# Towards a Diagnostic Framework for Understanding Complex Situations

**José J. Padilla**
**Andres Sousa-Poza Ph.D**
**Arturo Tejada Ph.D**
**Samuel Kovacic**

Old Dominion University
Norfolk, VA
jpadi002@odu.edu

This paper presents a theoretical framework for the concept of *understanding* and how it can be used for assessing complex situations. Understanding is presented as a cognitive process on how an individual *perceives and represents* a complex domain based on his/her own *predispositions*, and how he/she *selects knowledge* or what *may not be knowledge* based on the same predispositions towards finding a set of solutions for the situation. Predispositions, in this case, are based on his/her epistemological, ontological and teleological biases while the domain is represented by irreducible and transient conditions. The final outcome is the match or mismatch of the profile of the individual and the profile of the domain establishing an understanding profile. Understanding as a construct is based not only on the concept of knowledge as a combination of explicit and tacit, but also with the support and the necessary conditions for the selection of knowledge and what may not be knowledge.

# 1 Introduction

Most efforts of addressing problem domains are based on the exploration of the domain in an epistemic sense. In the technical area, this makes sense given time and resources; the conditions of uncertainty can be overcome with exhaustive search of new and improved technologies. However, when social conditions are studied, issues of irreducibility and transience become pervasive, and yet we continue to employ the same epistemic approach as in the technical domain. Perception of the participant designers/stakeholders also become a key issue and the assumptions is made that people participating have similar capabilities when dealing with complex situations.

It is the concept of complexity that receives the bulk of the focus when dealing with uncertainty and understanding. [Bar-Yam 2005] and [Biggiero 2001] mention that the complexity of a system can be based on the inherent complexity of the system or the capability of the observer to understand the situation. [Kovacic, Sousa-Poza, and Keating 2006] followed up on this and expanded it by defining the concept of complex situations as those formed through the interaction of three major elements: *a domain or entity, solution form, and observer*. The *entity* is what we are trying to understand, *observer* relates to the perception capability of the agent rating the situation, and *solution form* relates to the granularity required by the observer to develop a solution. [Padilla 2007] further elaborates on the model and propose that the model of entity be presented in terms of the *reducibility* and the *transience* of the domain, and *understandability* of the situation that allows for the generation of solution forms which are contingent to the profile of the *observer* that reflects how he/she *perceive* the situation. What this new representation does is that not only reflects the entity of the situation in a temporal and spatial scale, but also associates the solution form to the capability of understanding through the observer's personal profile.

*Reducibility* is defined as the maximum abstraction or maximum analysis obtainable of a situation without changing its nature. Some authors refer to it as decomposability or the capability to analyze and synthesize a system based on its components [Bar Yam 2005.Reducibility of a situation can also be seen as identifying relevant constructs, reducible and irreducible (mostly the second) and how much they can be analyzed [Padilla 2007]; for instance, the inner workings of a clock can easily be analyzed in a systemic sense, whereas concepts such as security, poverty, and culture are not. Most systemic analysis is done under the assumption of stable conditions; *transience* is defined as any change –internally or externally generated change – to the existing reducible/irreducible parameters within a predetermined range of time that alters in any way stable conditions of a situation [Padilla 2007]. [Bell 1989] defines transience as a time dependent system behavior that differs from a long-term system behavior. *Understandability* is the capability of a situation to be understood and it relates to how a particular individual perceives and understand a situation given his/her own predispositions as it evolves in its temporal and spatial dimensions [Padilla 2007], this concept of understanding will be further elaborated later in the paper. Figure 1a and 1b show the domain complexity of complex situations in terms of reducibility and transience. It basically states that the more transient (T) and

irreducible (Ir) a domain is, the higher the uncertainty factor; conversely, the more reducible (R) and intransient (In) the less uncertain. This suggests that complexity may not be solely characterized by the number of elements and relations, but how reducible and transient a domain is. We may have a case of a large number of elements and relations, but relatively simple and vice versa, few elements and relations, but highly complex.

