Fuzzy philosophy of science and education

Zekai Şen*
İstanbul Technical University, Civil Engineering Faculty
Maslak 34469, Istanbul, Turkey
E-mail: zsen@itu.edu.tr
*Corresponding author

Abstract

Scientific consequences are dependent on premisses that are logical propositions of the phenomena concerned. Propositions are verbal and linguistic statements, and at the initial philosophical thinking stage they all include vagueness and imprecision. As more scientific evidence becomes available either rationally or empirically proposition validity degree increases at the cost of vagueness. In some societies scientific propositions are assumed directly as absolutely correct, but in philosophical thinking they are valid with some uncertainty. Recent trend of falsifiability of scientific propositions brings into view fuzzy ingredients, which have not yet have wide spread recognition. Objective probability attachment to scientific statements is a difficult task, and therefore, subjective (Bayesian) proportions are attached in practice. After a detailed account of what are the advocates and opponents to scientific absolute correctness and probability, a fuzzy thinking and consequently, membership degree attachments rather than probability are presented by in this paper. Classical education systems are based on very systematic, crisp and organized framework on the basis of more than 25-century old Aristotalian logic with two opposite outcomes. Almost in every corner of information source gray fore and back grounds prevail. It is a big dilemma how to deal with gray information sources in order to arrive at scientific conclusions with crisp and deterministic logical principles. Fuzzy logic principles with linguistically valid propositions and rather vague categorization provide a sound ground for this purpose. The preliminary step is a genuine logical and uncertain conceptualization of the phenomenon with causal and result variables that are combined through the fuzzy logical propositions in a set of rules. Such an approach helps not only to visualize the relationships between different variables logically, but furnishes a philosophical background about the mechanism of the phenomenon that can be presented to anybody linguistically without any mathematical treatment. It is emphasized in this paper that in an innovative education system, the basic philosophy and fuzzy logic justifications in any problem solving should be given linguistically prior to any crisp bases such as mathematics or systematic, mechanical and crisp algorithms. In this way the student may be able to develop creative and analytical thinking capabilities with the support of teachers who can provide analytical thinking principles. Since, the modern philosophy of science insists on the falsification of current scientific results, there are always room for ambiguity, vagueness, imprecision and fuzziness in
scientific research activities. Innovative education systems are advised to lean more towards basic scientific philosophy with fuzzy logical principles.

**Keywords:** Crisp, education, fuzzy, innovation, language, logic, philosophy, proposition, reasoning, vagueness.

1. Introduction

In attempting to define what is meant by a "philosophy" of science, the first problem one encounters is the notorious vagueness of the term "philosophy" (McMullin, 1987). A direct consequent of this statement is to rise a question as to how the science itself is objective but its very foundation as philosophy is vague, imprecise, blurred and rather uncertain. How can scientific development become possible if the science and its philosophy are uncertain? The term philosophy has a wide meaning including from a cloudy speculative fancy to a piece of formal logic. Until recently, the formal logic in philosophy has been taken as the Aristotelian logic, which has alternatives of two completely defined classes as true or false; positive or negative; black or white; beautiful or ugly. All the scientific propositions, hypotheses, theories and ideas are measured first on the basis of this logic and consequently, classical scienticism followers believe in them dogmatically with insignificant scientific information, because they immediately defuzzify uncertainties through the crisp logic principles automatically. They become academicians who cannot have attributes of due to the crisp nature of the classical logic. In this logical domain even the cloudy, vague, uncertain, imprecise qualities are crisply classified to distinctive and mutually exclusive parts with the acceptance only one part as scientific. None of the scientific knowledge can be accounted as completely crisp without suspicions, otherwise scientific development cannot exist. The scientific development is possible due to its vague, imprecise and uncertain character. In the text so far the terms as vague, imprecise, uncertain, blurred, cloudy are altogether referred to as the fuzzy information (Zadeh, 1968). Most often common man expects or thinks that the science moves toward a unified account of the world, but the pictures of reality become ever more disparate. Especially, many scientific theories which were believed to be true turned out to be false or semi false or there are a lot of debates about their verifications or falsifications. Hence, in the domain of scientific philosophy, the scientists become rather uneasy in testing and providing demarcation for the distinction of scientific from, the so called non-scientific knowledge. It is not possible to have scientific thought without knowing or at least even unconsciously going through the process of philosophy, which provides complete freedom in scientific thinking. Although, today many academicians may think that they are producing scientific papers without thinking about the philosophical ingredients in their approach, in fact, their procedure has embedded scientific philosophical thinking. Complete freedom of philosophical thinking provides many scenarios about any phenomenon concerned, but logic eliminates many of them as opposed to common sense. Of course, common sense is not dependable on all the time. Philosophers of science seek for exploration of general scientific characteristics that mostly relate to its function as a knowledge-producing activity such as the nature of its validation procedures, its patterns of development, the truth-state of theories and the like. In order to clearify the distinction between the formal classical logic and the fuzzy logic, one should remember that according to Aristotelian logic, if something is true or
thought to be true, then it is given the number 1 and its completely opposite alternative number 0. Likewise, simply true statements are attached degree of belief as 1 and false ones as 0. The fuzzy logic attributes degrees to even a scientific belief (degree of verification or falsification) that assumes values between 0 and 1 inclusive. Verifiability of scientific knowledge or theories by logical positivists means on the classical grounds that the demarcation of science concerning a phenomenon is equal to 1 without giving room for falsification (Popper, 1952). The conflict between verifiability and falsifiability of scientific theories includes philosophical grounds that are fuzzy but many scientific philosophers concluded the case with Aristotelian logic of crispness, which is against the nature of scientific development. Although many science philosophers tried to resolve this problem by bringing into the argument the probability (Carnap, 1987) and at times the possibility of the scientific knowledge demarcation and scientific development, unfortunately so far the "fuzzy philosophy of science" has not been introduced into the literature. The scientists cannot be completely objective in their justification for scientific demarcation or progress, but ingredients of fuzziness are driving engine for the generation of new theories. All the scientific rule bases must be tested by fuzzy inference engine, which leads to fuzzy scientific domain but for classical understanding and dissemination of the knowledge, many render them into a defuzzified manner. In fact, the scientific phenomena are all fuzzy in nature and especially the foundations of scientific philosophy include embedded fuzzy components. Dogmatic nature of scientific knowledge, or belief in the science as if it is not susceptible, is the fruits of formal classical Aristotelian logic, whereas fuzzy logic holds the scientific arena vivid and fruitful for future scientific plantations and knowledge generation.

