

A Scientific Basis for Rigor and Relevance in Information Systems Research

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A Scientific Basis for Rigor and Relevance in Information Systems Research

- I. the story behind this research
- II. some fundamentals of logic
- III. the modus-ponens/modus-tollens framework
- IV. the MPMT framework “across the board”
- V. the MPMT framework in action research

A Scientific Basis for Rigor and Relevance in Information Systems Research

- I. the story behind this research
 - A. acceptance of qualitative IS research: sincere?
 - B. quality of qualitative IS research: rigorous?
 - C. my own research: significant?

A Scientific Basis for Rigor and Relevance in Information Systems Research

I. the story behind this research

What makes qualitative research scientific?

What makes quantitative research scientific?

What makes research scientific?

... positivist ...

... interpretive ...

... rigorous ...

... relevant ...

... action ...

... design science ...

A Scientific Basis for Rigor and Relevance in Information Systems Research

I. the story behind this research

If it's not mathematical propositions and numerical data that make quantitative research scientific, then what does make it scientific? There are higher principles that make quantitative research scientific. These principles can/must be used and are accessible to other forms of research that seek scientific rigor.

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I. the story behind this research

If it's not mathematical propositions and numerical data that make quantitative research scientific, then what does make it scientific? There are higher principles that make quantitative research scientific. These principles can/must be used and are accessible to other forms of research that seek scientific rigor.

By the end of this presentation, I will have shown:

- how the study of a single case is scientific
- why doing multiple case studies, compared to a single case, does not make the research more scientific
- how multivariate, sampling-based, hypothesis-testing research – as practiced – is incomplete in much IS research (and other disciplines)
- how to frame different forms of research (quantitative, qualitative, positivist, interpretive, action research, design science) as all having the same scientific basis

A Scientific Basis for Rigor and Relevance in Information Systems Research

II. some fundamentals of logic

A. the logic of science: induction or deduction?

B. formative validity versus summative validity

C. the syllogism

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II. some fundamentals of logic

A. the logic of science: induction or deduction?

Induction begins with propositions about instantiations and ends with propositions of a theory.

Deduction begins with propositions about a theory and ends with propositions about its instantiation.

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II. some fundamentals of logic

A. the logic of science: induction or deduction?

inductive validity: “more data supporting a theory provides stronger proof that the theory is true”; “large sample sizes are required”; “single-site case studies are not valid” ← at best, well meaning; at worst, incorrect

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II. some fundamentals of logic

A. the logic of science: induction or deduction?

inductive validity: “more data supporting a theory provides stronger proof that the theory is true”; “large sample sizes are required”; “single-site case studies are not valid” ← at best, well meaning; at worst, incorrect

deductive validity: the logic of the syllogism ← at best, is paid lip service; at worst, is entirely ignored; so simple, its significance escapes many

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II. some fundamentals of logic

B. formative validity versus summative validity

formative validity (I judge an artifact by the process by which I build it): “did I correctly follow the recipe for baking the cake?”; “did I follow all the steps in the given ISD methodology?”; “did I collect enough data, did I collect data in the right way, did I build the theory correctly?”

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II. some fundamentals of logic

B. formative validity versus summative validity

formative validity (I judge an artifact by the process by which I build it): “did I correctly follow the recipe for baking the cake?”; “did I follow all the steps in the given ISD methodology?”; “did I collect enough data, did I collect data in the right way, did I build the theory correctly?”

summative validity (I judge an artifact by its performance, its properties, its impacts): “does the cake taste good?”; “does the information system work?”; “do the theory’s predictions hold in this setting, in other settings, in other time periods?”

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II. some fundamentals of logic

C. the syllogism

major
premise

minor
premise

conclusion

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II. some fundamentals of logic

C. the syllogism

major premise if all humans are mortal,
 then the human Socrates
 is mortal

minor premise “all humans are mortal”
 is true

conclusion ∴ the human Socrates is
 mortal

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II. some fundamentals of logic

modus ponens

C. the syllogism

major
premise

if all humans are mortal,
then the human Socrates
is mortal

if p, then q

minor
premise

“all humans are mortal”
is true

p is true

conclusion

∴ Socrates is mortal

∴ q is true

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II. some fundamentals of logic