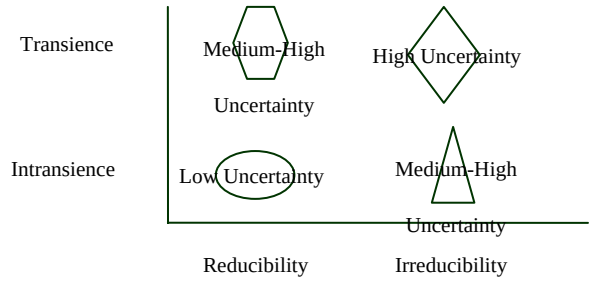


**Figure 1a** : Domain Uncertainty Matrix

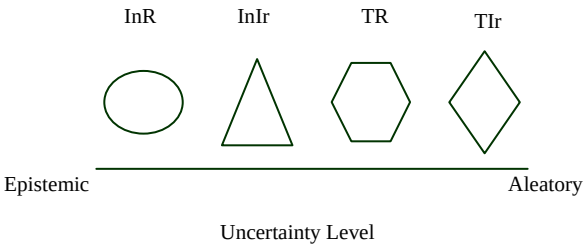


**Figure 1b** : Uncertainty level

Situations, as presented here, are different from problems. A situation can be defined as a not-definable problem because of those irreducible, intransient and perceptual elements, in other words, a problem that has not yet been framed. [Arthur 2000] says that when problems are too complicated to afford solutions or when they are not well-defined, agents face not a problem, but a situation and that to deal with the situation they must frame the problem, and that framing in many ways is the most important part of the decision process. New approaches are needed to better understand problems and assess situations that do not rely solely on analysis and the use of knowledge. Knowledge, being intransient by nature, does not capture the transience of the situation so the premise of full analysis does not apply in conditions where information is lacking or is constantly changing. According to Herbert Simon;

as humans, we make decisions or take actions - in most cases - based on incomplete information to reach satisfactory decisions [Waldrop 1987]. Not everything can be known at a given time, or may be too costly, or simply it is not feasible.

The premise of analysis is that everything can be broken into parts in order for "it" to be understood. The question in this paper is should "it" be broken into parts to gain more understanding? If not, what elements should we consider that do not rely solely on knowledge so we can achieve understanding?

## 2 The Concept of Understanding

Understanding is one of the few terms that is so widely used and yet so little examined in contemporary English-speaking philosophy [Franklin 1981]. Instinctively, people use it as equivalent of knowledge, in terms of *I thought I knew* or *understood*, or as a part of knowing how to do something (process) in terms of knowing that which is involved (substance) [Downie 1962]. According to [Franklin 1981], there are relations between knowledge and understanding. He presents that to *understand* is objective like *know* rather than subjective like *believe*. Artificial intelligence and psychology can be seen as the concept of comprehension; developing a cognitive structure that represents conceptual relationships [Greeno, 1974]. To put it in perspective with learning, according to [Shellens and Valcke 2005] Learning, is "the efficient assimilation of knowledge". Conversely, according to Klahr's definition [Klahr 1974] understanding can be defined as "*the appropriate use of knowledge when appropriate*". There is a great difference between the two; while learning acts as storage of knowledge, understanding acts as a selector of knowledge.

According to [Perkins 1987], there are five characteristics to understanding:

- Relations: Understanding is web-like in how different things relate to each other in terms of relations such as symbol-experience, cause and effect, form-function, part-whole, symbol- interpretation, example-generality, and so on. Also, it relates to "how" it is place in the web that gives meaning.

- Coherence: how well this web of concepts hangs together (do we have broken webs?).

- Standards of coherence reduce the ambiguity and paradoxes to increase level of coherence

- Generativity: the appropriate use of knowledge and movement of concepts out of the boundary where they where learn (not necessarily a totally different domain, but in a different situation within the same domain)

- Open-endness. Is there full understanding? Plainly, it is a never ending quest.

Perkins' perspective is very similar to Greeno's in terms of establishing understanding as a cognitive structure for relationships, but it is Klahr who puts understanding as a smart selector of knowledge giving purpose to that cognitive structure. It also could be suggested that understanding is the appropriate selection of knowledge in order to establish an appropriate cognitive structure representing conceptual relationships. Moreover, understanding could be seen as part of metacognitive processes instead of solely cognitive ones; one individual may have better understanding of a situation than other given the two having similar knowledge about the same situation. As it is suggested this could be the result of understanding being part of not only cognitive processing, but also due to personal attributes that relates more to personality traits than cognitive ones.

