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Untangling wicked problems

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Abstract

More than 40 years after Rittel and Webber published the first articles on the theory of wicked problems this theory has been applied to a wide range of fields involved in real-world problem solving. Interest in the theory seems greater than ever. This has led to an interest in rethinking the theory. A number of authors do this by imposing interpretations on the theory that are incompatible with each other and with the statements of the theory's authors. We agree that it is time to critically reexamine the theory and rethink what implications it has for design. However, rather than imposing an incompatible interpretation, our approach is see what new conclusions can be drawn from a systematic and critical examination of what Rittel and Webber actually said. This reexamination of their specific claims and arguments is what we call *untangling wicked problems*. From this untangling, we derive new conclusions about how designers should tackle wicked problems and how design rationale can aid them in doing so.

Keywords: Cause–Effect Relationships; Design Rationale; Participatory Design; Unforeseen Consequences; Wicked Problems

1. INTRODUCTION

Horst Rittel created the theory of wicked problems in the mid-1960s to describe "that class of problems which are ill-formulated, where the information is confusing, where there are many decision makers and clients with conflicting values, and where the ramifications in the whole system are confusing" (Churchman, 1967). This definition does not use "wickedness" to imply that these problems are immoral, although Churchman does point out that moral issues can arise in solving wicked problems. Instead, the term *wicked* is used in the sense of being malignant rather than malicious. The theory of wicked problems is described and defended in two papers, *On the Planning Crisis: Systems Analysis of the First and Second Generations* (Rittel, 1972) and *Dilemmas in a General Theory of Planning* (Rittel & Webber, 1973).

Rittel and Webber (1973) describe 10 properties that indicate how wicked problems are open-ended and controversial:

1. There is no definitive formulation of a wicked problem.
2. Wicked problems have no stopping rule.
3. Solutions to wicked problems are not true/false, but good/bad.
4. There is no immediate and no ultimate test of a solution to a wicked problem.
5. Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, and every attempt counts significantly.
6. Wicked problems do not have an enumerable (or exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.
7. Every wicked problem is essentially unique.
8. Every wicked problem can be considered a symptom of another wicked problem.
9. The existence of a discrepancy representing a wicked problem can be explained in numerous ways; the choice of explanation determines the nature of the problem's solution.
10. The designer has no right to be wrong.

Wicked problems contrast with *tame problems*, that is, well-defined problems. Example tame problems include proving theorems, determining molecular structure, and achieving checkmate in *n* moves. Wicked problems are by definition difficult to deal with, but this does not mean that tame problems are necessarily easy. Notoriously difficult problems like prov-

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ing Fermat's last theorem are tame by Rittel's definition, because they are well defined. The difficulties of solving wicked problems, however, are fundamentally different from those of solving tame problems.

The above-mentioned papers on the theory of wicked problems are entirely focused on planning problems. However, in his course lectures at the University of California, Berkeley, Rittel insisted that the term *wicked problem* referred equally to problems of design and planning (R. McCall, personal communication). He used the terms *design* and *planning* interchangeably because he felt they were different names for the same thing: "an activity that aims at the production of a plan which plan—if implemented—is intended to bring about a situation with specific desired characteristics without creating unforeseen and undesirable side and after effects" (Protzen & Harris, 2010). In this article, we use the term *design*, but according to Rittel we could have used the term planning with no change in meaning.

The idea that some problems are difficult in a way that they can be deemed "wicked" has received wide acceptance. This is demonstrated by Google Scholar search results for "wicked problem" giving over 15,000 hits (March 29, 2015). This literature provides examples of the application of the wicked problems concept in a wide range of real-world problem-solving fields, including software engineering (DeGrade & Stahl, 1990), interaction design (Stolterman, 2008), military science (Clemente & Evans, 2015), systems engineering (Kovacic & Sousa-Poza, 2013), architectural design (Fischer et al., 1996), environmental policy (Balint et al., 2011), health care (Arnett, 2012), and management science (Dunne & Martin, 2006). Much of the literature, however, has centered on wicked problems in design (e.g., Buchanan, 1992; Cherry, 1999; Coyne, 2005; Rith & Dubberly, 2007; Burge & McCall, 2014).

The theory of wicked problems led directly to Rittel's work on issue-based information systems (IBIS; Kunz & Rittel, 1970), which pioneered the field of design rationale (Moran & Carroll, 1996; Conklin, 2006; Dutoit et al., 2006; Burge et al., 2008). This is turn led to the creation of a variety of software tools that supported usage of design rationale using different software technologies, including hypermedia (McCall et al., 1983; Conklin & Begeman, 1988; McCall et al., 1994; Kirschner et al., 2003; Buckingham Shum et al., 2006), knowledge-based critics (Fischer et al., 1996), and natural language processing (Rogers et al., 2014).

With the theory of wicked problems more than 40 years old and with its popularity apparently at an all-time high, a number of authors, ourselves included, have thought that it was high time to take a critical look at the theory and see how it holds up. A good number of the articles doing this have taken the approach of trying to account for wicked problems in terms of other theories. Thus, Coyne (2006) attempts to show that seeing design problems as wicked is merely the first step in applying to design the postmodern philosophy currently popular in literary studies and architecture history. Similarly, Farrell and Hooker (2013) attempt to show that the notion of wicked problems is completely compatible with the notion of scientific problems, a view utterly incompatible with Coyne's. Conklin argues with Basadur and VanPatter, who attempt to portray wicked problems as merely being a manifestation of traditional notions, such as complexity (Conklin et al., 2007). These articles portray attempts at hostile takeovers of wicked problems theory by rival theories. None of these attempts is compatible with the statements of Rittel and Webber.