This paper proposes the use of fuzzy logic in the demarcation of scientific knowledge and education system. It is declared that whatever is scientific, it includes fuzzy information to a certain extent and Aristotelian logic cannot be valid in natural environment and human thoughts except after idealization (defuzzification) of the facts.

2. Historical perspective

Newton used a less restrictive conception of scientific knowledge than philosopher John Locke in natural philosophy. In his conception, science requires moral or practical certainty rather than metaphysics or absolute certainty, which implies that the scientific statements are naturally fuzzy in character. They had different understandings of what kind of uncertainty is required in scientific knowledge. Locke’s concept of scientific knowledge involved absolute certainty, which cannot be a matter of degree. He was able to preserve a sharp distinction between, on the one hand, scientific knowledge, and on the other “judgement”, this being his term for what had been called “probable opinion”, which is valid only in the case of vague information, in other words, when scientific statements include fuzziness. Newton’s practical certainty is a matter of degree, and to acknowledge the degrees of certainty is to acknowledge degrees of probability. In Newton’s philosophy, understanding of certainty could not be maintained as a sharp distinction between scientific knowledge and probable opinion. It is, therefore, necessary to benefit from fuzzy statements as intermediators. Newton agreed that his knowledge does not have absolute certainty until the integrity of experimental natural philosophy provides real knowledge. He had to supplement logic with rhetoric in order
to sustain his distinction. Rheoteric statements are sets of vague or imprecise information in the forms of fuzzy statements. Here again, rheoteric words may be treated as fuzzy sets.

On the other hand, in 17th century especially Christian Huygens promoted Newton’s rejection and he conceded no sharp distinction between the knowledge of nature that one counts as scientific and the judgements about nature as probable. Most recognized reasoning is probable reasoning in the sense that it generates conclusions, which have one or another degree of certainty, and therefore, one or another degree of probability and still, as a suggestion in this paper, one or another degree of fuzziness. Later, in the century with the idea of using especially experimental evidence for arguing, the truth or at least the credibility, the concept of probability become identical with the idea of something being credible or believable in the light of evidence. It is also alleged in this paper that all these last statements can be reconsidered under the light of fuzzy sets (Zadeh, 1965).

Not every probable reasoning is acceptable, but only to some degrees of uncertainty. For any probable reasoning, it is necessary to have a measure of when and why such reasoning is acceptable. One should to find ways of measuring the degree of uncertainty, which will show how a conclusion should be quantified. Towards this purpose, Huygens himself published an account in 1675. He tried first time to show the treatment of quantitative probabilistic reasoning in games of chance. In his treatment, words are missing for customarily use of signifying the probability concepts.

On the other hand, Leibniz stated that for promotion of scientific achievements, investigators must recognize that absolute certainty is an ideal case that they can achieve. During scientific studies degrees of probability should be accepted attached with knowledge. Objective probability definition requires measurements that are impossible at the scientific thinking experiment stage. The best that can be done is the attachment of subjective probability values to each statement. However, it is preferable and better to express the uncertainties in any scientific statement by words of vagueness, which can be expressed in terms of fuzzy subsets and degrees of memberships within each subset. Hence, reasonings with probable conclusions should be embraced rather than rejection. Leibniz probability is a relation between the evidence disclosed by investigators and the conclusions they draw. This suggests that Leibniz accepts a jurisprudential model for the logic of probable reasoning. As Leibniz says we need “a new logic in order to know degrees of probability, since this is necessary in judging the proofs of fact and of moral.” Hence, such a new logic is suggested as the fuzzy logic which has been already suggested by Zadeh (1965).

Although Leibniz was exploring for the first time the philosophy of probability, the Swiss mathematician Jacob Bernoulli was achieving some success by pursuing this practical line of thought. As the example, Gracchus might be considered with the accusation of a crime. He turns pale when accused, and on the basis of this fact, it is possible that we conclude in an argument for his guilt. However, this can only be a probable argument, because Gracchus’s pale may have a cause other than the presumed guilt. Hume had claimed that “all reasonings concerning matter of fact seem to be
founded on the reflection of cause and effect and the probable arguments with which Bayes was concerned can indeed be understood as reasoning from effect to cause”.

Keynes (1921) viewed that probabilities are not relative frequencies based on observation, as Russell (1948) believed and likewise as so many of his hard-headed empiricist colleagues at Cambridge supposed, but degrees of rational belief determined by reason. Furthermore, for Keynes probabilities were degrees of belief, and it was necessary not only to attribute probabilities primarily to propositions, but also to recognize that propositions are always probable in relation to other propositions. He, in fact, endorsed the “conceptual” or “classical” idea of probability associated with Leibniz and Laplace. A degree of rational belief has nothing to do with how frequently conclusions “of this kind” follow when one uses reasoning “of this type”, rather it is a function of the logical relations between conclusions and the reason one gives for its truth. Hence, in a fuzzy proposition, the premise includes the reasons for the evidence and the consequent part represents the partial conclusion in harmony with the premise. In this manner, each position carves a portion from the overall representative logic and yields its consequent part, which is also partial. That is to say, logicians should recognise not only that propositions can entail, or contradict other propositions, but also that propositions can partially entail or contradict other propositions. Hence, one may say that the conclusions of some measuring must be true when it is entailed by premises one accepts, so one can say that a conclusion is probably or possibly true when it is “partially” entailed by acceptable premises. In other words, where entailed conclusions are necessary in relation to premises, partially entailed conclusions are partly entailed conclusions. According to Keynes probability comprises “that part of logic, which deals with arguments that are rational but not conclusive. The same sentence can be read by replacing probability with possibility, which means to say that premises include fuzzy subsets. Hence, it is a part of logic, but not mathematics.