Now, it can be easily seen understanding is a cognitive process, but could we also see it as a behavioral predisposition? Campbell references Dummett [Campbell 1982] by presenting this idea within the context of the mastery of a language. Dummett says that understanding is held to be a behavioral matter and that it must provide a behavioral account of what it is to have implicit knowledge. Campbell disagrees with this position on the account of 'while purporting to describe a form of behavior is in fact employing concepts which do not effect any systematic classification of behavior at all'. In this paper we are trying to provide a systematic classification of behavior based on an individual's predispositions, in this case, philosophical predispositions.

In synthesis, it is suggested that understanding encompasses cognitive and metacognitive processes and behavior as well under the premise that for an individual to assess a complex situation not only needs to have the knowledge, but also the capability to appropriately select it and this is contingent on his/her personal predispositions. But, how about if knowledge is lacking and the addition of new knowledge is not creating more understanding ? We want to add another charactestic of understanding that is suppported by its open-endness and is non-monotinicity. According to [Kern-Isberner, G., 2001], *the purpose of non-monotonic reasoning is not to add certain knowledge where there is none, but rather to guide the selection of tentatively held beliefs in the hope that fruitful investigations and good guesses will result.* This definition is consistent with Minsky's point of reasoning by default : humans have the capability of changing conclusions when new information arises [Waldrop 1987]. This means that understanding will give us a range of possible alternatives that individuals can use to address situations when lack of knowledge (or abundance for that matter) is present and would allow us to select appropriate existing knowledge [Klahr 1974] and select tentative beliefs [Perkins 1988] with a final purpose of use [Klahr 1974] towards making a decision or take action about something in a defeasible manner. So taking as a depareture point Klahr's definition it can be said that *understanding is the appropriate selection of knowledge and some elements not considered knowledge (such as beliefs, ideas, loose observations) non-*

*monotonically in order to take action*. This definition requires the elaboration of some constructs that will be discussed in the next subsections.

## 2.2 Knowledge and not-knowledge

Epistemology is the branch of philosophy that deals with the way we seek knowledge, but it focuses on the way we justify "knowledge". In this sense, what we are justifying is a belief that we consider true. Knowledge can then be defined as justified true belief [Plato]. Philosophers have debated about the appropriateness and logic of this definition [Nonaka and Takeuchi 1995], but it is the most widely accepted. A more contemporary description of knowledge, according to [Pollock and Cruz 1999], is "what sets human beings apart from other animals is their capacity for sophisticated thought. This capacity for sophisticated thought is directly related to our cognitive capacity which in terms is related to the way we deal with knowledge". Knowledge consists of facts, truths, and beliefs, perspectives and concepts, judgments and expectations, methodologies and know-how". It is a broad definition that even considers beliefs to be knowledge which is in contradiction to Plato's definition.

In the Knowledge Management literature, after [Polanyi 1967] coined the term tacit knowledge; Knowledge (K) is seen as the combination of tacit (TK) and explicit knowledge (EK) [Nonaka and Takeuchi 1995] [Nonaka, Konno and Toyama 2001]. Explicit knowledge is the one that can be easily expressed with symbols or that we can create a representation of in written words, drawings, equations, pictures, etc. [Nonaka, Konno and Toyama 2001]. At the very moment something is being expressed, it becomes an explicit form of knowledge. It is important to mention that for knowledge to be expressed explicitly, it needs to be context independent. Conversely, tacit knowledge is more related to sensorial acquired information, individual perception, intuition, and personal experience [Nonaka, Konno and Toyama 2001]. It is context dependent, therefore, not easily extendable to other type of situations and if they are, the results may not be the same. Strong efforts have been conducted towards explicit knowledge. For one it is easily reducible, therefore it is easy to store, and retrieve; in other words, it is manageable. One particular characteristic of knowledge is its intransience. Knowledge has to be justified, and for this, an ossification process has to be undertaken [Berman, Down, Will 2002] in order to arrive to a point of maximum entropy where everything to be known is known about an entity. This lends also another characteristic, that of monotonicity, knowledge's property of monotonicity is crucial for classical deduction. However, it is suggested that knowledge solely does not create understanding.