Rather than trying to impose another theory on wicked problems, our approach is to analyze the original claims, explanations, and rationale given for the 10 properties of wicked problems so that we can critique the theory. In critiquing the theory, our intention is not to tear it down but rather to understand both its strengths and its deficiencies, to correct some of these deficiencies (in particular, to clarify some of the wording that is unclear as originally written), and to use this understanding to devise ideas for tackling wicked problems in ways that go beyond those described in Rittel's 1972 article. As explained below, these ideas help to resolve certain apparent conflicts between the theory of wicked problems and other theories widely discussed in the literature on design.

We begin with a property-by-property analysis and critique of the theory of wicked problems. We then identify novel implications for design. Finally, we summarize our conclusions and identify work that needs to be done to implement and test them.

2. ANALYSIS AND CRITIQUE OF THE THEORY

2.1. Property 1: There is no definitive formulation for a wicked problem

2.1.1. The explanation and rationale given for Property 1

The explanation of Property 1 given by Rittel and Webber defines the *formulation* of a problem as a set of information needed to understand and to solve it and defines a *definitive* formulation is one that is exhaustive, that is, contains all the information needed. While it is always possible to give a definitive formulation for a tame problem before solving it, this is never possible for a wicked problem (Rittel, 1972; Rittel & Webber, 1973).

The two articles give different rationales for this property. The 1972 article (Rittel, 1972) argues that each proposed solution for a wicked problem generates requests for information needed to evaluate and implement that solution. The nature of each question "depends on your state of solution at that point in time and the next question could not be anticipated at the beginning by the formulator of the problem" (Rittel, 1972). "In order to give exhaustive information ahead of time for a wicked problem you have to anticipate all potential solutions first" (Rittel, 1972). This means that with wicked problems, "you cannot understand the problem without solving it, and solving the problem is the same as understanding it" (Rittel, 1972).

The 1973 article (Rittel & Webber, 1973) takes a fundamentally different tack. Instead of discussing how solution ideas raise questions, it discusses how finding different causes of a wicked problem automatically produces different solution ideas. In the example of determining causes of poverty, attributing poverty to deficiencies in the economy produces different solution ideas than attributing it to deficiencies in the educational system (Rittel & Webber, 1973).

> If we can formulate the problem by tracing it to some sorts of sources—such that we can say, "Aha! That's the locus of the difficulty," i.e. those are the root causes of the differences between the "is" and the "ought to be" conditions—then we have thereby also formulated a solution.

Finding the cause of the wicked problem "is thus the same thing as finding the solution; the problem can't be defined until the solution has been found." With wicked problems, unlike tame problems, "one cannot first understand, then solve" (Rittel & Webber, 1973).

2.1.2. Analysis and critique of Property 1

Both articles describe a coevolution of problem understanding and problem solution during the full length of a design project. While this evolution continues, problem formulation is not complete, but the evolution terminates at the end of the project. This seems to leave open the possibility that there is a definitive formulation at the end of the project, which would contradict Property 1.

Other properties of wicked problems, however, imply that a definitive formulation is never possible. For example, the arguments for Property 2 (no stopping rule) and Property 4 (no immediate or ultimate solution test) are both based on the existence of endless chains of consequences of solutions. An exhaustive problem formulation would have to include all such consequences, which is impossible. In other words, the rationale for Property 1 really needs to include the rationale for Properties 2 and 4.

While the two articles on wicked problems give different rationales for Property 1, these rationales have a crucial commonality: both are discussions of the roles of cause–effect relationships in wicked problems. The Rittel and Webber article explicitly discusses the causes of wicked problems, but the Rittel article implicitly discusses cause–effect relationships when it talks about questions of implementation and evaluation. Implementation involves issues about how to cause desired states to come into existence. Similarly, evaluation of solution proposals requires understanding what effects (consequences) would be caused by such proposals. In other words, Property 1 is justified in both articles by reference to the questions that arise about cause–effect relationships. As we show below, cause–effect relationships are the overwhelmingly dominant topic in the rationales for properties of wicked problems.

A crucial shortcoming of the original formulation of the theory of wicked problems was that it failed to provide adequate support for Rittel's own work on IBIS, the method he proposed for dealing with wicked problems. His version of IBIS, as opposed to the versions of later IBIS researchers (Conklin, 2006; Dutoit et al., 2006, p. 8), dealt exclusively with issues that involved differences of opinion among design participants; he defined the term issue to mean a controversial design question (Kunz & Rittel, 1970; McCall et al., 1990). In wicked problems theory, however, the sole reference to difference of opinion is in the explanation of Property 3 (solutions are good/bad not true/false).

