South American Journal of Logic
Vol. 2, n. 1, pp. 127–153, 2016
ISSN: 2446-6719

Is Universal Logic 'Universal'?

Tzu-Keng Fu

Abstract

The aim of this paper is to provide a meta-analysis for those involved and interested in the interdisciplinary study of logic, particularly Universal Logic. Universal Logic provides a general theory of logic to study the most general and abstract properties of the various possible logics. While continuing to remain aware of the central issues of Universal Logic, we seriously consider the factor of "culture" for the Universal Logic project. As well as elucidating the basic knowledge and necessary definitions, we would especially like to address the problems concerning logical investigations from a cultural psychological point of view. In this regard, the universality of the modes of cognitive processes will be discussed by comparing these two ideas of "Universal Logic" in this paper.

Keywords: Universal Logic, Cognitive Process, Cultural Psychology, Formal Logic, Dialectical Logic

1 Introduction

While the Westerner attempts to emphasize formal reasoning in critical thinking, argumentation, and debate in their system of education, East Asians try not to treat every proposition as bivalent, namely, either true or false. The difference in the behaviors and thoughts of the East Asian and the Westerner has been reflected in many aspects of daily life. With a cultural-psychological assumption that *logic as cognitive process*, we are able to compare the modes of cognitive processes in different cultures. In an interdisciplinary manner, a discussion of psychologism, and so of the term "new logic" in relation to cognitive science and computation ([31]) will be carried out in the domains of cross-cultural studies. A result for comparing the modes of cognitive processes between East Asians and Westerners, based on an implementation for cultural psychological studies, has been provided by Richard Nisbett ([56], [57], [58], [59], [60]).

One academic study, in which the term *Universal Logic*, which is connected with the spirit of Universal Algebra, appears to propose a general theory of logics. This

study was conducted in the nineties, at almost the same time as Jean-Yves Béziau coined the term "Universal Logic". A different academic study in which the same term "Universal Logic" appears at first glance to satisfy the aims of classical AI (the good old-fashioned AI, generally abbreviated as GOFAI) in China. Compared with the Universal Logic project that was connected with the spirit of Universal Algebra, a universal logic system with dialecticism (C-UniLog), which was realized as a *universal* logical system, was proposed by Hucan He. et al. ([40], [42], [86], [87]). The development of such a universal logic system is an obvious case with different attitudes and purposes from the Universal Logic project. We have here two very different conceptions of universal logic, and the situation is considerably more perplexing in relation to cultures. With different cultures, the only way to have reasonable communication and develop understanding is by using cross-cultural comparison.[1]

The structure of this paper is as follows: In Section 2, we present the development of the Universal Logic project that originated from the formal logical tradition in western cultures. Section 3 then discusses the concept of one universal logic in China which our paper is attempting to address to compare with the Universal Logic project. In section 4, we start our discussions on the modes of cognitive processes in different cultures and on a cultural-psychological assumption of *logic as cognitive process*. Section 5 compares and discusses some common and different positions taken by two different theories, based on different academic interests. Finally, section 6 is the conclusion and outlook.

2 Universal Logic as Neo-Bourbakism

> "*Logica Universalis* (or *Universal Logic*, *Logique Universelle*, *Universelle Logik*, in vernacular languages) is not a new logic, but a general theory of logics, considered as mathematical structures." ([11] p.vii)

In the literature, three investigations intended to study logics at a general level. In 1920, Alfred Tarski proposed his theory of consequence operator as a very general theory of logical consequence. In 1930, Gerhard Gentzen's sequent calculus studied a family of formal systems which share a certain style of inference and certain formal properties. In 1970, Roman Suszko (with Stephen Bloom and Donald Brown) proposed a concept of "abstract logic" that consists of an algebra A and a closure system ©. Universal Logic promoted the concept of "general" logic to a far more abstract level in the same way by means of combining a general bivaluation semantics with Gentzen's

[1]Compared to the goal of proposing a universal logic system, endorsing a relatively conservative definition of universal logic –the general theory of logics– will produce some intuitively reliable results which can be applied to various areas ([3], [25], [84]). However, we have no assurance that this is a cross-cultural and universal method to produce the right assessment for every result expressible in different cultures.

sequent calculus ([11], [12], [16], [22]). In brief, these four investigations attempted to understand the *generality* of logical structure in an abstract logic perspective, whereby some particular properties of specific logical system could be reexamined.

2.1 Arbitrary Logical Structures with Bivaluations

Arbitrary abstract logical structures, taken as an extension of the Polish school of thought, have been generalized from the Tarskian abstract logic. Adopting this so-called conceptual approach ([12]), a direct abstraction of the Tarskian account of logical structures gives way to recognizable arbitrary logical structures with bivaluation.

Definition 2.1 *An arbitrary logical structure is a structure of the form* $\mathcal{LS} = \langle S, \vdash_{\mathcal{LS}} \rangle$, *where* S *is an arbitrary set and* $\vdash_{\mathcal{LS}}$ *is an arbitrary relation on* $\mathcal{P}(S) \times S$. *Equivalently, we could have described it as a pair* $\mathcal{LS} = \langle S, Cn_{\mathcal{LS}} \rangle$, *where* S *is an arbitrary set and* $Cn_{\mathcal{LS}}$ *is an arbitrary mapping from* $\mathcal{P}(S) \longrightarrow \mathcal{P}(S)$.

This conception of logical structures was firstly introduced in [22] (also see [11], [14], [15]) in order to capture the most general formalization of logical reasoning.[2] Note that logical structures being taken as mathematical structures does not imply Universal Logic is a mathematical structure. Universal Logic is a general theory of logical structures. People have taken this conception of logical structures as one of the prototypes of the fundamental mother structures based on Bourbakism in the Universal Logic project. They aim to capture all logical phenomena, called "Neo-Bourbakism".

Definition 2.2 *A bivaluation of* $\mathcal{LS}$ *is any characteristic function* $v : X \longrightarrow \{0, 1\}$, *for* $X \subseteq S$. *Given a set* V *of bivaluations of* $\mathcal{LS}$, *for all* $X \subseteq S$ *and* $\varphi \in S$, *the following semantical deduction relation is defined:*

$$X \models_V \varphi \text{ iff for all } v \in V,\ v(X) = 1 \text{ implies } v(\varphi) = 1.$$

[2] An arbitrary logical structure is said to be Tarskian (normal) when it obeys the following Tarskian conditions: Given a set S of formulas, we say that $\vdash \subseteq \mathcal{P}(S) \times S$ defines a (Tarskian) consequence relation on S if the following conditions hold, for any formulas α and β, and subsets Σ and Δ of S.

1. $\alpha \in \Sigma$ implies $\Sigma \vdash \alpha$. (Reflexivity)
2. ($\Delta \vdash \alpha$ and $\Delta \subseteq \Sigma$) implies $\Sigma \vdash \alpha$. (Monotonicity)
3. ($\Delta \vdash \alpha$ and $\Sigma, \alpha \vdash \beta$) implies $\Delta, \Sigma \vdash \beta$. (Cut)

A *compact* Tarskian logic $\mathcal{L}$ is definied as $\langle S, \vdash \rangle$ with *compactness*.

$*$ If $\Sigma \vdash \alpha$, then $\Gamma \vdash \alpha$, for some finite subset $\Sigma \subseteq \Sigma$. (Compactness)

The Tarskian conditions for consequence relation can be presented in the style of consequence operator $Cn_{\mathcal{LS}}$ as follows: For the theories, T, K, $T \subseteq Cn_{\mathcal{LS}}(T)$; $T \subseteq K$ implies $Cn_{\mathcal{LS}}(T) \subseteq Cn_{\mathcal{LS}}(K)$; $Cn_{\mathcal{LS}}(Cn_{\mathcal{LS}}(T)) = Cn_{\mathcal{LS}}(T)$.