[Brewer 2007] defines not-knowledge as "*the Boolean complement of knowledge within the sphere of thought; specifically processes of thought that are either: a) not held to be justified true beliefs or b) held to be justified true beliefs without a reliable context and method of justification*". Not-knowledge in this sense groups constructs such as beliefs, ideas and loose observations that can be seen as claims that have not reached the knowledge state or "not-properly" justified claims. Not-knowledge is presented not as what is not known in an epistemic sense, but what is needed to infer

new knowledge when dynamic conditions are present. Not-knowledge could be further discriminated in the study of beliefs and belief projection [Stanovich 2003], creativity and inference through observations, but for the purpose of this work it reflects the not-justified nature of beliefs, ideas and loose observations that discard them as knowledge either tacit or explicit. Just as Stanovich suggests, the case of use of beliefs and belief projection does not even fall in the case of knowledge projection and many disagree with the idea of using prior knowledge or beliefs given that bring wrong biases [Stanovich 2003], but they can be (and are) used as a pool of information for creating justified true beliefs when those are lacking. The case is not whether to use them or not, but how to assess their appropriateness during selection.

## 2.3 Selecting Systems and individuals' philosophical predispositions

As previously suggested, understanding cannot be achieved by knowledge alone, or not-knowledge for that matter; it requires the use of both in situations where high uncertainty is present. Following Klahr's definition if we have knowledge, and as this paper's suggest, not-knowledge, another component would be the *selecting process* of the appropriate knowledge and not-knowledge. How we select the appropriate knowledge when needed to be used has been studied in different areas of literature; from psychology in the context of knowledge and knowledge representation in terms of content and format [Gick and Holyoak 1987], chunking [Miller 1956] [Simon 1974] and system 1 and system 2 [Stanovich and West 2003] [Evans 2003] among others, to philosophically in terms of epistemological currents embedded in empiricism and rationalism [Nonaka and Takeuchi 1995].

[Evans 2003] presents the case initially proposed by [Stanovich and West 2000] of System 1 and System 2, of two minds in one brain and how our brain, depending on the type of situation, would use either one of the two systems to deal with the knowledge or not-knowledge at hand. According to [Evans 2003], System 1 is generally described as a form of universal cognition shared between human and animals that includes instinctive behavior and formed by associative learning processes making it rapid, parallel and automatic in nature. System 1 processes are characterized as automatic, heuristic-based, and relatively undemanding of computational capacity [Stanovich and West 2003]. System 2 is slow and permits abstract hypothetical thinking in terms of mental models or simulations of future possibilities. It encompasses the processes of analytic intelligence, rule-based, language-biased, computationally expensive cognition [Stanovich and West 2003].

What is presented is a model for selection of knowledge and not knowledge when faced in a complex situations (irreducibility and transient conditions) based on system 1 and system 2 processes. Now, it is suggested that the use of a selecting system is based on an individual's predisposition of how to seek knowledge or how to justify knowledge claims. For instance, if an individual has an empiricist tendency he/she will be more likely try to solve problems via analytical means whereas a person with rationalist tendencies will more likely try to use intuition to address it. [Bozkurt, Padilla and Sousa-Poza 2007] propose a philosophical profile of an individual (PPI)