From this perspective, the above-given definition of the term *definitive* in Property 1 may well represent a missed opportunity. This definition refers solely to the exhaustiveness of a problem formulation while neglecting the authoritativeness of its information. With tame problems, the information in the problem formulation is not only exhaustive but also authoritative, in the sense of being beyond reasonable dispute. This is not so with wicked problems, which have stakeholders with differing concerns, priorities, value systems, and beliefs. Several other properties of wicked problems implicitly undermine attempts to claim authoritativeness for much of the information in a problem formulation. These include Property 4 (solutions to wicked problems are good/bad, not true/false) and Property 9 (the possibility of alternative causal explanations in wicked problem).

2.2. Property 2: Wicked problems have no stopping rule

2.2.1. The explanation and rationale given for Property 2

For tame problems, for example, winning a chess game or solving an equation, there are objective criteria for determining when the problem is solved. Not so for wicked problems. Designers can keep trying to come up with what, in their opinion, are better solutions (or are solutions with different trade-offs between desirable and undesirable consequences). Projects do not end because of the "logic of the problem" but rather because of exhaustion of resources such as time, money, or manpower (Rittel 1972; Rittel & Webber, 1973).

The 1973 Rittel–Webber paper gives the following rationale:

> Because (according to . . . [Property1]) the process of solving the problem is identical with the process of understanding its nature, because there are no criteria for sufficient understanding and because there are no ends to the causal chains that link interacting open systems, the would-be . . . [designer] can always try to do better. Some additional investment of effort might increase the chances of find a better solution.

2.2.2. Analysis and critique of Property 2

The above rationale features two principles that are also found in the rationale for other properties of wicked problems. The first principle is the absence of "criteria for sufficient understanding" that are objective in the sense of being independent of personal opinion. The second is the existence of endless "causal chains that link interacting open systems." Below we see that both of these principles appear as underlying causes of other properties of wicked problem. Note that cause–effect relationships again play a crucial role in the rationale for this property. The interaction between problem and solution identified in Property 1, where problems and solutions coevolve, also contributes to the issue of knowing when to stop. Some possible stopping criteria for coevolution are proposed by Poon and Maher (1997): satisfying the requirements (difficult for wicked problems due to Property 1), running out of time, and when solutions cease to be sufficiently different from each other or the same solutions keep being proposed again and again.

2.3. Property 3: Solutions to wicked problems are good/bad, not true/false

2.3.1. The explanation and rationale given for Property 3

Here the theory claims that judgments of solutions to wicked problems are value judgments, not factual judgments. The explanation of this property given in the Rittel–Webber article also contains the crucial, additional claim that there are many people who can make these judgments, and their judgments "are likely to differ widely to accord with their group or personal interests, their special value-sets, and their ideological predilections" (Rittel & Webber, 1973).

The Rittel–Webber paper begins the rationale for this property as follows:

> Normally there are many parties who are equally equipped, interested and/or entitled to judge the solutions, though none has the power to set formal decision rules to determine correctness.

It later adds the claim:

> Their assessments of proposed solutions are expressed as "good" or "bad" or, more likely, as "better" or "worse" or "satisfying" or "good enough."

The Rittel–Webber article also claims that Property 3 means design cannot be a scientific process.

2.3.2. Analysis and critique of Property 3

Property 3 claims that the evaluation of solution ideas in design is an intrinsically political process, in the sense of involving differences of opinion among multiple, rightful participants, where no judgment of who is right can be objective in the sense of being independent of who does the judging. The notion that Property 3 precludes design being a scientific activity seems to be a consequence, first, of the notion that science produces factual knowledge not value judgments and, second, of the notion that politics is not a scientific activity. It may be possible to find a satisficing solution (Simon, 1956) if one exists that does not include intolerable undesirable consequences.

2.4. Property 4: There is no immediate or ultimate test of a solution to a wicked problem

2.4.1. The explanation and rationale given for Property 4

For a tame problem, there is always an immediate test available of the value of a solution. For a wicked problem, there is no such test, nor is there any ultimate test to apply later. This is because a solution to a wicked problem generates chains of consequences (i.e., consequences of consequences of consequences, etc.) extending over limitless future time. It is impossible to know all these consequences. Because unknown future consequences could well outweigh the known consequences, designers can never really know the real value of solutions.

The Rittel–Webber rationale for this property is that wicked problems, unlike tame problems,

> . . . will generate waves of consequences over an extended—virtually an unbounded—period of time. Moreover, the next day's consequences of the solution may yield utterly undesirable repercussions which outweigh the intended advantages or the advantages accomplished hitherto.

It adds, "we have no way of tracing all the waves through all the affected lives ahead of time or within a limited time span." This means that when dealing with wicked problems, the evaluation of a solution idea is always an educated guess at best.

2.4.2. Analysis and critique of Property 4

This property is attributed to fundamental difficulties that designers have in identifying cause–effect relationships, in particular, the difficulty of understanding all significant effects (consequences) caused by a would-be solution. This is the same basic principle used in the rationale for Property 2, which as explained above can also be used as a rationale for Property 1.

Many authors implicitly agree with this property by arguing that foreseeing all unintended effects, that is, side affects and aftereffects, is extremely difficult, if not impossible (Merton, 1936; Ermolaeva & Ross, 2010), an assertion often associated with what is called *the law of unintended consequences* (Tenner, 1997; Mansfield, 2010). This difficulty arises because designers seldom if ever have complete and reliable cause–effect models of the portions of the world that their design might affect. The two wicked problems articles repeatedly mention the difficulties of understanding cause–effect relationships in the interacting open systems that wicked problems deal with.