This logical two-valuedness originated from R. Suszko and N. C. A. da Costa independently. Suszko ([77]) proposed a method for providing any structural abstract logic with a complete set of bivaluations. "Suszko's thesis" was proposed, which states that any logic with a structural consequence operator conforming to Tarski's standard conditions is logically two-valued, while da Costa's theory of valuations ([28]) was used comprehensively in the analysis of the paraconsistent calculi. Béziau ([22]), in this way, analyzed the conditions for an arbitrary logical structure, which is a very abstract concept of logical structures, to obtain a complete set of bivaluations, linking the "theory of valuations" with the "sequent calculus" to show how it is possible to translate conditions defining bivaluations into sequent rules and vice versa ([11], p. 13). Considering "bivaluations" is crucial ([15], [22]), moreover, it can be regarded as seminal work with respect to modern developments in Universal Logic, which is typified by the following notion. This notion provides an important clue regarding a key step in treating *logic* in Universal Logic. In this regard, it attempts to dissolve the boundary existing between the syntactic and the semantic.

The conceptions of arbitrary logical structures and logical two-valuedness (bivaluations) have been considered together in the idea of Universal Logic.

Definition 2.3 *A theory* Γ *such that, if* $\Gamma \vdash a$ *then* $a \in \Gamma$*, is said to be closed. A theory is considered as a bivaluation by taking its characteristic function; a bivaluation can be considered as a theory by taking the set of true formulas under this function.*

Definition 2.4 *(Béziau 2001) An adequate bivalent semantics for a logic* $\mathcal{LS} = \langle S, \vdash_{\mathcal{LS}} \rangle$ *is a set of functions* **BIV** *from* S *to* $\{0, 1\}$ *such that the semantic deducibility relation* $\models$ *defined in the usual manner (* $T \models a$ *iff for every* $\beta \in$ **BIV***, if* $\beta(b) = 1$ *for every* $b \in T$*, then* $\beta(\alpha) = 1$*) by this set is the same as* $\vdash$*. If* $\vdash$ *is included in* $\models$*, we say that the semantic is sound (for* $\mathcal{LS}$*, and if* $\models$ *is included in* $\vdash$ *we say that the semantic is complete (for* $\mathcal{LS}$*).*

Theorem 2.5 *(Béziau 2001, 1995) The semantics of closed theories of a Tarskian (normal) logic is an adequate semantics for it. If* $\mathcal{LS} = \langle S, Cn \rangle$ *is a logical structure such that* $X \subseteq Cn_{\mathcal{LS}}(S)$*, for all* $X \subseteq S$ *(reflexivity), then* $\mathcal{LS}$ *has a adequate set of bivaluations.*

Theorem 2.6 *(Béziau 2001, 1995) A bivalent semantics is sound for a normal logic iff it is included in the semantics of closed theories. If* $\mathcal{LS} = \langle S, Cn \rangle$ *such that for all* $X, Y \in S$*,* $X \subseteq Y$ *implies* $X \subseteq Cn_{\mathcal{LS}}(X) \subseteq Cn_{\mathcal{LS}}(Y)$ *and* $Cn_{\mathcal{LS}}(X \cup Cn_{\mathcal{LS}}(X)) = Cn_{\mathcal{LS}}(X)$*, then* $\mathcal{LS}$ *has a sound set of bivaluations.*

Any set V_s of bivaluations of a logical structure $\mathcal{LS}$ which are adequate and sound for it: $X \models_{Vs} \varphi$ iff $X \vdash_{\mathcal{LS}} \varphi$, is called as a "Suszko set" for a $\mathcal{LS}$. Theorem 2.5 and Theorem 2.6 were mentioned in [15], [18], and the proofs can be found in [83].

The significance of this work is its claim that any semantics can be reduced to a bivalent semantics. Suszko's thesis is connected with the reduction of many-valuedness to two-valuedness (a discussion on this can be found in [49] and [27]). Bivaluation provides a more general formulation of Suszko's thesis. In other words, in a general sense, in relation to Universal Logic, it provides a general definition of semantics: a semantics on a given set S is a pair $\langle K, Fun\rangle$, where K is a set and Fun is a function from S to $\mathcal{P}(K)$. The logic induced by the semantics is defined: $\Gamma \Vdash \varphi$ iff $Fun(\Gamma) \subseteq Fun(\varphi)$, where $\Vdash$ represents a general sense of semantic relation, where given any semantics on a set S, we can find a bivalent semantics on S which induces the same logic ([27]). For Universal Logic, the *bivalent semantics* on a set S is a semantics, where K is a set of functions from S to $\{0, 1\}$ (bivaluations) and F is defined as follows: $\beta \in Fun(\varphi)$ iff $\beta(\varphi) = 1$. Here, bivaluations are logical values and not algebraic values, as in Suszko's terminology ([20], [27],[77], [83]). This definition is carried out at the abstract level.[3]

3 Universal Logic in China

In this section, we attempt to describe the whole concept and the motivations for developing *one universal logic* in China (C-UniLog). By elucidating these motivations of developing this C-UniLog, with the help of the results from cultural psychology (section 4), we will find how the factor of *cultural-differences* can be used to conduct meta-analysis on Universal Logic. Furthermore, we are able to compare C-UniLog with the Universal Logic project (section 5). This analysis comes from an observation, made at **the Second World Congress and School on Universal Logic**. A series of world congresses on universal logic were held firstly in 2005 (Switzerland), secondly in 2007 (China), thirdly in 2010 (Portugal), and fourthly in 2012 (Brazil), of which the second edition is worth mentioning here, not only because it was held in Xi-an, China, but the ideas of *one universal logic*, which were proposed by Huacan He, are as a totally different idea of "Universal Logic".

3.1 Motivation (i): The Development of Artificial Intelligence and Information Science

C-UniLog, which was pioneered by He et al.'s artificial intelligence research group, claimed to defend the stance of "symbolic artificial intelligence" (symbolic AI).[4] With

[3]Readers should note that what we have presented for Béziau's results should be attributed to Gentzen's sequent calculus, however, this requires in-depth knowledge of Gentzen's sequent calculus. Readers could consult [15], [22] to obtain a comprehensive understanding of this.

[4]Symbolic AI, which is regarded as an opposition to connectionist AI, asserts that the core of artificial intelligence research is to explore the possibility that human intelligence could be reduced to

their own advanced research regarding AI, they hoped to develop a universal logical system to facilitate the development of this symbolic AI. First, they proposed that "the magical parts of a human brain rely on the fact that they are *integrated*, *flexible*, *dialectic*, and *evolutionary*."[5] Second, they believe that people need to develop *flexible logics*, which are *smart*, *open* and *self-adaptive*. Third, they developed C-UniLog to study the common principles between mathematical logic (rigid logic) and flexible logic. They said ([40], p. 83):

> "Universal Logic is a theoretical framework that contains and integrates various rigid and/or flexible logics in such way that the whole framework still maintains its integrity and openness."

They believe that the primary function of AI is to study *experience thinking* and *learning processes*, and that there is uncertainty in the experience thinking of humans, and thus, **uncertain reasoning** will dominate it. They attempted to systematically study experience thinking by proposing a framework to unify the theories of uncertain reasoning.

A concept of a flexible logical system, which is *continuous* and *controllable*, was proposed to tolerate all uncertainty and manage some *contradictory situations*. According to He et al., such a flexible logical system is based on the following conception of logic:

- there is a fundamental distinction between the logical disciplines in the development of logic, namely logic can be separated into two categories: "formal logic" and "dialectical logic".

In this manner, they claim that to study formal logic is considerably different from studying dialectical logic. ([40], p. 84.) They said:

> "Formal logic focuses on the necessary relationship among concepts, and the intrinsic identity and extrinsic certainty among propositions. Without taking into account the specific content of a proposition, it concentrates on a formal relationship among the propositions. Dialectical logic, on the other hand, focuses on propositions that have intrinsic contradictions and extrinsic uncertainties, and considers the specific content and the formal relationships among the propositions. Of course, dialectical logic pays attention to the necessary relationships among concepts too."

symbol manipulation to create machines with artificial intelligence by symbolic approaches.