When evidence changes, vagueness, and therefore, degrees of belief also change in thought rather than in experience, because they are logical relations of partial entailment between propositions expressing conclusions in which one has degrees of belief and propositions expressing the evidence for the conclusions. Probabilities as degree of belief are subjective rather than objective; they represent psychological states (Ramsey, 1978). One should not understand the rationality of the probability judgements expressing partial beliefs arising from scientific investigations as a matter, not of their correspondence to something external to them, or of their derivability from a supposedly objective indifference principle, but of the relation of the beliefs to each other.

Russell (1948) states that the aim of the inductive arguments is, given the truth of their premises, to make their conclusions probably true. However, in deductive arguments, one requires that conclusions are necessarily true, given the truth of their premises. Instead of asserting that a regularity occurs in all cases, sometimes, assert that it occurs in only a certain percentage of cases. If the percentage is specified or if in some other way a quantitative statement is made about the relation of one event to another, then the statement is called a “statistical law” (Carnap, 1995).
The concepts of science, as well as those of everyday life, may be conveniently divided into three main groups, classificatory, comparative, and quantitative. Classificatory concept means simply a concept that places an object within a certain class. They vary widely in the amount of information that they give about an object. For example, if one says an object is blue, or warm, or cubical, he/she makes relatively weak statements about the object. In other words, all these statements include vagueness and consequently they can be conveniently expressed by fuzzy subsets. By placing the object in a narrower class, the information increases, even though it still remains relatively modest. Such a narrowness corresponds to the narrowness of the fuzzy subsets, which is also equivalent to information content increase in a fuzzy subset. For instance, a statement that “an object is a living organism” is very vague, but “it is an animal” says a bit more. As the classes continue to narrow one has increasing amounts of fuzzy sets but still vague information.

3. Uncertainty in science

Early humans had thinking in an entirely uncertain environment for their daily activities. It is possible to say that early knowledge and information were concepts derived from frequent observations and experience. Throughout the centuries, human thinking had support from scripts, drawings, calculations, logic and finally mathematical calculations. In the mean time science is separated from philosophy with its own axioms, hypotheses, laws and final formulations especially after the renaissance in the 17th century. It is possible to state that with Newtonian classical physics, science entered almost entirely a deterministic world where uncertainty was not even accounted among the scientific knowledge. However, today almost in all the branches of science, there are uncertainty ingredients and many scientific deterministic foundations became uncertain with fuzzy ingredients. Among such conceptions are quantum physics, fractal geometry, chaos theory and fuzzy inference systems. However, some others such as the natural and social sciences have never gone through the stages of determinism. With the advancement of numerical uncertainty techniques such as probability, statistics and stochastic principles scientific progresses in quantitative aspects had rapid developments, but still leaving aside the qualitative sources of knowledge and information, which can be tackled by the fuzzy logic principles only.

Recently, famous philosophers and scientists alike, started to spell out the uncertainty and fuzzy ingredients that are essential basis of scientific progress. For instance Russell (1923) stated that “All traditional logic habitually assumes that precise symbols are being employed. It is, therefore, not applicable to this terrestrial life but only to an imagined celestial existence”. On the other hand, as for the fuzzy conception Zadeh (1965) said that “As the complexity of a system increases, our ability to make precise and yet significant statements about its behavior diminishes until a threshold is reached beyond which precision and significance (or relevance) become almost mutually exclusive characteristics”.

As an esteem of the eastern thinking, philosophical objects may be raised by logical premises and implications along three basic mental activities, namely, imagination, conceptualization and idealization jointly leading to idea generations. Since the
existence of terrestrial life, human beings have interaction with nature, which has provided the basic material in the form of objects and events evolving with time and space for the human mental activity chain. At the early stages of human history or during the childhood of any individual these stages play roles in different proportions and with experience, they take final forms. Each thinking process includes uncertainty, because imagination, conceptualization and idealization stages are rather subjective depending on individual’s grasp. At any stage of human thinking evolution, the premises include to a certain extent uncertainty elements such as vagueness, ambiguousness, possibilities, probabilities and fuzziness. Implication of mathematical structure from the mental thinking process might seem exact, but even today it is understood as a result of scientific development that at every stage of modeling, physical or mechanical, there are uncertainty pieces, if not in the macro scale, at least at the micro scale. It is clear today that mathematical conceptualization and idealization leading to satisfactory mathematical structure of any physical actuality is often an unrealistic requirement. As Einstein (1952) stated “So far as the law of mathematics refer to reality, they are not certain. And so far as they are certain, they do not refer to reality”.

At the very elementary stages of mental thinking, activity objects are thought as members or non-members of a given or physically plausible domain of variability. This brings into consideration sets, which include possible outcomes or basis of the investigated phenomenon. In formal sciences such as physics, geology, meteorology, etc. almost invariably and automatically, these elements are considered as either completely members of the set or completely outside the same set. Hence, the Aristotelian logic of pairs in the form of one or zero; positive or negative; yes or no, black or white, etc., are employed at the foundation of any scientific phenomenon for mathematical modeling. However, Zadeh (1965) suggested instead of crisp membership consideration, continuity of membership degrees between 0 and 1, inclusive. Hence, fuzzy sets play intuitively plausible philosophical basis at every stage of the aforementioned mental activity chain.