2.5. Property 5: Every solution to a wicked problem is a "one-shot operation"; because there is no opportunity to learn by trial and error, every attempt counts significantly

2.5.1. The explanation and rationale given for Property 5

Tame problems, such as solving equations, have no significant costs for failed solution attempts. The situation is different for wicked problems, because their solutions have irreversible consequences (Rittel & Webber, 1973). Rittel and Webber argue that one cannot build a freeway just to see whether it works, then tear it down and start over again if it fails. The cost would be prohibitive, not to mention other disastrous consequences. Designers must endeavor to get it right the first time. Trial and error is unethical, because the errors

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would generate waves of negative consequences that could not be undone.

2.5.2. Analysis and critique of Property 5

This property once again claims the existence of a fundamental difficulty that designers have in understanding the effects of their proposed solutions before the design project is completed. In particular, it claims that trial and error cannot be used to understand these effects because errors would result in negative effects that could not be undone (effects such as loss of money and harm to users).

A key weakness of the rationale for Property 5 is its dependence on the large scale of the project and/or the cost of trial and error. While this property may be true for freeways, it will most likely not hold for small artifacts. If we look at the design of a product such as a consumer electronics device, the arguments against trial and error seem to fall apart. It is easy to imagine that designers could build an initial version of the device and try it out with users. Feedback from implementation and use of this version could then be used to produce improved versions to try out with users. While there is still the possibility of irreversible negative consequences of these tests (e.g., loss of important data), any such consequences are likely be confined to small groups of test users. This process could be iterated until the designer was convinced that the major consequences for potential users had been identified, so the device could be put into mass production. The costs of the trial and error are likely to be small compared to the profit to be made selling millions of these devices. Of course, there is no guarantee that this trial and error process has discovered all crucial negative consequences for all stakeholders. Still, it seems a highly reasonable way for designers to proceed.

While we believe that there is more ability to use trial and error in design than Rittel and Webber suggest, we agree with their basic claim that designers do not have the unrestricted use of trial and error available to tame problem solvers, such as mathematicians and game players. In particular, we agree that design solutions can produce effects that cannot really be undone, and therefore, experimenting in the real world to discover the effects of solutions presents fundamental ethical and financial difficulties.

An example where negative consequences were incurred in developing a new product was the introduction of New Coke in 1985. Initial taste tests ($4,000,000 worth) indicated that the new product was preferred, but what Coca-Cola did not realize was that the brand itself was the source of loyalty and not the taste of the product (Allen et al., 2008). Still, even though introducing the reformulated product was a massive blunder, the company did recover and rebounded, spawning rumors that the "mistake" was intentional (Allen et al., 2008).

The argument that, contrary to the claim of Property 5, it is possible to learn from mistakes applies to almost all types of software design. It is standard practice to build working prototypes of software and try them out with some users before the software is delivered to the larger user community. A primary goal of iterative software development is to discover unintended errors and misunderstandings early enough to be easily corrected. In domains where evaluation can be performed using a physical or abstract solution model, there are no limits to trial and error.

Another argument is that from a larger perspective, trial and error may be unavoidable even with the large-scale projects and consequences that Rittel and Webber refer to. The reason for this is that foreseeing all the consequences of a solution is just not possible, as they tell us (1972, 1973). However, once a solution is implemented, we begin to discover consequences we could not foresee. Such discovery is likely to require redesign. In this sense, solving a wicked problem is very unlikely to be a one-shot operation. After all, does anyone seriously believe that a wicked problem like poverty could be solved with a single, one-shot design project? Despite their claims in Property 5, Rittel and Webber (1973) do not believe this themselves, for they point out that such problems, "are never solved. At best they are only resolved—over and over again."

2.6. Property 6: Wicked problems do not have an enumerable (or exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan[1]

2.6.1. The explanation and rationale given for Property 6

With chess, as with other tame problems, there is a limited set of possible solutions; new moves cannot be invented. However, with wicked problems, it is always possible to invent new solution ideas. The only rationale given for why there can be no provably finite list of solutions to a wicked problem is merely the assertion that it is not possible to prove that any list of alternative solutions is complete.

2.6.2. Analysis and critique of Property 6

The rationale for Property 6, although minimal, is reasonable. It is seldom possible for designers to prove that they found all things that fit a given description, because this would require proving that there cannot exist anything that fits but has not been found. Such proofs are seldom possible outside of mathematics.

Property 6 is another claim by Rittel and Webber about difficulties in identifying cause–effect relationships. A solution to a problem is, by definition, something that causes a problem to be solved. An inability to prove that all solutions have been identified is then just an inability to prove that all things that can cause the problem to be solved have been identified.

[1] Plan is Rittel's term. Rittel tended to use the terms *design* and *planning* interchangeably and also stated in his lectures that wicked problems theory applied to both.

