controlled by them rather than by mathematization and theoretization (although moderate mathematization and sensible theoretization of science are generally acceptable and useful as long as they follow the footsteps of observation and experimentation and remain close to intuition and common sense):

1. Mathematics is a tool that is created by the human being using the fundamental principles of logic in association with abstraction, quantification and generalization. Accordingly, it is not guaranteed that Nature follows our mathematical models in every detail even when there is general agreement between the two, i.e. mathematics as represented by our mathematical models and Nature as represented by our observations may not be identical even when they look very similar. In other words, the logic of human being may not be identical to the "logic" and rules of Nature. We may even say that Nature is not necessarily a mathematized entity (i.e. its properties and behavior are regulated by the patterns and rules of mathematics) in every detail (even though it is generally so), and hence Nature may violate the patterns and rules of our mathematics in some details.
2. Mathematical models and formulations usually reflect only some aspects of the physical reality which they supposedly reflect and represent (even when they look general and comprehensive) and hence they are not necessarily correct in depicting and predicting all the consequences and implications that they theoretize and hypothesize. Also, mathematical models and formulations are usually limited in validity and endorsement since any model is partially validated by a limited number of observations and hence its generality (with regard to many aspects and details) is not guaranteed. This means that observation and experimentation (rather than mathematization and theoretization) should always be the main compass for steering the scientific development and determining its direction and destiny to avoid making wrong conclusions and deviating from the correct path of progress and development. So in brief, mathematical models and formulations of science are generally limited in applicability and validity (although from a formal perspective they may not look restricted in such way) and hence they should always be treated with caution and suspicion from this perspective.
3. At the practical level, excessive mathematization and theoretization lead to complexities

which consume precious resources and hinder progress and development. For example, solutions (whether analytical or numerical) are very difficult (if not impossible) to obtain except in very simple and rather trivial cases. Also, excessively mathematized and theoretized scientific theories contain and imply many non-realistic aspects and this should affect their status as viable and realistic scientific theories. Overall, excessive mathematization and theoretization cause draining of resources and wasting of huge amounts of time and effort in pursuing (through academic work and research projects) futile routes of investigation and deliberation about fantastic entities, nonsensical issues, impractical subjects and objectives, non-verifiable results and consequences, (and the list goes on and on). A quick inspection to the modern literature of theoretical physics (as an instance) reveals the huge amount of waste in time, effort and resources (which can be used in pursuing and tackling many other useful issues and solving real and urgent problems) that this sort of academic and research work consumes in modern science. In fact, entire academic departments and research projects in the universities and scientific institutes around the world are dedicated these days to this sort of futile and absurd activities.

4. Mathematical models and formulations are generally more subjective while observations and experimentations are more objective and hence if mathematization and theoretization take the lead in the development of science it is logical to expect that science will become susceptible to (intentional and non-intentional) prejudice, selectivity, eccentric views, baseless convictions, stereotypes, and so on.
5. Excessive mathematization and theoretization make the epistemologization of science difficult (or impossible) because highly mathematized and theoretized scientific theories are non-intuitive and hence it is difficult (or impossible) to make sense of them or find proper epistemological interpretation to their formulations. This should defy the theoretical objective of science as an attempt to understand the physical world (see § 2 of [1]).
6. We should also include all the reasons and aspects that make mathematics a "lure" to science as reasons for our rejection to excessive mathematization and theoretization of science.[6] These reasons and aspects were investigated in detail in § 4 (and hence we do not repeat).

[6] In fact, some of these reasons and aspects are indicated already.

7 Conclusions

We outline in the following points the main conclusions that we can obtain from the investigation of the present paper:

1. Mathematics is one of the best and most important theoretical tools invented (or discovered!) by the human species and it generally plays very useful and important roles in science (and human knowledge in general). However, mathematics is not such a perfect and ideal tool when used in the physical sciences (and physics in particular). Hence, we should always be careful when using this tool for formulating and theoretizing the physical world. We should also be careful in reading and interpreting our mathematical formulations and models which supposedly represent the physical world and depict its events and phenomena.
2. Mathematical models and formulations are generally not equivalent to the physical reality which they supposedly represent, and hence although the two may agree in general they do not necessarily agree in every aspect and detail. For example, the mathematical models may be based on certain assumptions, some of which can be implicit or hidden, and hence their extension and generalization cannot be justified. Also, mathematical models and formulations are generally valid in certain regimes of their domain but not in all regimes. Hence, it is very unlikely that a mathematical model or formulation can be so comprehensive that it captures and includes all the physical factors involved in a given phenomenon and this is particularly true in highly complex physical phenomena and highly abstract scientific theories. These factors necessitate caution and skepticism when reading and interrogating mathematized and theoretized science to draw the physical consequences and implications.
3. Excessive mathematization and theoretization should be seen as one of the curses and diseases of modern science (and modern physics in particular). Contemporary scientists are obsessed with excessive mathematization and theoretization of science where symbolic formulations and theoretical sophistication and abstraction are generally admired and valued regardless of their empirical justification and physical value. Large parts of modern mathematized science are utterly useless, and very often the excessive use of mathematics in science does not serve any legitimate practical or theoretical purpose that is beneficial to science (although it serves certain purposes to some scientists such as promoting their egos by these mathematical exhibitions or hiding defects and deficits in their theories or magnifying trivial ideas by these artificial complications). We call for rationality and moderation in the use of mathematics in the physical sciences in

general and physics in particular with emphasis on empiricism and realism (as opposite to excessive theoretization and abstraction).

4. Deliberate and serious efforts should be spent to simplify science whenever possible, and make simplicity a virtue and objective (opposite to the current trend in science which glorifies and exalts complexity and sophistication). This is inline with the epistemological principle of non-uniqueness of science as well as being in the letter or spirit of other epistemological principles of science (see § 5 of [1]).
5. In this paper, we presented a number of reasons and justifications for preferring simplicity in science and rejecting over-mathematization and excessive theoretization of science (see § 2 and § 6). We also identified several reasons and aspects that can make mathematics (and over-mathematization in particular) a dangerous tool for scientific formulation and modeling and hence it becomes a "lure" and dangerous tool (see § 4). These should justify our advocacy of simplicity of science and our call for rationality and moderation in the use of mathematics in the physical sciences.
6. To construct realistic scientific theories that reflect the reality of the physical world, observation and experimentation, rather than mathematization and theoretization, should lead the scientific research or at least the observation and experimentation should go hand in hand with the mathematization and theoretization. Accordingly, many of the theoretical results and consequences which are habitually inferred from highly mathematized and theoretized scientific theories and formulations are questionable (and hence the related research work and literature should be questioned).

References

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