and is defined as an indicator that uses not only epistemology, but also ontology and teleology to establish embedded values of an individual. They contend that reality may be absolute, but depending on the lenses one uses – predispositions – reality will be seen and interpreted differently. Epistemological beliefs are individual's beliefs about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides and how knowledge occurs [Hofer 2002]. Epistemological predisposition then would show the tendency of an individual of how he/she seeks knowledge or justifies knowledge claims. As previously mentioned, a person with empiricist's tendency would favor analysis over heuristics and favor system 2 thinking instead of system 1. Ontology, according to [Bozkurt, Padilla and Sousa-Poza 2007] deals with the nature of things and the way we see reality. [Rescher 1996] says that a person can see reality as individual elements (substantive reductionist approach) or as a collection of elements (process holistic approach). An ontological predisposition is then consistent with the way we select knowledge and non-knowledge using system 1 and system 2 ; just as an empiricist would have a tendency to favor analysis, he/she would favor a substantive ontology of reality. Finally, teleology deals with how an individual sees the future and can be defined as a feed-back purposeful active behavior that can be predictive or non-predictive [Bozkurt, Padilla and Sousa-Poza 2007]. Teleological predispositions would then show the tendency of an individual to see the future as predictable or non predictable. Prediction is something that an engineer would seek, and can be sought in more technical and stable situations. On the other hand, in complex situations prediction becomes an illusion given the nature of irreducibility and transient conditions. Teleological predispositions are also consistent with system 1 and system 2 premises; an empiricist would see the future as predictable and use analysis to predict it whereas a rationalist sees the future as unpredictable and uses heuristics to solve problems. It is important to mention that as system 1 and system 2 exists within the human brain, epistemological, ontological and teleological flavors are present in an individual behavior, but as system 1 and system 2, there is a philosophical predisposition when selecting knowledge and not-knowledge that may be independent of reducibility/irreducibility and transient/intransient conditions.

It is fitting to end this section by suggesting, as a conclusion of the previous arguments that given conditions of irreducibility and transience there are individual that are more capable of understanding complex situations and therefore better able to solve problems and make decisions than others based on their predispositions. We run into this situation on a daily basis when we differentiate managers from leaders or managers from engineers. Some people tend to over analyze others tend to work with gut feeling ; the issue is not to say which is better, because both fail, but, depending of the situation, that one may be better than the other. Finally, notice that psychological types or psychological predispositions are not included given that it would require a more extensive study which would fall outside of the objectives of this work. The focus is on understanding, how we are predisposed to select the appropriate knowledge and not-knowledge when facing a complex situations and for this reason was the more fitting use of philosophy in a manner that would provide how we seek knowledge, see reality and think about the future. Finally, a definition is

proposed for *understanding in complex situations as a function of a) knowledge and not-knowledge and b) modes of reasoning and predispositions that allow for the selection of the appropriate knowledge when appropriate to c) address conditions of irreducibility and transience in order to take action at a given moment.*

# 3 A model of Understanding in Complex Situations

After defining understanding and the suggested constructs that constitute understanding, it is fitting to propose a model for it when dealing with complex situations. It has been the effort of the authors of making it as general and comprehensive at the same time as possible. The model presented in Figure 3 contains two main components: The r*educibility functions,* $R_{i(k)}$**,** that contains the epistemological predispositions that would allow for an individual to select either reducible or irreducible parameters and classifying as transient/intransient given his/her predispositions and the *understandability function,* $U_{i(k)}$, which puts knowledge into context of action depending of mode of reasoning and teleological predispositions.

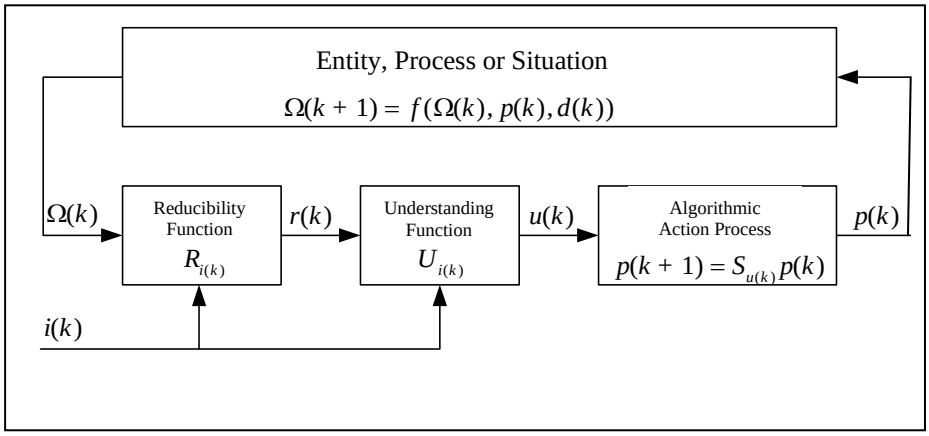


**Figure 3**: A model of Understanding Complex Situations

- ***Entity, Process or Situation***: The entity is described by a set of known or estimated parameters, $\Omega(k) \in ¡^{n_\Omega}$**,** that varies through time, denoted by $k \in ¢^{+}$, reflecting the situational transience. $\Omega(k)$ contains all the information that an individual can use to identity/represent a situation.