[5]Paraphrased from [96], p. 2.

3.2 Motivation (ii): Restrictions of Mathematical Logic

According to He et al., the development of modern mathematical logic is based on three basic principles: principle of bivalence,[6] principle of contradiction,[7] principle of excluded middle,[8] and one characteristic: *Closeness Evidences* (**CE**).

* (**Closeness Evidences**) *All evidence required in reasoning is known and static.*

Following this, modern mathematical logic was considered *rigid* and *formal*, relative to the concept of flexible logic, and these principles and characteristics restrict modern mathematical logic. In this regard, they make the following statement ([40], p. 85):

> "...many issues in the real world cannot be resolved through classical mathematical logic. This limitation has its roots in the fact that classical mathematical logic takes it as a theoretic base that the world is assumed to be 'closed, completed and determined', which is called the 'closed world assumption'."

They argue that these three principles along with CE restrict the scope of applying mathematical logic to a *close hologram two-valued reasoning process in a determined world* ([40], p. 85), because modern mathematical logic itself is just a kind of *approximate description* of the real world. In their opinion, we should not attempt to escape uncertain and contradictory situations in the real world, otherwise we are allowing ourselves to stay in an unreal state. The second motivation of developing C-UniLog is to transcend these restrictions.

According to He et al., the establishment of flexible logic is the primary task of universal logic research, "in which there are many new rules of dialectical logic to be discovered by us" ([40], p. 96). They introduced the so-called "dialectical mechanism" to modern mathematical logic, and they further suggest that this kind of *dialecticalization* and *flexibalization* is necessary to deal with uncertainty and contradiction. In addition, we are living in an *intellectualize information* era.[9] Thus, they state that logic should not only deal with what we have done in the twentieth century (or earlier for that matter), rather, it should be used to solve real problems. For further details on the flexibilization and dialecticalization of classical mathematical logic, refer to [41], [42].

[6] Given a proposition p, p is either true or false.

[7] Given a proposition p, p and its negation $\neg p$ cannot both be true.

[8] Given a proposition p, either p is true or its negation $\neg p$ is required to be true.

[9] He et al. in their writings stated that many mathematicians or mathematical logicians don't think that mathematical logic owns the defects and limitation as what he accused. The reasons they provides could be codified in general as follow: (1) mathematical logic is mature enough to be a theory to solve all various logical problems and issues in the determined worlds perfectly; (2) insufficient information is the source of all uncertainties which should or could be solved by every field instead of being solved at the logical level.

3.3 Motivation (iii): New Stages of Modern Sciences

The third motivation for the development of C-UniLog relates to changes in the subjects of science. They believe that modern mathematical logic is not suitable for solving issues that are fuzzy, chaotic, and with no clear boundary. For example, while explicit judgment, precise measurement, and accurate prediction could be obtained in the study of mathematics, mechanics, astronomy, physics, and chemistry, they cannot be obtained in the study of life sciences, social science, and intelligence science. Modern mathematical logic is actually insufficient in the transition of subjects in science.

According to He et al., "reductionism" and "determinism" dominate the foundations of modern science.[10] They further assert that, since the mid-twentieth century, changes to our conception of nature has rendered our old conception of nature, which was trying to pursue absolute accuracy and certainty, as follows:

> "nature is in the process of evolving with fluctuating, uncertainties, multiple options and limited prediction widely existing,..." ([40], p. 90)

In other words, evolvement should be placed in a central position in order to have a suitable conception of nature. In contrast, the old conceptions and theories, which are dominated by determinism and reductionism and are merely *rough descriptions* about object laws and rules, only capture some perspectives of nature. Thus, they suggests adopting a *holistic and changing* viewpoint to review nature and the technologies from this different conception of nature. Under such a background, mathematical logic is also regarded as facing a similar change, called the **Second Revolution of Mathematical Logic** by He et al.. They said: "it will be a real-world oriented, flexible, and self-adaptive logic with the capability of containing contradictions and uncertainties" to meet the needs of the modern science system ([40], p. 90).

4 Logic and Cognitive Processes across Cultures

In relation to the logical studies involving the cognitive processing dimension and cross-cultural psychology, two ideas, then, in combination, will help our meta-analysis on Universal Logic in this paper. By first adopting the position of **psychologism**, we

[10] This discussion is too complex, and hence, it cannot be provided at this point. For the purpose of understanding, we summarize as follows. A reductionist in science will believe that the things that happen in the world can be controlled and realized by some rules and elements. Further, he/she will assert that every explanation in every field of science should be reduced all the way down to another field, e.g., it is well-known and accepted that the foundations of chemistry are based in physics, and microbiology is based in chemistry, i.e., the former is reduced to the latter. In addition, reductionism is closely related to certain perspectives of determinism, i.e., the theory of causality. Every event is causally determined by the antecedent events by laws of nature. We use these two to explain that the developments and changes of the world can be "controlled," as expressed by He et al..

further make an assumption that logic is a cognitive process in the cultural psychological perspective ([56], [57], [58]). Secondly, to relate the issues between the Universal Logic project and the idea of a universal logic system to the cross-cultural aspect which is the focus of this paper, it is apparent that this issue has gone beyond the confines of logic that go back to Gottlob Frege and Edmund Husserl's **anti-psychologism** (compare e.g. [31], [44], [45]).[11]

4.1 The Modes of Cognitive Processing

In relation to the culture of East Asia, East Asians do not encourage people to think about things and events that are too abstract; rather, they encourage people to be more practical. Moreover, the fact that everything changes is core to their vision of the world and is especially influenced by three traditional philosophies – Taoism, Confucianism, and Buddhism ([56], [57], [58], [60]). In the context of the knowledge system in East Asians, people believe that a proposition and its negative proposition should hold at the same time. More specifically, the existence of a proposition implies the existence of its negative proposition ontologically. Furthermore, due to the concept of *change*, it is claimed that given a proposition, the negation of this given proposition will immediately hold after this given proposition. Consistency is not a necessary condition in this kind of belief system.

According to cultural psychology investigations, it will sometimes be more difficult for Westerners to accept eastern schools of thought, such as **Taoism** or the concepts of **yin and yang** due to the fundamental differences in their cognitive processes. There are at least two systems of thoughts that exist in different cultures, one is the "holistic system" and the other is the "analytic system". They also reflect the two entirely different cognitive processes of the Eastern Asian and the Westerner, respectively ([56], [57], [58], [75]).

Several relative contributions in cultural psychology describe how systems of thoughts contribute to the formation of theories in different cultures. East Asians adopt a holistic attitude toward the relationship between a part and the whole; they seldom use the framework of formal logic but instead use dialectical reasoning. On the contrary, Westerners adopt an analytic attitude toward an object and the categories to which it belongs. They use rules to realize the behaviors of an object, e.g., formal logic ([58], [60]). Moreover, there is a significant extent to which Westerners are interested in categorization, which provides rules in addressing various issues during the course

[11] A more general usage of the term "psychologism", is given in [45]: "many authors use the term 'psychologism' for what they perceive as the mistake of identifying non-psychological with psychological entities." To relate to the issue raised in the philosophy of logic,[...] 'psychologism' then refers (approvingly) to positions that apply psychological techniques to traditional philosophical problems." Briefly, in logic, people who think that logical laws are not identical to psychological laws or do not apply psychological techniques to logic, would be viewed as adopting anti-psychologism.