4. Fuzzy logic thinking and reasoning stages

Understanding, explanation and reasoning are the steps necessary in a complete thinking process. Each one of the steps cannot be explained in a crisp manner and each individual depending on his/her capabilities may benefit from this sequence. Although human wonder and mind are the sources of fuzziness, they also seek problem overcoming with human experience, i.e. expert views. The fuzzy concepts in understanding complex problems are dependent on observations, experiences and consciousness. In problem solution there is always fuzziness, which paves ways for further developments. Hence, the scientific solutions cannot be taken as absolute truths in a positivistic manner.

The precise knowledge is possible only when a phenomenon or process is isolated from its surrounding again with a set of restrictive assumptions, which render the problem into certainty world by ignoring all fuzzy uncertainty features. For instance, the factor of safety (FoS), also known as safety factor, is a multiplier applied to the
deterministically (crisp logic) calculated maximum load (force, torque, bending moment or a combination) to which a component or assembly will be subjected in engineering design. Thus, a FoS accounts for imperfections in materials, flaws in assembly, material degradation, and uncertainty in load estimates. In fact, the FoS can be named as "ignorance factor" due to the exclusion of all fuzzy information about the engineering design. However, fuzzy logic and system help to solve the engineering design problem without considering safety factor, because the solution is based on fuzzy uncertain information domain. There are no isolated phenomena and processes in nature, and any knowledge about them is always fuzzy. The significance of fuzziness opens ways for changes, evolution, growth, and continuous scientific development. Figure 1 gives the steps in fuzzy thinking and problem solving. Fuzziology concentrates on the study of the human mind possibilities to know external objects by collecting information through observations or readings (Şen, 2010).

Once the collection of such fuzzy linguistic information is completed then human inquiry expands the field of understanding along different directions. In the mind, the objects and their different visible properties are expressed first by words. This point indicates how significant the language is. Each item concerning the phenomenon under investigation is labeled by a word or a set of fuzzy words (statements, propositions). This is equivalent with the categorization of the objects into different classes again in a fuzzy manner and at this stage the crisp logic cannot be helpful. For instance, when some objects are labeled by a word, say "tree", one is certain that there is fuzzy uncertainty in this labeling. After all the stages in Figure 1, it is possible to carry on analytical thinking and solution procedures.

Fuzzy impressions and conceptions are generated by human mind, and it divides the seeable natural, environmental or engineering reality into fragments and categories, which are fundamental ingredients in classification, analysis and deduction of
conclusions after labeling each fragment with a "word" such as a name, noun or adjective. The initial labeling by words is without interrelation between various categories. These words have very little to do with the wholeness of reality. Hence, common linguistic words help to imagine the same or very similar objects in our mind in a fuzzy manner. The fuzziness of knowing never ceases to exist. This is a paramount characteristic of the human knowing, which challenges humanity and constantly propels its search for truth and understanding the secrets of reality.

Every act of holistic understanding is inevitably fuzzy. The fuzziness and truth are not mutually exclusive as it is assumed in classical scientific research methodology, but they go hand in hand in every aspect of scientific research.

Conscious direction of attention towards an external object causes the object to be received by mind into the realm of our fuzziness, which causes in sequence to perception, experience, feeling, thinking, understanding, knowing, and finally, acting for meaningful description and analytical solution. Fuzzy statements have meaning and relevance only. "As the complexity of a system increases, human ability to make precise and relevant (meaningful) statements about its behavior diminishes until a threshold is reached beyond which the precision and the relevance become mutually exclusive characteristics" (Zadeh, 1968).

Fuzziness is an essential characteristic of our imaginations that raise and dissolve in our thoughts about the future plans. Human thoughts have blurred boundaries and consist of fuzzy immaterial "ubstance". Having in mind how important is to think in images for the development of our intelligence and capacity to learn and know, to act and to create, to evolve and to transform, one should not underestimate the role of fuzziology. At this stage it is useful to mention about the three stages of human thinking in the middle eastern philosophy for reaching to a solution of any problem in general (Şen, 2010). These three words are "takhayyul" (imagination), "tasawwur" (geometric configuration) and "tafakkur" (idea generation). Any external object whether it exists materialistically or not, human beings try to imagine its different properties in a fuzzy world. This gives him/her the power of initializing individual and personal thinking domain with whole freedom in any direction. After the object comes into existence vaguely in the mind, then it is necessary to know its shape, which is related to geometry. It is essential that the geometric configuration of the phenomenon must be visualized in mind in some way even though it may be a simplification under a set of assumptions. Again the fuzzy shapes in the mind are put down as crisp geometrical shapes such as square, triangle, circle, ellipsoid, etc., or their mixtures for the mathematical treatments.

In 1932 Gödel proved that in any axiomatic mathematical system (theory), there are fuzzy propositions, that is, propositions which cannot be proved or disproved within the axioms of this system.
5. Approximate reasoning

Reasoning is the most important human brain operation that leads to creative ideal methodologies, algorithms and deductions giving way to sustainable research and development. Reasoning stage can be reached if there is stimulus for the initial driving of mental forces. Ignition of pondering on a phenomenon comes with the physical or mental effects that control an event of concern. These affect trust imaginations about the event and initial geometrical sketches of the imaginations by simple geometries or pieces and connections between them. The ideas begin to crystallize and they are expressed verbally by a native language to other individuals to get their criticisms, comments, suggestions and support for the betterment of the mental thinking and scientific achievement. Finally, all the conclusions must be expressed in a language, which can then be converted into universally used symbolic logic based on the principles of mathematics, statistics or probability statements. This explanation shows that linguistic (fuzzy) logic is followed by symbolic logic (mathematics). Unfortunately, in many education systems all over the world, this sequence of language and symbolism is overturned into the sequence of first symbolism (mathematics) and then linguistic understanding, which is against the natural perception abilities of human perception. This is especially true for countries or societies who are trained in some other language with symbols and those when they return to their community, the first difficulty is to convey the scientific messages in his/her native language, and therefore, in order to avoid such a dilemma the teacher bases the explanation on symbolic logic. This is one of the main reasons why scientific thinking and reasoning are missing in many countries including Turkey.