C. the syllogism

modus tollens

major
premise

if all humans are mortal,
then the human Socrates
is mortal

if p, then q

minor
premise

the human Socrates is not
mortal

q is not true

conclusion

∴ “all humans are
mortal” is not true

∴ p is not true

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II. some fundamentals of logic

C. the syllogism

modus tollens

$[(x)Hx \supset Mx] \supset Ms$ if all humans are mortal, then the human Socrates is mortal if p, then q

$\sim Ms$ the human Socrates is not mortal q is not true

$\therefore \sim [(x)Hx \supset Mx]$ \therefore “all humans are mortal” is not true \therefore p is not true

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II. some fundamentals of logic

C. the syllogism

theory

modus tollens

$[(x)Hx \supset Mx] \supset$
 M_s

if all humans are mortal,
 then the human Socrates
 is mortal

if p, then q

$\sim M_s$

the human Socrates is not
 mortal

q is not true

$\therefore \sim [(x)Hx \supset Mx] \therefore$ “all humans are
 mortal” is not true

\therefore p is not true

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II. some fundamentals of logic

C. the syllogism

theory

modus tollens

$[(x)Hx \supset Mx] \supset$

if all humans are mortal,
then the human Socrates
is mortal

if p, then q

M_s

the human Socrates is not
mortal

q is not true

$\sim M_s$

prediction

$\therefore \sim [(x)Hx \supset Mx]$

\therefore "all humans are
mortal" is not true

\therefore p is not true

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II. some fundamentals of logic

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modus tollens

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Note:

1. This is a logic for testing a theory, not for building a theory in the first place.

$[(x)Hx \supset Mx] \supset Ms$ if all humans are mortal,
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is mortal if p, then q

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Note:

1. This is a logic for testing a theory, not for building a theory in the first place.
2. This logic implies that the validity of a theory depends on its end result (summative validity), not the process by which it was built or formed (formative validity).

$\therefore \sim [(x)Hx \supset Mx]$ \therefore “all humans are mortal” is not true

$\therefore p$ is not true

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Note:

1. This is a logic for testing a theory, not for building a theory in the first place.
2. This logic implies that the validity of a theory depends on its end result (summative validity), not the process by which it was built or formed (formative validity).
3. This logic makes no distinctions between quantitative, qualitative, positivist, interpretive, action, or design-science research.

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MODUS TOLLENS EXPRESSED IN DIFFERENT FORMS

	modus tollens in everyday English	modus tollens in sentential or propositional logic	modus tollens in relational predicate logic with multiple quantifiers	modus tollens in relational predicate logic with multiple quantifiers, where the variables are interpreted as the traditional independent variables x_i and dependent variable y that are familiar to empirical science	modus tollens in algebraic form with mathematical functions
major premise	If p is true, then q is true.	$p \supset q$	$(x)(y)(z)\Phi xyz \supset \Phi abc$	$(x_1)(x_2)\dots(x_{n-1})(x_n)(y)\Phi x_1x_2\dots x_{n-1}x_ny \supset \Phi a_1a_2\dots a_{n-1}a_na_y$	if the theory " $y = f(x_1, x_2, \dots, x_n)$ " is true, then the prediction " $a_y = f(a_1, a_2, \dots, a_n)$ " is true
major premise	q is not true.	$\sim q$	$\sim \Phi abc$	$\sim \Phi a_1a_2\dots a_{n-1}a_na_y$	$a_y \neq f(a_1, a_2, \dots, a_n)$
conclusion	Therefore p is not true.	$\therefore \sim p$	$\therefore \sim (x)(y)(z)\Phi xyz$	$\therefore \sim (x_1)(x_2)\dots(x_{n-1})(x_n)(y)\Phi x_1x_2\dots x_{n-1}x_ny$	therefore the theory " $y = f(x_1, x_2, \dots, x_n)$ " is not true

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III. the MPMT framework

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III. the MPMT framework

but first, some notation that should be a bit more familiar...