of education. Formal logic indeed plays an important role in this process of education and problem solving. On the contrary, East Asians are concerned with the contexts within which an object exists; the world is more complicated for them than for Westerners. When they face an event, they feel the need to consider many factors and the relationships among these factors. They definitely do not try to understand events through a deterministic framework. For them, formal logic does not play a key role in solving problems ([56], [58], [75]). These notions are unacceptable in the traditional western system of thought. When the East Asian engages in daily reasoning, they appeal to dialectical notions from the very outset ([58]. [60]), specifically, in assessing the counter-factual statements or engaging in the counter-factual reasoning which plays a crucial role in western society. Following this, it is fair to say that East Asians adhere to the non-western pattern. Ben Goertzel makes a similar statement as follows:

> "[...] After all, every Chinese mathematician uses reductio ad absurdum, a theorem-proving strategy which is explicitly counterfactual in nature. Obviously, Chinese mathematicians develop a mental 'schema' for applying counterfactual reasoning to mathematical statements. [...] My informal survey indicated that Chinese people, even those who speak reasonable English, are simply not comfortable thinking counterfactually about commonplace situations. Counterfactual reasoning in mathematical proofs would seem to be, psychologically, a different "routine" from counterfactual reasoning regarding politics and everyday life. This is an intriguing example of mental 'modularization'. Just as a person who reasons logically about chess need not reason logically about her boyfriend's activities, a person who reasons counterfactually in mathematics need not reason counterfactually about commonplace real-world events." ([38], pp. 92–93)

Interestingly, the birth of "paraconsistent logic" in modern formal logic displays similar ideas found in the thoughts of East Asians ([62], [66], [72]). Further, the path taken by paraconsistent logic is similar to that taken by dialectics, namely, both attempt to overcome or transcend two contradictions in a situation instead of attempting to resolve them. Hence, within the cultural-psychological context, while logic is treated as a cognitive process, the details of the story of logic are completely different from what we learn in our first course on formal logic. In contrast, the development of formal logic tries to capture the ordinary truth of statements and intuitive validity of arguments by means of treating logical forms suitably.

A philosophical criticism about Tarski's model theory which plays an important role in modern formal logic has been presented by John Etchemendy, namely that Tarski's model-theoretic definition with representational semantics which equates the logical truth of a sentence with the ordinary truth of another sentence is misleading ([29]). The moral that we can learn from such a reflection might be: the mere truth

expressed in such (western) development of logical studies can, in general, guarantee nothing more than the truth of its logical forms. It cannot further guarantee that we will have all intuitive validity and ordinary truth of statements. More specifically, it cannot guarantee that those formal logical distinctive features that were usually thought to capture logical truth properly will capture the common, daily, run-of-the-mill truths, whether from proof-theoretic or model-theoretic perspectives.

As a matter of fact, people do not always think of truth in the formal logical way, and our ordinary concept cannot be fully captured only in the way of relativizing a completely formal methodological selection. Nevertheless, to mention this non-western pattern of thought supports the notion that the truth of the ordinary statements did not completely depend on the specific meanings of the selections of formal methods in practices, especially to East Asians. For the Universal Logic project as a mathematical theory, which is connected with Universal Algebra, it seems to be reasonable to develop such kind of meta-study by employing psychological techniques to logic, especially since the idea of a universal logic system has taken the same term "universal logic" but with an opposite meaning.

The two ideas of "universal logic": the Universal Logic project and a universal logic system are born from entirely different academic research and can be distinguished from each other. Nevertheless, the succession of the Universal Logic project that expresses a general theory of logics comes from a series of studies on paraconsistent logics ([11]) in which the underlying thought rejects the principle of explosion, also known as *ex falso quodlibet* or *ex contradictione sequitur quodlibet*, meaning "from a contradiction, anything follows" which is the opposite to the western tradition.[12]

4.2 Cognitive Instrumentalism in Logic

As we have seen, two modes of cognitive processes are observed in cultural psychology: the dialectic logical mode and formal logical mode, where the conception that logic as a cognitive process is a common assumption. Thus, by adopting a position of taking logic as the cognitive process through which basic beliefs about the nature of the world are formed, there is such an analogy in Claude Lévi-Strauss's classic *The Savage Mind (La Pensée sauvage)*: when people endeavor to solve the problems of daily life, it is likened to craftsmen with a cognitive toolkit which provides them with tools to create their piece of art; different cultures reflect different preferences regarding their choice of tools and their mastery in making such a choice, as well as the skills and the appropriateness

[12]The principle of explosion: Call $\models$ is explosive if it validates $\{\varphi, \neg\varphi\} \models \psi$ for every φ and ψ. Paraconsistent logics can be defined in the most general sense as any logic with a non-explosive consequence relation. A branch of paraconsistent logic called dialethesim argued that there is a view that some contradictions are true, i,e, there are sentences, statements, propositions, or anyone taking to be truth-bearers φ, such that both φ and $\neg\varphi$ are true.

of the timing associated with their choices. Similarly, in Nisbett and Norenzayan's words:

> [...] actual possession of particular cognitive processes may differ across cultures in that different cultures may invent com- posite cognitive structures out of universal primitive ones, thus performing feats of cognitive engineering, as suggested by Dennett's (1995) characterization of culture as a 'crane-making crane' [...] As the mutual interdependence of culture and cognition becomes better understood, "crane-made cranes" such as these will tell us much about the cultural foundations of the cognitive tools of everyday life [...]" ([56]).

Hence, according to [56], [57], [58], there are two representative world-views or reality-views: the holistic world-view and analytic world-view. On one hand, if the world (reality) is largely determined by the relationships between objects and events, then the ability to observe all important elements in the surroundings, the relationships between these elements, and the relationship of the part with the whole is important. For the time being, the development of the process of attention, perception, and reasoning focuses on identifying important events and distinguishing the complicated relationship between events. On the other hand, if outcomes are significantly determined by objects' behaviors which are, in turn, significantly determined by rules and categories, then the ability to identify objects by distinguishing them from their surroundings and their contexts as well as their abilities to infer the rules and categories to which they belong assumes importance. Depending on how to consider the world (reality) functions, the processes of cognition would then involve the development of the corresponding abilities.

By the analogy that logic is seen as a cognitive tool, then dialectics is a key tool in the toolbox for the East Asian. Before we can address the issue of the role of dialectics in various empirical sciences, such as cultural psychology, it is important to discuss the attitude of the East Asian to *contradiction*. With no preference for using formal logic, the East Asian does not look for ways to *resolve* contradiction but rather *facilitates the transcending* (or synthesizing) of all contradictory situations. Emphasizing these transcending and synthesizing contradictions opens up a promising avenue for assessing these contradictions. Further, they may accept some opinions that are not consistent or harmonious, but facilitate *edification* and *enlightenment*. Following up the aforementioned statements about cognitive processing, a further investigation was made that East Asians are more likely to prefer proverbs that explicitly contain contradictory meanings within them (see [56]). For example, "too humble is half-proud". On the contrary, the Westerner is more likely to prefer proverbs that are free of contradictions. For example, "one against all is certain to fall".

Another challenge posed in [56], [58] pertains to the East Asian's infrequent reliance on formal logic and a greater reliance on experiences in the process of reasoning

compared to the Westerner. Experience is the dimension that culture in the East Asian stresses should not be ignored, although we will not call this the principle of experience. Moreover, other studies reveal that the East Asian has maintained such tendencies nowadays (see e.g. [56], [59]).

We can now consider the abstraction of various principles that govern dialectics, even at the risk of violating its very spirit that no *explicit rules* should be associated with dialectics. Clearly, there are at least three principles concerning dialectics that we can endorse without hesitation. First is the simple principle of the nature of reality, *the principle of change*: ([56], [58])

(a) The Principle of Change (1) The nature of reality is that of constant change, that is, reality is a dynamic and changeable process; (2) a thing will not resemble itself over time because of the fluid nature of reality.

Second is a principle, so to speak, *about logic*

(b) The Principle of Contradiction Oppositions, paradoxes, and anomalies are continuously being created. Thus, the old and new, the good and bad, the strong and weak coexist and are dependent on each another for their existence.