2.7. Property 7: Every wicked problem is essentially unique

2.7.1. The explanation and rationale given for Property 7

Both wicked problems articles state that no matter how many similarities there are between a new wicked problem and previous problems, there is no way to guarantee that the new problem does not have unique characteristics that will turn out to be of overriding importance in determining what its solution should be. The authors imply that this argument means that there are no classes of wicked problems in the sense that for each class a single solution solves every problem in the class.

The Rittel–Webber (1973) article argues that the uniqueness of design problems is due to the complexity of the world in which the problem exists. It gives the following example to persuade us of this point:

> The conditions in a city constructing a subway may look similar to the conditions in San Francisco, say; but planners would be ill-advised to transfer the San Francisco solutions directly. Differences in commuter habits or residential patterns may far outweigh similarities in subway layout, downtown layout and the rest.

2.7.2. Analysis and critique of Property 7

The example in this rationale describes potential differences in the social and physical environment of the problem of designing a subway system as the source of the uniqueness of that problem. The example implies that the user needs of a previous design project may not be reliable predictors of the user needs in the current project and therefore that the solution to the previous project is unlikely to be appropriate for the current one. User needs are part of the problem that the design must solve; the solution is what causes those needs to be met. In summary, the rationale for this property is based on an alleged difficulty that designers face in dealing with cause–effect relationships.

The term *essential uniqueness* seems to promise that every wicked problem is unique in ways that matter. Nevertheless, the given explanation of this term only asserts that at the start of a project, designers *cannot be sure* the problem is *not* unique in ways requiring a unique solution. This leaves open the possibility that the problem might eventually turn out not to be unique in such ways. Rather than showing that wicked problems are *essentially* unique, this argument only shows that they are *potentially* unique.

If wicked problems are only potentially unique, this implies that the same solution might be used for two or more such problems. The set of these problems would constitute a class in which the same solution applies to every member of that class: exactly what the explanation of the property claims cannot exist. In other words, the claim that there are no classes of wicked problems is a much stronger claim than can be supported by the argument that wicked problems are potentially unique. It is only this latter claim that seems to justify a problem being called *essentially uniqueness*, yet Rittel and Webber provide no argument supporting this claim.

The Rittel and Webber explanation of essential uniqueness makes it clear that even if we assume that wicked problems are essentially unique, this only means that there exist some unique factors that influence what the solution to the problem should be. Rittel (1972) claims that essential uniqueness makes it hard for designers to learn from past projects. However, Property 6 is an intrinsically weak claim whose rationale, such as it is, actually shows that designers can learn a great deal from past projects (especially from the rationale for such projects) as long as they do not assume that past projects are identical in all respects to current projects. While Rittel never reused IBIS rationale from past projects, such reuse of IBIS rationale has long been a central feature of McCall's work on wicked problems (Fischer et al., 1989; McCall et al., 1994). Buchanan's (1992) doctrine of placements describes the importance of placements (signs, things, actions, or thoughts) in design. Designers are able to invent new designs by utilizing their own set of previously developed placements and using them in new and novel ways.

2.8. Property 8: Every wicked problem can be considered the symptom of another wicked problem

2.8.1. The explanation and rationale given for Property 8

Both articles claim that every wicked problem can be viewed as the symptom of another, "higher level," problem and that there is no "natural" level to attack the problem. If there are differences of opinion about which level at which to solve the problem, there is no objective way of determining which level is best.

The two wicked problem articles provide no rationale for Property 8 other than a few such examples of wicked problems as symptoms of other wicked problems (Rittel & Webber, 1973):

> "crime in the streets" can be considered as a symptom of general moral decay, or permissiveness, or deficient opportunity, or wealth, or poverty, or whatever causal explanation you happen to like best.

2.8.2. Analysis and critique of Property 8

The examples given as rationale for the property show that one wicked problem might be viewed as the symptom of another; nevertheless, Property 8, as originally stated, seems indefensible. The trouble lies with the word "every." If *every* wicked problem can be considered a symptom of another, this means that for any given wicked problem, there exists a second wicked problem that can be considered as causing it, and that this second problem can be considered as being caused by a third wicked problem, which can be considered as being caused by a fourth, and so forth. In other words, every wicked problem can be seen as caused by an infinite chain of other wicked problems. This cannot be true, because it would lead to absurd conclusions (e.g., that there are more wicked problems than there are atoms in the universe).

A second problem with Property 8 results from the use of the term *symptom*. To understand what is meant by this term, it is useful to look at the given example of a designer trying to solve the problem of poverty. That designer might come to see that the cause of this problem was inadequate education. In this sense the designer would view poverty as a symptom of the problem of inadequate education. In other words, a given wicked problem is a symptom of another if the latter causes the former; thus, *symptom of* is a type of cause–effect relationship.

A limitation of the "symptom of" relationship between wicked problems is that it is only applicable when the problem in question represents a negative discrepancy, that is, something bad that needs to be corrected, such as the societal ills on which the Rittel–Webber article focuses. Not all design problems have this character. Some are not about remedying deficiencies but about providing amenities, including things that people had no sense that they needed before these things were available to them. Numerous examples exist of hardware and software technologies that enable people to do things that they never thought of doing before the technologies were available. In such cases, looking for "symptoms" makes no sense and cannot help designers find solutions.