Table 1: the Logic of the Syllogism, Illustrated with Positivist Notation

<i>the theory</i> (major premise – general statement)	$y = f(x_1, x_2, \dots, x_n)$
<i>the initial conditions</i> (minor premise – singular statement)	$x_1=a_1, x_2=a_2, x_3=a_3, \dots, x_n=a_n$
<i>the prediction</i> (conclusion – singular statement)	$y_{\text{obs}} = f(a_1, a_2, \dots, a_n)$

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III. the MPMT framework

Table 2: Modus Ponens (MP) – positivist research

$p \supset q$	If the theory T_k , “ $y = f_k(x_1, x_2, \dots, x_n)$,” is true, then the prediction “ y_{obs} takes the value of $f_k(a_1, a_2, \dots, a_n)$ ” is true.
p	The theory T_k , “ $y = f_k(x_1, x_2, \dots, x_n)$,” is true.
$\therefore q$	Therefore “ y_{obs} takes the value of $f_k(a_1, a_2, \dots, a_n)$ ” is true.

Table 3: Modus Tollens (MT) – positivist research

$p \supset q$	If the theory T_k , “ $y = f_k(x_1, x_2, \dots, x_n)$,” is true, then the prediction “ y_{obs} takes the value of $f_k(a_1, a_2, \dots, a_n)$ ” is true.
$\sim q$	y_{obs} takes a value that is not $f_k(a_1, a_2, \dots, a_n)$.
$\therefore \sim p$	Therefore the theory T_k , “ $y = f_k(x_1, x_2, \dots, x_n)$,” is not true.

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Table 4: Modus Ponens (MP) – interpretive science

$p \supset q$	If a reader's interpretation I_k of a text is a valid hermeneutic interpretation, then the reader's interpretation of any passage P_i or set of passages (e.g., P_2, P_3, P_5) in the text does not give rise to any contradiction, inconsistency, or other anomaly with regard to the reader's interpretation of any or all of the other passages in the text. ⁸
p	A reader's interpretation I_k of a text is a valid hermeneutic interpretation.
$\therefore q$	Therefore the reader's interpretation of any passage P_i or set of passages (e.g., P_2, P_3, P_5) in the text does not give rise to any contradiction, inconsistency, or other anomaly with regard to the reader's interpretation of any or all of the other passages in the text.

Table 5: Modus Tollens (MT) – interpretive science

$p \supset q$	If a reader's interpretation I_k of a text is a valid hermeneutic interpretation, then the reader's interpretation of any passage P_i or set of passages (e.g., P_2, P_3, P_5) in the text does not give rise to any contradiction, inconsistency, or other anomaly with regard to the reader's interpretation of any or all of the other passages in the text.
$\sim q$	A reader's interpretation of a particular passage in the text (which could be a new passage that the reader encounters) gives rise to an anomaly with regard to the reader's interpretation of another particular passage or set of passages in the text.
$\therefore \sim p$	Therefore the reader's interpretation I_k of the text is not a valid hermeneutic interpretation.

Notes for Tables 4 and 5

- a. In I_k , I refers to a reader's interpretation of a text and k refers to the reader's k^{th} reading and k^{th} interpretation of the text. I define the term "interpretive theory" to be such an interpretation, I_k .
- b. $p = \{\text{a reader's interpretation } I_k \text{ of a text is a valid hermeneutic interpretation}\}$. $q = \{\text{the reader's interpretation of any passage } P_i \text{ or set of passages (e.g., } P_2, P_3, P_5) \text{ in the text will not give rise to a contradiction, inconsistency, or other anomaly with regard to the reader's interpretation of any other passage or set of passages in the text}\}$.
- c. Constituting a text are the passages P_1, P_2, \dots, P_n . The passages P_1, P_2, \dots, P_n may or may not be mutually exclusive, but are mutually exhaustive of the text.
- d. In interpreting a text, a reader strives for an interpretation of both the text as a whole and the different passages making up the text.
- e. To show that an interpretation I_k is not a valid hermeneutic interpretation, an assessment would use the logic of modus tollens. Such an assessment would call for I_k it to be replaced by an improved version or a completely new interpretation. This

Notes for Tables 4 and 5

interpretation, I_{k+1} , would then be assessed as to whether it is a valid hermeneutic interpretation of the text, just as I_k was assessed. The process of crafting an interpretation in this iterative manner, involving the logic of modus tollens, is precisely the logic of the hermeneutic circle, which Klein and Myers (1999) characterize as the overarching principle of interpretive research.

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III. the MPMT framework

not modus ponens (MP), not modus tollens (MT)

$p \supset q$	If the theory p is true, its prediction q is true.
q	The prediction q turns out to be true.
$\therefore p (?)$	Therefore the theory p is true (?)