This second principle follows from the fact that reality is not precise or cut-and-dried but is full of contradiction ([60], p. 743). The third principle follows from the second principle.

(c) The Principle of Relationship Nothing either in human life or nature is isolated or independent; instead, everything is connected.

Principle (a) puts forth the East Asian worldview, principle (b) expresses the consequence of the constantly changing nature of the world, and principle (c) explains that due to the nature of reality, which is characterized by change and opposition, in order to meaningfully consider a part, it is essential to consider its relationship with other parts and with the whole as well. Clearly, if these three principles could accurately characterize dialectics or the dialectic logic mode, then it would also be easy to understand the deep-seated reasons for and the effect of culture on the preference of attempting to build a universal logic system to unify the various logics that have been described ([42]).

Of course, the accounts above take some formalization to be relativized to a sort of cognitive mode, of *logical mode*, and so the underlying principles will be a somewhat formulation of the observations in East Asian cultures, histories, and societies. There is a single way these principles might go, and we will consider this in due course. In relation to experience, it is important to see that the East Asian bases their accounts on this rather unlikely principle, in some form or other.

Indeed, the substantial technical and mathematical attraction of the modern account of various logic applications, e.g. many-valued logic, paraconsistent logic, and fuzzy logic that are widespread in the East Asian is mainly derived directly from principles (a) and (b). This is an important selling point for the account of dialectics. Assuming the above-mentioned observations are right, it is experience that allows the direct application of well-known ideas for defining *truth* to the task of defining "logical truth" in the various widespread logical systems mentioned here. This is a tremendous advantage, one we should not undervalue. Furthermore, it is an advantage not well-shared by Westerners. As Nisbett states:

> "It is precisely because the Chinese mind is so rational that it refuses to become rationalistic and... to separate form from content." ([48] and [56], p. 165)

5 Comparisons

In brief, mathematical formal logic (rigid logic) is a kernel within C-UniLog, whereby various flexible logics can be changed arbitrarily according to the application requirements. By introducing a dialectical mechanism into mathematical logic, He et al. create a flexible mathematical logic. Thus, it becomes necessary to adjust the foundation of mathematical logic.

In the literature, the development of C-UniLog is based on two main characteristics: the continuity of the domain and controllable propositional connectives operations, and attempts to develop a logic to deal with all pragmatic circumstances. Proponents of C-UniLog realize that their subject has important implications for empirical sciences. The question as to how to introduce dialectics to mathematical logic is technically sophisticated. Here, only the main steps of this approach may be summarized as follows:

- First, abstract the truth value range for flexible logics, operation model clusters of flexible propositional connectives and flexible quantifiers from the real world.
- Second, prove the logical properties with respect to these operation model clusters to build flexible propositional (quantifier) logics.
- Third, abstract the mathematical theories pertaining to these flexible logics.

According to He et al., mathematical logic is only one specific form in all possible transformations (infinite and are changeable) of mathematical dialectic logic.

In addition to this, it will be helpful to discuss the conception of logic they hold:

- Logic is a sort of criterion or device that can be applied for judging and regulating doctrines and theories. Logic can be found in all doctrines and theories by

abstracting and extracting judgments and deductive rules. It cannot stand alone outside the development of doctrines and theories ([42], p. 1).

- Theories should conform to the logics that they own.
- An existing logic needs to be refined or expanded; otherwise, it must be able to explain new scientific theories and discoveries.

A meta-analysis about logic may be carried out by reviewing the differences between a large extent of the Universal Logic project and C-UniLog. As we have seen, apart from supporting the classicalism of AI, He et al. aimed to develop a continuous and controllable logical system such that it is possible for it to be developed as a logic for dealing with different possible cases.

5.1 The first comparison:

Recalling the motivation for developing one universal logic system, perhaps it is not a coincidence that Béziau also claimed that modern logic should not be limited (In the Preface of [9], p. 1):

> "Modern logic can be divided in set theory, proof-theory, recursion theory and model theory, these four disciplines have developed in that order in the history of modern logic, and they can be considered as the core of mathematical logic. They are the core of mathematical logic. But modern logic does not limit to this. There is also philosophical logic. One important aspect of philosophical logic is the study of non-classical logic."

Both He et al. and Béziau proposed that modern logic should not be limited, albeit their meaning of "limitation" is different. He et al. observed that "three laws and CE" limit modern logic and prevent modern logic from describing the real world. Béziau, however, observed that modern logic is limited, stating "mathematical logic is not the whole of modern logic" and "modern logic does not refer to mathematical logic only". Although Béziau stated that "being more mathematical" is a core feature of modern logic, which is opposite to traditional logic (ibid, p. 1), he believes that modern logicians studying "mathematical reasoning" should consider mathematical studies on reasoning and this can further be extended to other philosophical studies. Béziau stated as follows (ibid, p. 1):

> "many-valued and modal logics can be considered as part of philosophical logic because they have motivations and applications related to philosophy... the study of mathematical reasoning itself has led to the development of

> non-classical logics such as intuitionistic logic. The expression 'mathematical logic' is ambiguous because it can mean the study of mathematical reasoning and/or the mathematical study of reasoning. It seems reasonable to understand mathematical logic mainly in the second sense which includes the first sense."

Unlike He et al.'s revised method on mathematical logic, Béziau proposes that modern philosophical logics should be viewed as enhancing mathematical logic. As a result of this, Béziau puts forward the idea of Universal Logic. What He et al. and Béziau are developing are similar but different revisions of modern logic and each put forward their ideas on Universal Logic in their own right.

5.2 The second comparison:

As we have seen, He et al. aim to use flexible and changeable logics that include mathematical logic as their rigid aspect to solve all uncertain and contradictory situations in AI. Moreover, they claimed that humans nowadays face relatively different issues than those which occur in modern science. In this section, we will provide the second comparison by considering different concerns about mathematical logic.

In ([40], p. 89), He et al. states that mathematical logic is insufficient for addressing these new circumstances:

> "The second issue, representing a problem in the real world as a closed, completed, static and binary problem, is a relative simple one with which people have been faced for almost 300 years. Classic mathematical logic was established for matching the needs of disciplines like mathematics, mechanics, astronomy, physics, and chemistry. Such needs had also been confirmed in the subsequent science fields like principle of relativity, quantum mechanics, molecule biology, nuclear energy, computer science and space technology. The characteristics of these systems are that they are mechanical systems, and most of the information in these systems are explicitly defined and accurately measured if some non-primary factors can be ignored or certain proximateness can be achieved. Because of these, these systems are suitable to be represented by classical mathematical logic. But in recent 50 years, some disciplines that a complex and uncertain in nature, such as life science, social science, and intelligence sciences, have become increasingly important. The objects in these disciplines often are fuzzy or chaotic without any clear boundary. Neither explicitly judgement, precise measurement nor accurate predication can be achieved easily for them, so classic mathematical logic is not suitable for resolving the issues."

Undoubtedly, all those modern sciences mentioned by He et al. use *reasoning* to develop their theories and to understand *some (particular) reasoning* in their theories. In this way, building up a logic for a specific subject of science, particularly a more mathematical one, has been considered to be reasonable work. However, with the development of various increasingly important disciplines, classical mathematical logic becomes defective and insufficient when addressing some new subjects in modern science.

Béziau made a similar observation about AI in [12], p. 140, where he stated that the trend of Universal Logic gained prominence in the 1980s when more "practical" questions in the new development of different fields, such as AI, linguistics, and computer science, were raised. Further, he stated:

> "[...] universal logic plays a crucial role with respect to AI, expert systems and automated reasoning, since it helps to develop systems adapted to the most various data: that is called 'logical engineering'. ... universal logic is not cut off from reality, as is the case of Aristotelian syllogistic of first-order logic. It is a useful theory." ([12], p. 147)

Béziau uses a *diagnosis-tool* metaphor to elucidate the role of Universal Logic as follows:

> "universal logic allows understanding some particular reasoning in supplying one with a tool box that serves to construct a logic accounting for that sort of reasoning." ([12], p. 146)

5.3 The third comparison:

Béziau believes that no specific logic can be adapted to every situation and every problem; in other words, "there is no miraculous universal logic" ([12], p. 147). This is considerably different from the basic idea shown in He et al.'s C-UniLog. The idea of a "one universal logic system" should be discussed, particularly with regard to the motivations and the relationship with Béziau's universal logic.