In fuzzy logic there are no mathematical symbols and it is intermingled with the linguistic statements, which can only be acceptable on the logical grounds. It is impossible to work with fuzzy logic if a sound as well as clear language and basic logical thinking are missing. It is possible to set down the necessary logical rules connecting the input and output variables of any phenomenon. After the completion of such logical deductions one can then enter the mathematical domain and express his/her ideas in the realm of symbolic logic, which is mathematics.

In the philosophical thinking for scientific and technological achievements, and another three essential steps are perceptions (feelings, chaos), sketches (geometry, design) and ideas (language, fuzzy). The perception part is very significant because it provides complete freedom of thinking without expressing it to others who can restrict the activity.

The subjectivity is the greatest at the perception stage and as one enters the sketch domain, the subjectivities decrease and at the final stage, since the ideas are exposed to other individuals, the objectivity becomes at least logical, but still there remains some uncertainty (vagueness, incompleteness, missing information, etc), and hence, the final conclusion is not crisp but fuzzy.
6. Scientific sense and thinking

Various phenomena in engineering, medicine and sciences take place in a complex world, where complexity arises from uncertainty in the forms of ambiguity. Scientists address problems of complexity and ambiguity at times sub-consciously, since they could think, these ubiquitous features pervade most natural, technical, and economical problems faced by the human race. The only way for computers to deal with complex and ambiguous issues is through fuzzy logic thinking, systemizing, controlling and decision procedures.

Common sense dictates that some form of empiricism is essential to make sense of the world. In traditional quantitative educational training, the classical dualism as the tension between subjectivity and objectivity is often addressed by adopting an objectivist, empiricist or positivistic approach, and then by applying a scientific research design. Even based on classical logic, scientific thinking starts in an entirely subjective medium. Subjective thinking penetrates objectivity domain by time through imagination and visualization, and hence there is not a crisp line between subjectivity and objectivity. Empirical works, which are based on either observations or measurements as experimental information help to decrease the degree of subjectivity on behalf of objectivity. None of the scientific formulations obtained up to now is completely crisp, but they are regarded as crisp information provided that the fundamental assumptions such as mutually exclusiveness and exhaustiveness are taken into consideration. The crispness of any scientific information can be shacked by modifying one of the basic assumptions. This implies that all the scientific principles are not crisp completely, but include vagueness, incompleteness and uncertainty even to a small extent, and hence they can be considered as fuzzy by nature or by human understanding.

As mentioned in the previous section, any scientific thinking has three major steps imagination, visualization and idea generations. Imagination part includes the setting up of suitable hypothesis or a set of logical rules for the problem at hand and the visualization stage is to defend the representative hypothesis and logical propositions. Scientists typically use variety of representations, including different kinds of figures (geometry) to represent and defend the hypotheses. On the basis of hypotheses, the scientists behave as a philosopher by generating relevant ideas and their subsequent dissemination, which should include new and even controversial ideas, so that other scientists can overtake and elaborate more on the basic hypotheses. Whatever are the means of thinking, the scientific arguments are expressed by verbal expressions prior to any symbolic and mathematical abstractions. Especially, in engineering and physical sciences visualization stage is represented by algorithms, graphs, diagrams, charts and figures, which include tremendous amount of condensed verbal information.

The scientific visualizations are conducted with geometry since the very early beginning of scientific thoughts. This is the reason why the geometry was developed and recognized by early philosophers and scientists than any other scientific tools such as algebra, trigonometry, and mathematical symbolism Al-Khawarizmi (died 840 A.D.) who is known in the west as his Latinized name "algorithm" solved second order equations by considering geometric shapes. For instance, he visualized $x^2$ as a square with sides equal to $x$, and terms such as $ax$ are considered as rectangles with base length
x and height equal to a. This geometrical thinking and visualization made him the father of "algebra". All his discussions were explained linguistically.

All the conceptual models deal with parts of something that is perceived by human mind. Of course, among the meaningful fragments of the phenomenon, there exist clear and hidden interrelationships, which are there for the exploration of human intellectual mind. Such possible relationships can be explained by a set of fuzzy rule statements (base). Among the fragments of thinking are perception, sensations, thoughts, which serve collectively to provide partial and distorted conceptual models of reality. The success in understanding of any scientific theory or publication is not only through the text, but additionally verbal expressions of the mathematical formulations and figures. Hence, the whole basic philosophy and working mechanism of any scientific work can be understood through the linguistic expressions, where there are not only crisp logic propositions, but most of the time vague, incomplete, uncertain statements that are more valuable for scientific developments. Such uncertain linguistic statements have fuzzy contents that can be assessed by fuzzy logic principles. Scientists treat figures as integral parts of their arguments, whose strength and soundness depend on visual representations as much as they do on linguistic representations. Arguments are expressed in terms of statements and this is one of the main reason why the scientific philosophy has paid little attention to figures.

In everyday life human beings make many predictions and estimations especially on the basis of qualitative data and past experience. Additionally, expert opinions help to shape and refine such predictions besides the mutual discussion and confidence. In predictions there are similarities, which are the input information about the phenomenon concerned, output clues and the logical connectivity between these two sources of information. On the basis of certain clues, it is possible to make judgments about output information. The default of these judgments is the commonly available scientific thinking and its sublime version of logic (crisp or fuzzy) leading to rational results. This provides ability for any individual to develop actuarial models for various real-life prediction problems. It is possible to make predictions either by crisp logic mathematical formulations or fuzzy logic expert views with a set of linguistic rules.

An important question is whether the predictions of human experts are more reliable than mathematical models? Experts make their predictions on the basis of the same evidence as for the mathematical foundations, but additionally they consider the usefulness of the linguistic data in the form of vague statements in the adjustment of the final model. Such vague information cannot be digested by crisp logic. Fuzzy modeling by experts considering vague information is more successful than mathematical models, which are valid for ideal cases under the validity of a set of assumptions. Among the most important problems are natural phenomena predictions, because they have the following properties.