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III. the MPMT framework

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to conclude that p is true in this situation would be to commit the “fallacy of affirming the consequent”

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III. the MPMT framework

not modus ponens (MP), not modus tollens (MT)	
$p \supset q$	If the theory p is true, its prediction q is true.
q	The prediction q turns out to be true.
$\therefore p (?)$	Therefore the theory p is true (?)
not modus ponens (MP), not modus tollens (MT)	
$p \supset q_1 \bullet q_2 \bullet \dots \bullet q_n$	If the theory p is true, its predictions q_1, q_2, \dots, q_n are true.
$q_1 \bullet q_2 \bullet \dots \bullet q_n$	The predictions q_1, q_2, \dots, q_n all turn out to be true.
$\therefore p (?)$	Therefore the theory p is true (?)

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III. the MPMT framework

to conclude that p is true in this situation would be to commit the “fallacy of affirming the consequent” n times

not modus ponens (MP), not modus tollens (MT)

$p \supset q_1 \bullet q_2 \bullet \dots \bullet q_n$	If the theory p is true, its predictions q_1, q_2, \dots, q_n are true.
$q_1 \bullet q_2 \bullet \dots \bullet q_n$	The predictions q_1, q_2, \dots, q_n all turn out to be true.
$\therefore p (?)$	Therefore the theory p is true (?)

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III. the MPMT framework

first of two ramifications:

Our theory-testing is incomplete.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n$$

$$y = 1.2 + 2.3 x_1 + 1.7 x_2 + \dots + 0.6 x_n$$

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III. the MPMT framework

first of two ramifications:

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$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n$$

$$y = 1.2 + 2.3 x_1 + 1.7 x_2 + \dots + 0.6 x_n$$

$$BI = \beta_0 + \beta_1 EOU + \beta_2 U$$

$$BI = 1.2 + 2.3 EOU + 1.7 U$$

Table 3: Modus Tollens (MT) – positivist science

$p \supset q$	If the theory T_k , “ $y = f_k(x_1, x_2, \dots, x_n)$,” is true, then the prediction “ a_y takes the value of $f_k(a_1, a_2, \dots, a_n)$ ” is true.
$\sim q$	a_y takes a value that is not $f_k(a_1, a_2, \dots, a_n)$.
$\therefore \sim p$	Therefore the theory T_k , “ $a_y = f_k(x_1, x_2, \dots, x_n)$,” is not true.

first of two ramifications:

Our theory-testing is incomplete.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n$$

$$y = 1.2 + 2.3 x_1 + 1.7 x_2 + \dots + 0.6 x_n$$

$$BI = \beta_0 + \beta_1 EOU + \beta_2 U$$

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Table 3: Modus Tollens (MT) – positivist science

$p \supset q$	If the theory T_k , “ $y = f_k(x_1, x_2, \dots, x_n)$,” is true, then the prediction “ a_y takes the value of $f_k(a_1, a_2, \dots, a_n)$ ” is true.
$\sim q$	a_y takes a value that is not $f_k(a_1, a_2, \dots, a_n)$.
$\therefore \sim p$	Therefore the theory T_k , “ $a_y = f_k(x_1, x_2, \dots, x_n)$,” is not true.

first of two ramifications:

Our theory-testing is incomplete.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n$$

$$y = 1.2 + 2.3 x_1 + 1.7 x_2 + \dots + 0.6 x_n$$

When we earlier measured the beta’s (and we got 1.2, 2.3, 1.7, ..., 0.6), we presumed the theory T_k to be true. This allowed us to go ahead and measure the beta’s. But measuring the beta’s is not the same thing as testing the theory.

A Scientific Basis for Rigor and Relevance in Information Systems Research

III. the MPMT framework

second of two ramifications:

Our interpretation-assessing is incomplete.

A Scientific

In

III. the N

sec

Out

formative criteria and summative criteria in articles in the *MIS Quarterly* special issue on intensive research

authors and article title	formative criteria specified in the article	summative criteria specified in the article
Walsham, G. and Sahay, S. "GIS for District-Level Administration in India: Problems and Opportunities," Volume 23, Number 1, March 1999, pp. 39-65.		
Gopal, A. and Prasad, P. "Understanding GDSS in Symbolic Context: Shifting the Focus from Technology to Interaction," Volume 24, Number 3, September 2000, pp. 509-546.		
Nelson, K.M., Nadkarni, S., Narayanan, V.K., Ghods, M., "Understanding Software Operations Support Expertise: A Revealed Causal Mapping Approach," Volume 24, Number 3, September 2000, pp. 475-507.		
Schultze, U. "A Confessional Account of an Ethnography About Knowledge Work," Volume 24, Number 1, March 2000, pp. 3-41.		
Trauth, E.M. and Jessup, L.M. "Understanding Computer-Mediated Discussions: Positivist and Interpretive Analysis of Group Support System Use," Volume 24, Number 1, March 2000, pp. 43-79.		