As mentioned in the previous sections, He at al. aim to develop a *continuous* and *controllable* logical system, such that it is possible for it to be developed as a logic for dealing with different possible cases. However, as claimed by He et al., "probability theory", "fuzzy logic", and "triangular norm theory" are three possible theories that have ever been considered be a universal logic system in the literature, i.e., a logic system that can be applied to every circumstance ([43], [86], [87]).

According to He et al., probability theory is a logical system with a continuous truth value, which introduces the continuous changeability of variables, AND-operation and OR-operation.[13] It successfully demonstrates the changeability of these two operations

[13]This paragraph is taken from the words and ideas expressed in [43], pp. 76-77.

in three principles: *principles of minimal correlated*, *maximal correlated*, and *independent correlated*. However, it fails to be a universal logic system, since it fails to develop the *changeability* of the OR-operation and the AND-operation in a general case. They further claimed that the probability theory is just a special instance of one universal logic system. In discussing fuzzy logic, they provided a very similar reason, which states that fuzzy logic develops the continuous changeability of the OR-operation and the AND-operation but it only admits the principle of maximal correlation. Thus, it fails to be developed as a universal logic system. Similarly, they claimed that fuzzy logic is just a special instance of one universal logic system. In addition to this, they observed that the triangular norm theory has been introduced to study the changeability of the OR-operation and the AND-operation and to determine the different operation models of the OR-operation and the AND-operation, based on the three above-mentioned correlation principles. However, they stated that the triangular norm theory fails to be a successful universal logic system, because nobody has ever connected it with a controllable continuous logical system in the literature.

In summary, He et al. believed that these three theories can be possibly developed into a universal logic system. However, we raise the following questions: "Is obtaining a universal logic system a common goal for these three theories in their own development in the history?" As seen in [40] and [43], to develop such a universal logic system to deal with all possible circumstances is an ongoing work, based on two main characteristics, "the continuity of the domain" and "controllable propositional connectives operations". It seems that, when they considered these three theories/logics had failed to become "one universal logic system", they inadvertently considered their idea of universal logic as a standard and assumed that this C-UniLog would become a successful universal logic. However, in the literature, it has not been claimed these three theories/logics have achieved the goal of becoming one universal logic system. Furthermore, let us consider the following case: "these three theories/logics should be universal logic systems if and only if all their mentioned defects are improved". For example, if the probability theory achieves the continuous changeability of the OR-operation and AND-operation in a general case, it seems that these aforementioned reasons, which motivated He et al. to develop one universal logic system, can be resolved by revising probability theory. If so, probability theory could become "one universal logic system", so there is no advantage of creating "a new" universal logic system from this point of view. The other two theories can be improved in a similar way. Thus, we ask: "do we still need He et al.'s C-UniLog?"

From the citation given below, we may able to realize the basic stance that He et al. held for developing such a universal logic system.

> "From the level on which that Universal Logic stands, it is easy to see the successes and defects of other logical systems." (This quotation is translated from [43], p. 76.)"

One aim of building such a universal logic system is to study all other logical systems already known in the literature. Such a universal logic system actually stands at a meta-logical level. Thus, we suggest taking He et al.'s idea about "one universal logic system" as a **metatheory** that relates to probability theory, fuzzy logic, and triangular norm theory. It seems more reasonable to treat C-UniLog as a metatheory, even though C-UniLog was proposed in competition to these three theories. Furthermore, if C-UniLog is taken as a metatheory, this will mean that it is not be trivialized. In this case, C-UniLog seems to be acceptable in the western sense of modern mathematical logic.

Our suggestion may have also been found in He et al.' s own words: "universal logic is just a theoretical framework, containing and integrating various rigid logics and/or flexible logics" ([40], p. 83). Again, it is claimed that the primary function of their theory is to flexibilize mathematical logic. This is why we suggest that their C-UniLog, due its primary motivation, could be realized as a meta-theory. One would understand clearly why a universal logic system cannot not be "a logical system". Consider the following statement: for any logical system l, there is a logical system L containing all ls, so we ask: "how about L per se?

Unless L is a logical system, which is claimed to "contain all logical systems", it is allowed to include itself, otherwise it is not possible that L is a *logical system* with the properties of containing all logical systems. More specifically, it is not reasonable to claim that there is "a logical system", containing all logical systems under the condition of realizing "this logical system" as a logical system as well. Thus, if flexible mathematical logics were placed at the same high level as being "a logical system", this flexible mathematical logics would encounter a *self-reference problem*.

We doubt that it is reasonable to expect to find one "miracle" logic for every different situation to find a "miracle" logical system, containing all logical systems. In our opinion, from a western logical point of view, it is necessary to thoroughly revise He et al.'s theory for it to be a reasonable theory. Similarly, Béziau has always rejected the possibility of the existence of one universal logic which accounts for everything:

> "Let us immediately reject some misunderstanding; universal logic, as I understand it, is not one universal logic. In fact, from the viewpoint of universal logic, the existence of one universal logic is not even possible, and this is a result that can easily be shown. One might thus say, somehow ironically, the following: according to universal logic there is no universal logic ([12], p. 133).

However, He et al.'s idea on one universal logic is not "a logic" in the western sense of logic. In contrast, the idea of forming a flexibilized mathematical logic, which renders mathematical logic itself as a loose theory, particularly being a "logical system" in a pan-Chinese sense, will cause us to build more theories of studying problems occurred in reality. Thus, it is fair to say that if people are able to start from a pan-Chinese

holistic culture and systems of thought, that is to regard things as whole, then it might be easier for them to realize why this kind of "logical system" which includes itself, is acceptable without being trivialized.

From the western logical point of view, although it is considerably arbitrary to claim to have found a logical system that contains all logics, He et al. have asserted humbly as follows: ([43], p. 76.)

> "[...] Universal logic has only been proposed recently, so many related questions have to be studied. But the continuity of its domain and 'continuous-controllable' logical systems will make it possible that it could be developed as a logic containing all logics, so we named it universal logic. [...]"

Apparently, if He et al.'s C-UniLog is able to be expanded, it should be a meta-theory. Otherwise, we should arbitrarily realize it in the western sense of logic.

6 Conclusion and Outlook

In the theme of the journal *Logica Universalis*, Special Issue "Is logic universal?", the Universal Logic project has caused linguists, logicians and philosophers to raise this question again (see [26]). People who have intersected the realms of culture psychology with this question will follow up different cultural psychological work to study how to interpret this general question. For example, in cross-cultural psychology, people addressed the question: Is there a *universality* of the modes of cognitive processes?

This is similar to "logic as algebra" in algebraic logic, which pertains to mathematical enterprises, and "logic as structure" in structuralism, which pertains to philosophical enterprises, and "logic as a cognitive process" which pertains to cognitive scientific or psychological enterprises. The cultural psychological assumption that logic is taken as the cognitive process will enlarge our perspectives of studying logic, in particular about the concept of "Universal Logic" per se.

Logical pluralism, where it is believed that there is no one true logic, nor is there one true model theory, has been in vogue since Beall and Restall's work ([1], [2]). It has already been described in some application-oriented research ([46], [53]). This seems to be a possible philosophical position that could be taken by the Universal Logic project. Following this, we address two intricately linked questions by referring to the five specific questions that were addressed in the Special Issue of the *Logica Universalis* as follows:

- Is it correct to claim the singularity of logic?
- Is there a universality in the mode of cognitive processes?