The problem with the symptom of relationship between wicked problems is that it is only one type of a more general and useful relationship, namely, the cause–effect relationship. A crucial thing to note about the cause–effect relationships between wicked problems is that by saying a given wicked problem causes another wicked problem, we are also saying that solving the given wicked problem also solves the other. The statement of Property 8 focuses on only one special case of this relationship; it only looks at negative problems (negative discrepancies) and only looks for wicked problems that cause the originally stated problem. It fails to mention that it is also possible and useful to ask what wicked problems this originally stated problem itself causes.

To deal with the above-described criticism of Property 8, we recommend the following revision of the wording of this property: *a given wicked problem might be caused by another wicked problem, and this given problem might cause still another wicked problem.* We see here that, as with so many other properties of wicked problems, cause–effect relationships are central to the explanation and rationale for Property 8.

2.9. Property 9: The existence of a discrepancy representing a wicked problem can be explained in numerous ways; the choice of explanation determines the nature of the problem's solution

2.9.1. The explanation and rationale given for Property 9

Carefully controlled laboratory experiments in science are designed to eliminate confounding variables so as to make it clear what causes what. However, this kind of experimentation is not possible with the complex and open-ended causal networks associated with wicked problems.

The rationale for this property asserts that with wicked problems, there are more ways to argue about causality than there are in the sciences. For example, if we believe that crime in the streets is caused by inadequate numbers of police officers, we might increase the number of police. However, if crime then does not seem to go down, does this mean we were wrong about crime being caused by too few police? Perhaps, but there are many counterarguments. It could be argued that crime has gone down despite the appearance that it has not. It could be argued that crime would have gone even higher if there had not been so many police. It could even be argued that there has not been enough time for the reduction in crime to take effect (Rittel & Webber, 1973).

2.9.2. Analysis and critique of Property 9

The expression "a discrepancy representing a wicked problem" in Property 9 means the difference between a current state of affairs and a desired state of affairs. When this property refers to the "explanation" for a discrepancy, it means the cause of that discrepancy (e.g., the cause of the discrepancy between poverty and the desired absence of poverty). A crucial but unstated implication of Property 9 is that legitimate differences of opinion can exist between reasonable and informed participants in a design project about these causal explanations. From this we can infer that there is no objective way to decide which of the disagreeing parties is right and thus no way to be sure that designer is right. In addition to being another example of difficulties associated with cause–effect relationships in design, Property 9 shows how such difficulties can actually create conflicts among stakeholders. This provides additional justification for Rittel's focus on controversial questions in IBIS.

Property 9 also implies that design is an error-prone activity wherever questions of causal explanation are involved. Designers should therefore assume that there will be unforeseen consequences of their implemented solutions. Rittel (1972) states explicitly that designers cannot foresee all the consequences of their design solutions. Thus, designers and the world in general should be prepared to deal with such unforeseen consequences whenever wicked problems are tackled.

2.10. Property 10: The designer has no right to be wrong

2.10.1. The explanation and rationale given for Property 10

According to Rittel, "the tame problem solver . . . may lose or win a chess game without being blamed for it or may state a wrong hypothesis which will be refuted by someone else," again without being blamed. However, "the wicked problem solver" is not off the hook if a design fails or produces "unacceptable side- and after-effects" (Rittel, 1972). Designers are responsible for the consequences of their decisions, because those consequences take the form of irreversible effects on people (Rittel & Webber, 1973).

2.10.2. Analysis and critique of Property 10

In a sense, Property 10 is the "punch line" of wicked problems theory. After listing nine properties of wicked problems that claim designers cannot be guaranteed of "getting it right," Rittel and Webber announce in Property 10 that designers have no right to "get it wrong." This is really wicked.

Designers are legally responsible for their design decisions. They can also be tried in the court of public opinion. This seems perfectly appropriate. At the same time, wicked problems theory shows that unforeseen consequences are inevitable (Rittel, 1972). The confusing causal networks of real-world design and the endless chains of consequences guarantee this. Because this means that it is to some degree inevitable that designers will be wrong, it is appropriate to ask whether not having the right to be wrong means that designers do not have the right to design. We argue that it should not be taken to mean this, because the one thing more dangerous than designing is failing to design. While actions can have undesirable consequences, so can failing to act.

Instead of "no right to be wrong," we recommend the following reformulation of Property 10: *While designers must be accountable for the reasonably foreseeable consequences of their design decisions, they should not be held accountable for consequences that they could not reasonably have foreseen*. This statement, of course, leaves undefined the crucial term *reasonably*, but this is what courts of law and public opinion are for. Of course, this does not mean that designers (and the rest of the world) should not worry about what designers might fail to foresee.

2.11. Summary analysis and critique of the theory

Our analysis produced four minor conclusions and four major conclusions. The four minor conclusions took the form of revisions to the descriptions and rationales of wicked problem properties.

2.11.1. Recommended revisions to wording and explanations of properties

To provide better support for Rittel's work on controversial questions in IBIS, we suggested two revisions. One was that the explanation of Property 9 (multiple explanations for causes of wicked problems) should make it clear that this property is a source of potential disagreements among participants in design projects. The other was that Property 1 (no definitive formulation) redefine the term *definitive* to mean not only *exhaustive* but also *authoritative*, to reflect the potential for controversy stemming from Property 3 (solutions are good/bad) and Property 9.