1. Even the best mathematical models are not reliable,
2. The best results seem reasonable predictions, but somewhat unsafe, and therefore, as mentioned in the previous section the FoS is imported to make the results more dependable.
In order to move understanding towards a deeper and broader grasp of complexity, the emergent meanings need to be neither stable nor unstable, that is stable enough to rely upon them when generating hypotheses, concepts, and emotional attitudes, and unstable enough not to allow these concepts and attitudes to harden and become dogmas and addictions. In other words, after scientific thinking, meanings need to be fuzzy (flexible), ready to immediately respond to the changes continuously occurring in each of the countless dimensions of reality.

7. Education and uncertainty

Education is a terminology that is used to enlighten others through a sequence of systematic courses that include basic concepts, which are expected to provide for the students a vivid domain of idea creation by pondering on some phenomena. Of course, in such a training, the rational thinking is the core of creative and free opinion. Besides, education has three main facets that should contribute interactively for fruitful and even emotionally stable end purposes. Figure 2 indicates these three ingredients in their interactive courses.

![Figure 2. Education system parts](image)

It is obvious from this figure that education does not mean knowledge influx from teacher to student only. In an effective education system, there are instances when sudden and rather unexpectedly knowledge flows either from the student to the teacher or new knowledge emergence through mutual discussion in the midst of fuzzy logic (linguistic) domain. Unfortunately, in many parts of the world and especially in the developing countries, classical educational systems provide crisp and elusive knowledge leading to locally valid certificate with mass production. The defective points in any traditional education system can be specified as follows,

1) There is a tough authority of teaches who are directed according to a set of state or traditional rules, which does not give freedom of creative reasoning or thinking. In such a system, logic means any answer to any question in black or white. This is classical logical attitude towards the problem solving,

2) Teaching media, which can be referred to as educational gadgets, may become indispensable organs and they are exploited in a crisp and rather
dogmatic manner without improvement throughout years. In non-native English speaking communities, such devices may easily become show offs for affecting the attention of learners only rather than basic educational concepts.

3) There are expectations of ready answers to questions in textbook style of information, which are only jointly shared by different learners and teachers alike without uncertainty,

4) Scientific concepts are provided in a crisp manner as if there is only one way of thinking and solving the problems with scientific certainty,

5) Assumptions, hypotheses and idealizations are the common means for mind to grasp the natural phenomena, and therefore, any scientific conclusion or equation is valid under certain circumstances.

In a modern and innovative educational system almost all the concepts must be provided with uncertainty flexibility especially at the higher educational systems. It is fixed from the long history of science by experience that not only freedom of thinking, but also suspicion from scientific conclusions should be incorporated for better advancements. The very word of suspicion leads to expectation and even viewing scientific knowledge as uncertain. Hence, the basic points in a modern and innovative educational system, the following points must be considered which are contrary to classical or traditional education.

1) Traditional and classical elements must be minimized and even dismissed from an innovative education system. The authorizable teacher is the one who is regarded as knowledgeable (crisp logic), and especially, who has the ability of knowledge and information giving only,

2) The teacher should not be completely dependent on educational gadgets, and the students through discussions and questions should try to force the teacher on the margins of the presented material for more information,

3) It should be kept in mind that each scientific conclusion is subject to uncertainty, fuzziness and suspicion, and hence, to further refinements leading to innovative ideas and modifications,

4) Especially, the fuzzy logical principles and philosophical basis must be kept in the education agenda by the teachers so that each student can grasp and approach the problem with his/her abilities,

5) At higher educational level, scientific thinking must be geared towards the fuzziness and falsifiability of the conclusions or theories rather than exactness and verifiability.

After the consideration of these points collectively, it is possible to conclude that modern and innovative educational training should include philosophical thinking and then logical trimmings which imply fuzziness in the scientific training. This implies that the conclusions are acceptable with a certain degree of belief that is not completely certain. The graduates must be confident that there is still domain to make creative inventions and scientific discoveries. Otherwise, a classical logic and traditional educational system with the certainty principles does not leave any room for future development, and consequently, graduates from such a system may hold only the certificate and dogmatic knowledge. However, with the advancement of time in their
later ages, they may be frustrated that the knowledge they obtained during their education were not certain, but fuzzy.

8. Fuzzy logic education

In natural sciences rather than numbers, qualitative descriptions are dominant at initial information in any reconnaissance study with descriptive linguistic explanations. Ordinary people thinks in a fuzzy manner because they do not have proper terminology or concrete scientific laws for the descriptions and modeling of the phenomenon concerned. This indicates the effectiveness and naturality of fuzzy logic, which is linguistic in content, but connective between different categories at the background. In order to distinguish between the classical Aristotelian and fuzzy logics, let us consider the statement that “one variable (output) is directly proportional with another variable (input)”. Such a proposal gives a crisp logical relationship between two variables, which implies that as the input increases, output variable also increases. It is not possible to clearly identify from this statement the following points,

1) Whether the increase is linear or nonlinear?
2) What is the validity domain of both variables?
3) What are the sub-domains of each variable?