To adopt the aforementioned cultural psychological viewpoint, that is "logic as a cognitive process", our answer should clearly be "no". Nonetheless, this answer does not in any way reject "universality" in the other sense, where universality pertains to various objective and systematic scientific findings for common features for the cognition of *Homo sapiens*. However, it does not presuppose that there is a unique way of reasoning or one mode of cognitive process. **Universal Logic** could be not 'universal' in the light of culture.

References

[1] Beall, J.C., Restall, G. (2006) Logical Pluralism, Oxford University Press

[2] Beall, J.C., Restall, G. (2000) Logical Pluralism. Australasian Journal of Philosophy 78:4, 475–493

[3] Baten, D. (2007) A Universal Logic Approach to Adaptive Logics, Logica Universalis, 1:1, 221–242

[4] van Benthem, J. (1979) What is Dialectical Logic? Erkenntnls 14: 333–347

[5] Beth, E. W., Piaget, J. (1966) Mathematical Epistemology and Psychology. Dordrecht: D. Reidel

[6] Béziau, J.-Y. (2012) Universal Logic: An Anthology From Paul Hertz to Dov Gabba, Birkhäuser, Basel.

[7] Béziau, J.-Y. (2010) Logica Universalis: Special Issue: Is Logic Universal? 4:2

[8] Béziau, J.-Y. (2010) Preface: Is Logic Universal? Logica Universalis, 4:2, 161–162

[9] Béziau, J.-Y. (2007) Preface, Logica Universalis, 1, 1–2

[10] Béziau, J.-Y. and C.-Leite A. (2007) Handbook of the Second World Congress and School on Universal Logic, UNILOG'07, August 16th-August 22th, Xi-an, China

[11] Béziau, J.-Y. (2007) From Consequence Operator to Universal Logic: A Survey of General Abstract Logic. In: J.-Y.Beziau (ed.) Logica Universalis, 2^{nd} edition, Birkhäuser, Basel, pp. 3–17

[12] Béziau, J.-Y. (2006) 13 Questions about Universal Logics, Bulletin of the Section of Logic 35: 2/3, 133–150

[13] Béziau, J.-Y. (2005) Logica Universalis: Towards a General Theory of Logic, Birkhäuser, Basel

[14] Béziau, J.-Y. (2005) From Consequence Operator to Universal Logic: A Survey of General Abstract Logic. In: J.-Y. Beziau (ed.) Logica Universalis, Birkhäuser, Basel, pp. 3–17

[15] Béziau, J.-Y. (2001) Sequents and Bivaluations, Logique et Analyse, 44, 373–394

[16] Béziau, J.-Y. (2001) From Paraconsistent Logic to Universal Logic, Sorites, 12, 5–32

[17] Béziau, J.-Y. (2000) What is paraconsistent logic? In: D. Batens et al. (eds.) Frontiers of paraconsistent logic, Research Studies Press, pp. 95–111, Baldock

[18] Béziau, J.-Y. (1999) La véritable portée du théorème de Lindenbaum-Asser, Logique et Analyse, 167/168, 341–359

[19] Béziau, J.-Y. (1999) A sequent calculus for Łukasiewicz's three-valued logic based on Suszko's bivalent semantics, Bulletin of the Section of Logic, 28: 2, 89–97

[20] Béziau, J.-Y. (1997) What is many-valued logic? In: Proceedings of the 27th International Symposium on Multiple-Valued Logic, IEEE Computer Society, Los Alamitos 117–121

[21] Béziau, J.-Y. (1997) Logic may be simple. Logic and Logical Philosophy, 5, 129–147

[22] Béziau, J.-Y. (1995) Recherches sur la logique universelle (Excessivité, negation, séquents), Ph.D., Department of Mathematics, University of Paris 7

[23] Birkhoff, G. (1987) Universal Algebra. In: Rota, G.-C. and Oliveira, J. S. (eds.), Selected Papers on Algebra and Topology by Garret Birkhoff, Birkhäuser, Basel, 111–115

[24] Bourbaki, N. (1950) The Architecture of Mathematics, The American Mathematical Monthly, 57:4, 221–232

[25] Carnielli, W., Coniglio M., D'Ottaviano I (2009) New Dimensions on Translations Between Logics, Logica Universalis, 3:1, 1–18

[26] Corry, L. (1992) Nicolas Bourbaki and the concept of mathematical structure, Synthese, 92:3, 315–348

[27] da Costa, N. C. A., Béziau, J.-Y., Otávio A. S. B. (1996) Malinowski and Suszko on Many-valued Logics: On the Reduction of Many-valuedness to Two-valuedness, Modern Logic 6: 3, 272–299

[28] da Costa, N. C. A., Alves, E. H. (1977) A semantical analysis of the calculi Cn, Notre Dame Journal of Formal Logic, 16, 621–630

[29] Etchemendy, J. (1999) The Concept of Logical Consequence, Center for the Study of Language and Informat Publisher

[30] Etchemendy, J. (1988) Tarski on Truth and Logical Consequence, The Journal of Symbolic Logic, 53:1, 51–79

[31] Gabbay, D. M., Woods, J. (2001) The New Logic, Logic Journal of the IGPL, 9:2, 141–174

[32] Gabbay, D. M. (1994) What is a logical system?, Oxford University Press

[33] Gabbay, D. M. (1990) Editorial. Journal of Logic and Computation

[34] Gentzen, G. (1934) Untersuchungen über das logische Schließen. I. Mathematische Zeitschrift 39:2 176–210

[35] Goguen, J. and Roşu, G. (2002) Institution Morphisms. Formal Aspects of Computing 13: 274–307

[36] Goguen, J. A., Burstall, R. M. (1992) Institutions: Abstract Model Theory for Specification and Programming, Journal of the ACM, 39: 95–146

[37] Goguen, J. A., Burstall, R. M. (1984) Introducing institutions. In: E. Clarke and D. Kozen (eds.) Proc. Logics of Programming Workshop, LNCS, 164: 221–256

[38] Goertzel B. (1994) Chaotic Logic: Language, Thought, and Reality from the Perspective of Complex Systems Science (IFSR International Series on Systems Science and Engineering), Springer

[39] Hajeck, P. (1998) Metamathematics of Fuzzy Logic. Dordrecht: Kluwer

[40] He, H.-C. (2007) Philosophical Significance of Universal Logic – On Second Revolution of Mathematical Logic, In Béziau, J-Y. and C.-Leite A. (eds.) Perspectives on Universal Logic, pp. 83–100, Polimetrica International Scientific Publisher Monza/Italy

[41] He, H.-C., Ai, L.-R., Wang, H. (2007) Mathematics Trend in Dialectical Logic, Journal of Hechi University, 27:1, 6–11

[42] He, H.-C. (2005) Principle of Universal Logic. Science Press

[43] He, H.-C., Liu Y.-H., and He, D.-Q. (1996) Universal Logic in Experiential Thought, Science in China (Series E), 26, 72–78

[44] Jacquette, D. (2003) Philosophy, Psychology, and Psychologism: Critical and Historical Readings on the Psychological Turn in Philosophy (Philosophical Studies Series), Springer

[45] Kusch, M., "Psychologism", The Stanford Encyclopedia of Philosophy (Winter 2011 Edition), Edward N. Zalta (ed.), http://plato.stanford.edu/archives/win2011/entries/psychologism/

[46] Kutz, O., Mossakowski T., and Luecke, D. (2010) Carnap, Goguen, and the Hyperontologies: Logical Pluralism and Heterogeneous Structuring in Ontology Design, Logica Universalis, 4:2, 255–333.