We also suggested that Property 8 (every wicked problem is a symptom of another) be reworded as follows: *a given wicked problem might be caused by another wicked problem, and this given problem might cause still another wicked problem*. This rewording avoids the implication that each wicked problem is caused by an infinite number of other wicked problems. It also generalizes the principle of Property 8 by replacing the narrow term *symptom of* with the more general terms *caused by* and *cause.*

Finally, we suggested the following rewording of Property 10. *While designers must be accountable for the reasonably foreseeable consequences of their design decisions, they should not be held accountable for consequences that they could not reasonably have foreseen*. This avoids the implication that designers have no right to design because of the difficulties associated with the first nine properties of wicked problems.

The four major conclusions identified four features of wicked problems theory that have major implications for rethinking how to tackle design problems. These are described in the following section.

2.11.2. Four conclusions about features of wicked problems

The first conclusion is that difficulties in identifying cause–effect relationships are the central theme of wicked problems. Wicked problems theory is not a collection of 10 unrelated properties, for the properties have crucial commonalities. The first 9 properties identify things that make it difficult for designers to get it right, while the 10th property says that designers are obligated to get it right. Eight of these first 9 (all except Property 3: solutions are good/bad, not true/false) describe difficulties in identifying cause–effect relationships. These difficulties are, above all, what make design problems deserve the label wicked.

The second conclusion is that wicked problems theory does not preclude all trial and error. Rittel and Webber mistakenly downplay the role of trial and error in addressing wicked problems. They fail to see how trial and error can play a crucial role within many design projects. They also fail to see that their objections to trial and error are inconsistent with their own statement about the need to use multiple projects to address wicked problems.

The third conclusion is that wicked problems theory does not preclude learning from past projects. Rittel and Webber mistakenly downplay the role of learning from past projects. The notion of essential uniqueness and the rationale for that notion leave vast amount of room to learn from past projects. Research has shown that databases of domain-based and precedent-based design rationale in IBIS and other formats can inform designers working on new wicked problems (Fischer et al., 1996; Burge et al., 2008).

The fourth conclusion is that wicked problems theory predicts the inevitability of unforeseen consequences. Wicked problems theory implies the existence of a profound difficulty that neither Rittel nor Webber ever explains how to address. This difficulty is that, in Rittel's own words, "we cannot anticipate all the consequences of our plans" (Rittel, 1972). Unforeseen consequences threaten the success of design projects, because they "may yield utterly undesirable repercussions which outweigh the intended advantages or the advantages accomplished hitherto" (Rittel & Webber, 1973). Of all the difficulties that designers confront in their attempts to understand cause–effect relationships, this is by far the worst, in the sense that it represents the cases where those attempts fail completely.

3. IMPLICATIONS FOR DESIGN

3.1. Rittel's approach to mitigating the difficulties of wicked problems

Rittel concluded that the theory of wicked problems required an *argumentative approach* to design. This approach views design as a collaborative process of reasoning by all parties with a stake in the outcome of a design project, including designers, clients, users, and others affected by that outcome. Rittel felt that collaborative processes help designers to do a better job designing. These processes help them to "forget less" when trying to identify cause–effect relationships, including causes of problems, means of solving problems, as well as side- and after-effects of such means. He saw debate as the best means for evaluating alternatives, and he felt that even solitary designers should debate things in their heads (Rittel, 1972).

To implement his argumentative approach, Rittel created the IBIS method, which documents design as a process of answering controversial design questions, called *issues*. Collaborators in a design project propose answers, called *positions*, for each issue and then make *arguments* for and against positions and other arguments. The collaborators eventually make *decisions* about which positions to accept. The issues are linked together by various relationships into a network called an *issue map*. Rittel thought IBIS would facilitate collaborative design by making it clear to all participants exactly what issues were tackled and what rationale was used to tackle them.

3.2. Beyond Rittel's approach

Rittel thought IBIS would mitigate the difficulties of identifying cause–effect relationships though use of issue-based discussion among participants in design projects. Our critique suggests that this is by no means the only, much less the best, source of such information. Other sources include implementing and testing design ideas, learning from past projects, and learning from use of implemented designs.

3.2.1. Implement and test as a superior method for identifying the effects of design ideas

We argued in our critique of Property 5 (no trial and error) that trial and error is possible in many design projects in ways that Rittel and Webber did not recognize. Implementing prototype or preliminary designs is possible where the cost of implementation is not prohibitive. Feedback from building such artifacts and testing them with users provides information about consequences of design decisions that generally cannot be discovered by discussion alone. With an implement and test approach, we move away from the purely speculative argumentation of design discussion into an approach that discovers otherwise unforeseeable consequences. This approach thus mitigates a primary difficulty of wicked problems: foreseeing otherwise unforeseeable consequences of design decisions. In doing so, it provides far better design rationale than the purely speculative argumentation that Rittel had in mind. It also provides a new approach to user participation in design.

3.2.2. Rationale from past projects as an aid to understanding causes and effects in a current project

To learn from past projects, what is needed here is not only rationale from the design of those projects but also rationale from the use of the implemented designs resulting from those projects. We need both if we are to judge which rationale was correct and which was not. If we have both, we can begin to get an understanding of what works and what does not work in design. It should also be noted that getting information from users of implemented designs is yet another way of facilitating participation by stakeholders in design.