In any research, these are significant questions that need proper answers. In the classical scientific educational systems, these points can be objectively identified by measurements and observations. However, herein the very word of observation must be closely examined and its meaning must be explained again linguistically. Measurements need instruments suitable for the study. However, observations may be achieved by human senses and put into words accordingly. Observations are especially significant sources of information in natural sciences. It is rather impossible for a naturalist to set forward logical statements about the phenomenon concerned prior to making effective observations and measurements. In natural sciences, each case has its special and different features that may not be repeated completely. Hence, right at the beginning, it is known that different cases will have common specifications, features, trends and descriptions, but even so, there are also be dissimilar features. The dissimilarities make the comparison or deduction of information on more than two cases to have fuzzy behaviors. This is tantamount to saying that natural patterns at different sites are dissimilar to a certain degree of content. For instance, globally two different sites of igneous rocks might have the same rock types, say, granite, diorite and gabbro, but it is not possible to insist that each rock type has the same degree of membership in these sites. From the classical logic point of view, these two sites are identical to each other without any further detailed specifications. However, the geologist is not convinced fully that they are identical, because whatever the circumstances, there are uncertainties linguistically which are fuzzy in content. It is possible to ask what is the hardness of the granite in different sites? In general, they will have hardness but not at equal degrees, and hence the variation in the hardness can be categorized relatively as “low”, “medium”, or “high”, which allows the entrance of the fuzzy concepts into the assessments. Similar to the word of “proportionality” in the above proposition, “hardness” in the description of the same rock category, cannot be distinctive in sub-
categorization. This leads to the general rule that in any logical assessment, sub-
categories are significant, and it is possible to deduce that the more (the finer) the
categories, the better is the description.

In fuzzy logic, the fundamental significance is not the sub-categorization, but the
relationship between them. So far, one can summarize that for fuzzy assessment of any
phenomenon the following steps are a priori necessity.

1) Identify the variables for the description of the phenomenon at hand, such as
the input and output variables,
2) Sub-categorize the variables through adjectives such as “low”, “medium”,
“high”, “warm”, “more”, etc.,
3) State proposals between the sub-categorization of at least two variables
(inputs and output), which must include the logical connections in “IT . . .
THEN . . .” forms.

Many scientists are not familiar or do not prefer to apply mathematical rules in their
preliminary works, and therefore, most of the information are in the form of rather
vague statements. This is the main reason why especially in natural and social sciences
the fuzzy logic rule is preferable. It is possible to state that in every walk of daily life
individuals unconsciously use fuzzy concepts, but this paper gives a formal forum for the
fuzzy logic ingredients into an innovative education system.

Fuzzy logic approach provides a way of identifying vague relationships between
different variables that play role in the causal of a certain phenomenon. In fact, the
mathematical equations either through analytical, statistical or probabilistic approaches
might lead to such relations, but they are in concrete form attached with numbers, where
non-numerical effects cannot be taken into consideration.

Each fuzzy proposition can be thought of consisting two parts as before and after the
word THEN. The part before THEN is the antecedent segment, and after THEN it is the
consequent segment. These pair-wise fuzzy logical statements can be generalized into
triple-wise, quadruple-wise, etc. propositions with care. It is stressed, herein, that in any
innovative educational system, a systematic must be given to the students, so that they
can tackle any problem with logical solutions prior to any quantitative investigation.
Correct logical statements empower the students with quantitative solutions only after
the availability of numerical data. In classical education systems, students are given
already cooked equations or algorithms without logical steps, and hence, they become
formula, equation, procedure, algorithm, and certainty addicted. Whenever they are
confronted with a different problem than what they have learnt in the classrooms, then
they still expect ready answers from the previous crisp information arena in their mind.
Had it been that they are trained with fuzzy logical thinking and self confident logical
and rational solutions, they will be eager to attack any problem even the ones that are
not directly in their domain of specification, but still in their personal interest.

Another comparison of classical and fuzzy logic propositions can be effectively
observed and grasped on the basis of Cartesian coordinate system display. Let us
assume that output, O, increases with input, I. This is a crisp logical statement, which
may be rendered into a formal proposition as “IF I increases THEN O increases” and there are no adjectives (fuzzy words) in this statement (Figure 3). Non-existence of adjectives is the main difference from fuzzy propositions. Any classical statement does not tell whether the relationship is linear or non-linear.

![Figure 3. Classical logic domain](image)

On the other hand, in the case of fuzzy logic categorization, I and O can be specified at least by three adjectives, which implies that the two axes on the Cartesian coordinate system can be considered as three divisions, which are shown in Figure 4 for different proportions of each adjective. Herein, h, m, s and w letters imply adjectives of “high”, “medium”, “small”, and “weak”, respectively.

![Figure 4. Fuzzy logic domains](image)
Comparison of these four domains with Figure 3 indicates that after the fuzzy partitioning there are now nine sub-domains each corresponding to a specific relationship between the two variables. Hence, more detailed and logical interpretations can be done with ease. There are three sources of information for the identification of valid sub-domains for the problem at hand. These are,

1) Logical deductions, which may be completely work of a non-specialist in the subject,
2) Expert deductions with specific knowledge on the problem from the previous similar or the same studies,
3) Data deductions provided that there are measurements or records of previous similar problems.

In many classical educational systems the students are trained with concentration on the third point whereas the first and second steps are grossly overlooked. Many techniques are thought concerning the third point, especially in engineering and physical sciences through the scatter diagrams and consequent curve fitting procedure by the well known least squares technique without noticing that this technique has many restrictive assumptions.