[47] Johnson-Laird, P. N., Lee, N. Y. L. (2006) Are there cross-cultural differences in reasoning? Proceedings of the 28th Annual Conference of the Cognitive Science Society, pp. 459–464

[48] Liou, S.-H. (1974) The Use of Analogy and Symbolism in Traditional Chinese Philosophy, Journal of Chinese Philosophy vol. i, no. 3/4 : 313–338

[49] Malinowski, G. (1993) Many-Valued Logics. Oxford Logic Guides 25, Clarendon Press, Oxford

[50] Massad, E., Regina, N., Ortega, S., Barros L. C., Struchiner, C. J. (2009) Fuzzy Logic in Action: Applications in Epidemiology and Beyond (Studies in Fuzziness and Soft Computing), Springer

[51] Marquis, J.-P., "Category Theory", The Stanford Encyclopedia of Philosophy (Spring 2011 Edition), Edward N. Zalta (ed.), http://plato.stanford.edu/archives/spr2011/entries/category-theory/

[52] Mortensen, C. (1995) Inconsistent Mathematics, Dordrecht: Kluwer

[53] Mossakowski, T. and Kutz, O. (2011) The Onto-Logical Translation Graph. In: Kutz, O. and Schneider, T. (eds.) Proceedings of the Fifth International Workshop on Modular Ontologies, Frontiers in Artificial Intelligence and Application, IOS Press, pp. 94–109

[54] Mossakowski, T., Goguen, J., Diaconescu, R., Tarlecki, A. (2007) What is a Logic? (revised version) In: Béziau, J.-Y. (ed.), Logica Universalis, pp. 111–133, Birkhäuser Verlag Basel

[55] Mossakowski, T., Goguen, J., Diaconescu, R., and Tarlecki, A. (2005) What is a Logic? In: Béziau, J.-Y. (ed.), Logica Universalis, pp. 113–133. Birkhäuser Verlag Basel

[56] Nisbett, R. (2003) The Geography of Thought, Free Press

[57] Nisbett, R. Norenzayan, A. (2002) Culture and Cognition. In: Pashler, H. and Medin, D.L. (eds.), Stevens' Handbook of Experimental Psychology, Memory and Cognitive Processes, vol. 2, 3^{rd} Edition, pp. 561–596. Also see: `http://onlinelibrary.wiley.com/doi/10.1002/0471214426.pas0213/full`

[58] Nisbett, R. Peng K.-P., Choi I., and Norenzayan, A. (2001) Culture and Systems of Thought: Holistic Versus Analytic Cognition, Psychological Review, 108:2, 291–310

[59] Norenzayan A., Smith E., Kim, B. J., and Nisbett, R. (2002) Cultural preferences for formal versus intuitive reasoning, Cognitive Science 26: 653–684

[60] Peng, K.-P. and Nisbett, R. (1999) Culture, Dialectics, and Reasoning: About Contradiction, American Psychologist, 54:9 741–754

[61] Priest, G. (2008) An Introduction to Non-Classical Logic: From If to Is, 2^{nd} edition, Cambridge University Press

[62] Priest, G. (2007) Paraconsistency and Dialetheism. In: Gabbay, D. and Woods, J. (eds.) Handbook of the History of Logic, vol. 8, pp. 129–204, Amsterdam: North Holland

[63] Priest, G. (2006) Doubt Truth to be a Liar, Oxford University Press

[64] Priest, G. (2006) In Contradiction: A Study of the Transconsistent, 2^{nd} edition, Oxford University Press

[65] Priest, G., Beall, J.C., Bradley, A.-G. (2004) (eds.) The Law of Non-Contradiction, Oxford: Oxford University Press

[66] Priest, G. (2002) Paraconsistent Logic. In: Gabbay, D. and Guenthner, F. (eds.) Handbook of Philosophical Logic (2^{nd} Edition), vol. 6, pp. 287–393, Dordrecht: Kluwer Academic Publishers

[67] Priest, G. (2001) An Introduction to Non-Classical Logic, Cambridge University Press

[68] Priest, G. (2001) Logic: One or many? In: Woods J. and Brown B. (eds.), Logical Consequences: Rival Approaches, 23-38, Oxford, Hermes Scientific Publishers

[69] Priest, G. (2000) Inconsistent Models for Arithmetic: II, The General Case", The Journal of Symbolic Logic, 65, 1519–29

[70] Priest, G. (1997) Inconsistent Models for Arithmetic: I, Finite Models, The Journal of Philosophical Logic, 26, 223–235

[71] Priest, G. (1989) Dialectic and Dialetheic, Science & Society, 53: 4, 388–415

[72] Priest, G., Routley, R., Norman, J. (1989) (eds.) Paraconsistent Logic: Essays on the Inconsistent, München: Philosophia Verlag

[73] Routley, R. (1979) Dialectical Logic, Semantics and Metamathematics, Erkenntnis 14: 301–331

[74] Routley, R., Meyer, R. K. (1976) Dialectical Logic, Classical Logic, and the Consistency of the World, Studies in Soviet Thought 16: 1–25

[75] Seok B. (2007) Change, Contradiction, and Overconfidence: Chinese Philosophy and Cognitive Peculiarities of Asians, Dao, 6:3, 221–237

[76] Da Silva Lopes, H.F., Abe J. M., and Anghinah, R. (2010) Application of Paraconsistent Artificial Neural Networks as a Method of Aid in the Diagnosis of Alzheimer Disease, Journal of Medical Systems, 34:6, 1073–1081

[77] Suszko, R. (1975) Remaries on Łukasiewicz's three-valued logic. Bulletin of the Section of Logic, 4, 87–90

[78] Tanaka, K. (2003) Three Schools of Paraconsistency, Australia Journal of Logic, 1

[79] Tarski, A. (1935) Grundzüge des Systemenkalküls. Erster Teil. Fund. Math., 25, 503–526. English translation appears in [82]

[80] Tarski, A. (1935) "Über einige fundamentale Begriffe der Metamathematik" Comptes Rendus de la Société Des Sciences et des Lettres de Varsovie, Classe III 23, 23-29, repr. In Tarski (1986a), vol. I, pp. 311–320. English translation appears in [82]

[81] Tarski, A. (1935) "Fundamentale Begriffe der Methodologie der deduktiven Wissenschaften I", Monatshefte für Mathematik und Physik 37, 361-404; repr. In: Tarski (1986a), vol. I, pp. 341–390. English translation appears in [82]

[82] Tarski, A. (1983) Logic, Semantics, Metamathematics, Papers from 1923 to 1938, trans. by J. H. Woodger, 2^{nd} edition with an Introductory Note by J. Corcoran, Hackett, Indianapolis, IN

[83] Tsuji, M. (1998) Many-Valued Logics and Suszko's Thesis Revisited, Studia Logica, 60:2, 299–309

[84] Vasyukov, V. L. (2007) Structuring the Universe of Universal Logic, 1:2, 277–294

[85] Wang, P. (2006) Rigid Flexibility: The Logic of Intelligence (Applied Logic Series), Springer

[86] Wang, W.-S. and HE, H.-C. (2005) Research and Analysis of Probability Logic based on Universal Logic, Journal of Computer Research and Development, 42:7, 1204–1209 (in Chinese with English abstract)

[87] Wang, W.-S. and HE, H.-C. (2005) Research on Flexibility of Logic Relation Based on Universal Logics, Journal of Software, 16:5, 754–760 (in Chinese with English abstract)

[88] Wansing, H., Shramko, Y. (2008) Suszko's Thesis, Inferential Many-Valuedness, and the Notion of a Logical System, Studia Logica, 88: 3, 405–429

[89] Zadeh, L. A. (1965) Fuzzy sets, Information and Control 8: 3, 338–353

Tzu-Keng Fu
General Education Center, National Kaohsiung University, Kaohsiung City,
General Education Center, National Pingtung University, Pingtung City,
Center for General Education, Chung Yuan Christian University, Taoyuan City,
Department of Applied Philosophy, Chang Jung Christian University, Tainan City, Taiwan
E-mail: futzukeng@gmail.com