3.2.3. Use of implemented designs as a source of design rationale

Wicked problems theory predicts the inevitability of unforeseeable consequences of design decisions. Until these consequences are actually discovered, there is nothing that designers can do about them. The only way to discover them is to observe them at or after their actual occurrence. Once they are discovered, designers can and probably should do something about them. This requires redesign. Of course, not all of the unforeseen consequences happen at the same time. Some can go on being revealed over many years. This then requires repeated redesign.

Taking the theory of wicked problems seriously requires a serious commitment from designers to redesign. In other words, designers as a profession should expect and be willing to tackle the design problems raised by unforeseen consequences. Designers and other stakeholders need to realize that because designers cannot be guaranteed of being right in their design decisions, dealing with wicked problems cannot simply be a one-shot process. Design of wicked problems is better viewed as an ongoing process of design and redesign stretching over many iterations of design and even over generations of designers.

A commitment to repeated redesign has important implications for design methods and software systems that support such methods. Among these implications is the need to rethink the nature of design rationale and its role in promoting the creation of high-quality designed artifacts. In particular, design rationale must

- record the rationale for individual design projects and make this available for use in future projects,
- record the feedback from implementation and use of preliminary and prototype designed objects and make this available for use in the same project, and
- record the rationale from implementation and use of completely designed objects and make this available for use in redesign projects and other future projects.

3.2.4. Toward a more general theory of design and its rationale

Our conclusions that wicked problems require learning from past projects and using real-world trial and error are new to wicked problems theory, but they are not new to design. Design practice, education, and theory have long embraced these notions. What then is the value of these conclusions? One answer is that they reveal that design rationale can and should be used to support trial and error design and redesign, something for which there is little or no precedent in the literature. A second and potentially more important answer is that our conclusions clear the way for combining the theory of wicked problems with other theories of design, especially ones portraying design as a process of learning through repeated trial and error. Before we derived our conclusions, it appeared to us and others who believed in the reality of wicked problems that this reality could not be reconciled with use of an iterative trial and error approach to design. Rittel certainly felt this way (H.W.J. Rittel, personal communication). Now it appears to us that there is much to be gained by combining the ideas of wicked problems and design rationale with well-developed theories of design as iterative trial and error. Especially interesting, for example, is Schön's theory of *reflective practice* (1983). This theory addresses a major difficulty that Rittel and Webber imply but never deal with: what to do about the inevitable unforeseen consequences of design decisions. Reflective practice portrays design as an iterative process of reflecting on the unanticipated consequences of decisions made by the designer who then, on the basis of this reflection, makes new decisions. Schön's theory thus looks like an important supplement to the theory of wicked problems. However, Rittel and Webber give a better account than Schön of why unanticipated consequences exist, while design rationale research provides a far more detailed account of the structure of reflection than Schön does. By combining the theory of wicked problems with theories of design as iterative trial and error, it may well be possible to create a far more general and useful theory of design.

4. CONCLUSIONS AND FUTURE WORK

In the above sections, we analyzed the theory of wicked problems as originally stated more than 40 years ago (Rittel, 1972; Rittel & Webber, 1973). From this analysis, we derived four suggestions for revisions of the wording and explanations of properties of the theory. We also identified four conclusions about the theory that have major implications for rethinking how to tackle wicked problems.

In particular, we rejected Rittel's recommended strategy of treating each wicked design problem as a solitary entity that cannot benefit from real-world trial and error or learning from previous projects. We concluded instead that, whenever possible, each wicked problem should be treated using an iterative process of trial and error based on building prototypes or preliminary designed artifacts and then testing them with users during the design process itself. In addition, we concluded that learning from previous projects should be maximized through use of rationale from the design and use of artifacts.

Finally, we concluded that a belief in the wickedness of design problems requires a commitment to ongoing redesign as a way of dealing with unforeseen consequences of previous design efforts. The overall picture we paint is of design as an iterative process of reasoning based on building and testing designed artifacts, this process happening both within projects and in sequences of projects stretching over generations, with design rationale used to link designs to redesigns as well as back to the initial requirements. This is a fundamentally different picture than the one originally painted by Rittel and Webber.

We have not discussed how to detect or diagnose a wicked problem in this paper other than through Rittel's properties. Rittel's work was not clear about whether all 10 properties were required to hold in order for a problem to be wicked. Our earlier work suggested that Rittel's properties could be used along with analysis of the cause of the wickedness to determine if a problem was wicked or just challenging (Burge & McCall, 2014).

Much work needs to be done to realize this picture of design. Design rationale management systems must become practical tools for practicing designers. While there are some tools that capture and use rationale as part of the design process (Bracewell et al., 2004) and tools that integrate rationale capture into existing tools (Burge & Brown, 2006), this is not yet part of standard practice. In addition, research needs to be done on the capture of rationale derived from the experiences of implementation and use of designed artifacts. Research also needs to be done on the integration of rationale capture and delivery into the sorts of computational tools that practicing designers actually use. Finally, research is needed on how to integrate the ideas of wicked problems and design rationale into theories of design as an iterative trial-and-error process. Currently, we are working on integrating Rittel's and Webber's ideas with those of Schön.

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