These parameters are available to all individuals. However, a particular individual may use only a subset of the parameters to asses the situation. The parameter evolve through time governed by the nonlinear dynamical equation

$$\Omega(k+1) = f(\Omega(k), p(k), d(k)),$$

where $f : ¡^{n_\Omega} \times ¡^{n_p} \times ¡^{n_d} \mapsto ¡^{n_\Omega}$ is a nonlinear function that maps the current parameters value, the algorithmic action process state, $p(k) \in \Sigma_p \subset ¡^{n_p}$, and the process disturbance, $d(k) \in ¡^{n_d}$, into the next state, $\Omega(k+1)$. The function $f$ represents the reducible portion of the entity (e.g. production levels, number of good, etc.). The irreducible aspects of the entity (e.g. company culture) and the under modeled reducible aspects of the entity are represented by the bounded disturbance vector $d(k)$.

- ***Individuals and the Reducibility Functions***: $i(k) \in ¢^+$ identifies the particular individual observing the situation. The individual $i(k) = l$ will reduce the information describing the situation, $\Omega(k)$, to a small number, $n_r(l)$, of characteristics, $r(k) \in ¡^{n_r(l)}$. This reduction is done through the individual's reducibility function, $R_l : ¡^{n_\Omega} \mapsto ¡^{n_r(l)}$, $l \in ¢^+$. That is, $r(k) = R_{i(k)}(\Omega(k))$.

- ***Understanding Functions:*** Once an individual has reduced the situation, he/she uses his/her situational understanding and unique mode of reasoning to deal with the situation. For simplicity, it is assumed that the individual $i(k) = l$ chooses a particular action process to deal with the situation, $u(k)$, through the individual's understanding function $U_l : ¡^{n_r(l)} \mapsto ¢^+$, $l \in ¢^+$. That is, $u(k) = U_{i(k)}(r(k))$ The action process is assumed to be algorithmic. That is, it can be represented by a finite state automaton or, equivalently, by the set of finite difference equations

$$p(k+1) = A_{u(k)} p(k),$$

where $p(k) \in \Sigma_p$ represents the internal state of the action process algorithm, $\Sigma_p$ is the set of elementary vectors in ¡ $^p$, and $S_l$, $l \in ¢^+$ are state transition matrices (i.e., they have a single 1 in every column and zeros elsewhere), which describe the evolution of action process state.

Finally, action process state, $p(k)$, affects the situation through a feedback loop. This feedback will more likely have a delay, so its effect may not influence the next state of the situation, $\Omega(k+1)$.

# 4 Conclusions

Bill Watterson's character Calvin of Calvin and Hobbes on Sep 21, 1993 issue says: "*The more you know, the harder it is to take decisive action. Once you become informed, you start seeing complexities and shades of gray. You realize that nothing is as clear and simple as it first appears. Ultimately, knowledge is paralyzing. Being a man of action I can't afford to take that risk*". This reflects the thought when dealing with complex situations; we face a decision and action that needs to be taken in a moment when perhaps there is no time, with an abundance of knowledge, but little understanding. The situation changes and we have knowledge for stable conditions, we try to analyze, but the domain presents conditions of irreducibility. This work suggests that for understanding in complex situations we should consider irreducibility and transience conditions as generator of domain uncertainty, but also considers the individual predispositions as a way of contributing to that uncertainty. The work seeks to change the paradigm of analysis/synthesis in a situation when it may not be analyzable. The impact of this is when a decision needs to be made or a problem solved we keep trying to address it, or understanding it, under the wrong conditions.

Understanding is a complex concept that needs further research and study to further its facilitation and as Klahr adequately puts it, "at least that is my *understanding* at this point in time"

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