In the innovative educational systems, perhaps, the last point must be left to students more than the two first ones, which constitutes the fundamentals of creative thinking. Logical deductions should furnish the basis for tackling any problem. If the history of science is reviewed properly, it is possible to see that most of the famous scientists became successful outside of their proper trainings. This indicates that, classical and systematic educational training renders the thinking capability of students into moulds with definite boundaries. For instance, if asked to many students all over the world about the Newton’s law, the ready answer will be as $F = ma$, or force equals the multiplication of mass by acceleration. Such minds cannot be creative but dogmatic, mechanic or robotic, because given the two of the variables (F, m and a) the student will be able to calculate the third one. Such an approach is a nonsense and nuisance for the prosperity of scientific atmosphere. This is exactly what the third step is in the above explanation. Rather than the formulation, if someone states the Newton’s law as saying that the force is directly proportional with acceleration, then he/she has exploited dependence on logical principles to a certain extent. The same saying can be put into a formal form as “IF acceleration increases THEN force increases”. This statement does not tell anything about the rate of increase. Let us consider the same law from the fuzzy logic point of view by sub-categorizing the force and acceleration into three categories as “low”, “moderate” and “high”. Consequently, consideration of acceleration as input and force as output variables, there will be 9 sub-domains as in Figure 4 but not all of these sub-domains will be valid logically. Rational and logical thinking without any expertise or data exposition will invalidate 6 of these sub-domains which are, (low acceleration-moderate force), (low acceleration-high force), (moderate acceleration-low force), (moderate acceleration-high force), (high acceleration-moderate force), and finally, (high acceleration-moderate force). Hence, three logical statements remain, namely, (low acceleration-low force), (moderate acceleration-moderate force), and (high acceleration-high force). Furthermore, the graphical representations of these three sub-domains are already shown in Figure 4 with black shaded sub-domain. In Figure 4,
black and white sub-domains are still indicators of classical logical taste, which can be further fuzzified for complete description of fuzzy logic assessments. One of the fuzzy logic properties is that there must not be sharp (crisp) boundaries between sub-domains. This brings still another question as “adjective domains” and what are representatives of “adjectives”. The logical answer is that any adjective domain has degrees of representativeness by each adjective. The most representative point in each sub-domain is in the centroid of the area. Such an approach leads to the gray areas in the sub-domains depending on the degree of membership of the adjective attachment to the sub-domain. Hence, the blackness fades away towards the edges and even there appears overlapping between the adjacent sub-domains as shown in Figure 5.

![Figure 5. Fuzzy partitioning of sub-domains](image-url)

9. Innovative education

In an effective innovation education system for scientifically productive results, the following implementations are necessary. It is assumed at this stage that not only the students are considered for the improvement but also the staff members must be ready to undertake these implementations.

1) General behavior of the phenomenon considered must be explained from different points of view on a rather philosophical level, which indicates the significance of language in the planning and tackling of the problem. This step exposes the significance of language structural and grammatical features in a scientific thinking procedure,

2) During the presentation and definition stages of the problem, by all means the students’ contribution must be encouraged through various related questions and views. Accordingly, rather than the unique view and the style
of the teacher, the topic is rendered to be the common mental property of the student group. It may not be possible to guarantee 100% agreement between the individuals, but at least a common and majority agreement is created. The students’ ability is not at the same level, and consequently, there will remain fuzzy uncertainties at the minds of some students. This is also useful, because it will give further room for discussion among them after the formal classroom sittings,

3) The causative effects on the problem must be identified with all possible detail and verbal attachments to variables. Subsequently, the verbal variables must be ordered mentally in the best possible manner according their significance in the problem at hand. This stage may be considered as dismantling of joint causative effects into individual effects,

4) Among the causative effects, a single variable of interest is depicted as the subject of the problem, and hence there are causative and subject variables. As a first stage, it is necessary to consider the classical logical relationships between these variables. These relationships are quite primitive and indicate direct or inverse proportionality. Initially there is a list of logical proportionality relationships, which may be further exploited for the refinement of the problem solution,

5) Sub-categorization of each variable with at least two and preferably three or more classes. This is the stage where the variable names are attached with suitable adjectives. In this manner, each classical variable is rendered into fuzzy variable with various sub-categories,

6) Logical propositions including premises among the sub-categories of causative variables are constituted, and subsequently, each one of these premises is attached with sensible, rational and logical consequent parts of the subject variable. In this manner, the linguistic structure of innovative education by fuzzy logic principles is complete,

7) In order to assure the understanding of the students, it is useful to give a common homework and to request the solution of problem with their individual abilities and linguistic background.

It is possible to conclude that the innovative training through fuzzy logical ingredients is completely linguistic in character, which gives basic principles of learning and discussing the fuzzy remains from the complete solution. In this manner, information and knowledge are transferred from teacher to student or vice versa. Furthermore, fuzzy logic training does not include any mathematical formulations or restrictive assumptions. This implies that in educational systems the mathematical concepts are not the preliminary requests. It should be stated herein that any statement, which insists that the more the mathematics, the better is the research, is mistaken, because the creative education takes place at institutions where the philosophical discussions and consequent logical regularizations are plenty.
10. Conclusions

Present education systems are rather classical with extensive dependence on crisp and blueprint type of information. In many institutions almost spoon fed knowledge and information loadings on fresh brains are given without creative or functional productivities. This is perhaps one of the main reasons why in many institutions all over the world, analytical and especially creative thinking capabilities are not advanced sufficently. It is easy to mention about the quality of students, but the view taken in this paper is that the quality of staff member should also be improved. In developing countries, it is thought most often that the quality control can be improved through the improvement of students’ quality only, which is a defective approach, since highly qualified staff members may lead to improvements in students’ quality whereas the reverse is not true. In classical educational systems, more than basic logical propositions, formulations and determinism are mentioned for the solution of problems. Especially, in natural and social and even in engineering and physical sciences almost each case study is different from other cases even though they may be close to each other. Therefore, determinism or crisp information systems cannot be sufficient for the description of phenomena concerned.

It is stated in this paper that rather than crisp information and solution techniques, as a first step in any innovative education system, fuzzy logic fundamentals must be provided to the students, because it is the natural logic, which has been forgotten unfortunately, due to continuous classical (crisp, Aristotalian) logic training in education institutions. For instance, prior to any equation proposition or verification by data, fuzzy logic concepts may lead to general solution of the problem concerned with philosophical background and logical rule. In a fuzzy logic education training the causes of a phenomenon must be identified as variables and then these variables are considered as sub-categories, which are then combined together through logic propositions to each other.

The main conclusions are that the scientific knowledge cannot be completely varifiable or falsifiable but rather it is always fuzzifiable which provides potentiality for further researcheres. As a general conclusion of this paper, it is suggested that the science and any related attribute to it is never completely verifiable or falsifiable, but always fuzzifiable and hence further developments in the form of prescience, traditional science and occasional revolutionary science will be in view for all times, spaces and societies.

References