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complete.

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IV. the MPMT framework “across the board”

Table 7: Modus Tollens – four forms of academic inquiry as specific cases of pragmatism

	Positivist Research	Interpretive Research	Action Research	Design Science Research	Pragmatism of Peirce, James, Dewey ¹²
$p \supset q$	If a positivist theory about a phenomenon is true, then what the theory predicts about an instantiation of the phenomenon is true.	If a reader’s interpretation of a text is a valid hermeneutic interpretation, then the reader’s interpretation of a particular passage or set of passages in the text does not give rise to any contradiction, inconsistency, or other anomaly with regard to the reader’s interpretation of any or all of the other passages in the text.	If a theory of action about how to solve problems or achieve goals pertaining to a phenomenon is effective, then the action that the theory prescribes will solve the given problem or achieve the given goal pertaining to an instantiation of the phenomenon.	If a design principle is valid, then an artifact implementing the design principle will be successful in solving the given problem or achieving the given goal.	If a person’s belief about the world has the quality of “truth in the case of statements, rightness in the case of actions, and value in the case of appraisals,” then an action based on it will “work out.”
$\sim q$	For an instantiation of the phenomenon, what the theory predicts turns out not to be true.	For a particular passage or set of passages in a given text, the reader’s interpretation gives rise to a contradiction, inconsistency, or other anomaly with regard to the reader’s interpretation of another particular passage or set of other passages in the same text.	The action that the theory of action prescribes does not solve the given problem or achieve the given goal pertaining to an instantiation of the phenomenon.	An artifact implementing the design principle is not successful in solving the given problem or achieving the given goal.	An action based on the belief does not “work out.”
$\therefore \sim p$	Therefore the positivist theory is not true (thereby suggesting that an improved or new positivist theory needs to be developed and then also tested).	Therefore the reader’s interpretation of the given text is not a valid hermeneutic interpretation (thereby suggesting that an improved or new interpretation needs to be developed and then also tested).	Therefore the theory of action is not effective (thereby suggesting that an improved or new theory needs to be developed and then also tested).	Therefore the design principle is not valid (thereby suggesting that an improved or new design principle needs to be developed).	Therefore the person’s belief about the world lacks the quality of “truth in the case of statements, rightness in the case of actions, and value in the case of appraisals.”

¹² The quoted material in this column is taken from Nicholas Rescher, “Pragmatism,” in *The Oxford Companion to Philosophy*, Oxford University Press, 2005, p. 747.



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V. the MPMT framework in action research

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V. the MPMT framework in action research

Start with the major premise:

”If positivist theory T is true, then...”

”If the interpretation I is valid, then...”

”If theory of action TA is true, then...”

”If design principle DP is true, then...”

Determine the minor premise:

”What we measure or observe is...”

”The evidence is...”

”The result is that...”

∴ Conclusion:

T/I/TA/DP is refuted or confirmed.

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V. the MPMT framework in action research

Start with the major premise:

I. "If positivist theory T is true, then..."

II

II

$$(x_1)(x_2)\dots(x_{n-1})(x_n)\Phi_{x_1x_2\dots x_{n-1}x_n} \supset \Phi_{a_1a_2\dots a_{n-1}a_n}$$

IV. "If design theory DT is true, then..."

Determine the minor premise:

V. "What we measure or observe is..."

V

V

$$\sim\Phi_{a_1a_2\dots a_{n-1}a_n}$$

∴ Conclusion:

I.T/I.TA/DT is refuted or confirmed.

$$\sim(x_1)(x_2)\dots(x_{n-1})(x_n)\Phi_{x_1x_2\dots x_{n-1}x_n}$$

Kohli & Kettinger (2004)

Start with the major premise:

”If positivist theory T is true, then...”

”If the interpretation I is valid, then...”

”If theory of action TA is true, then...”

”If design principle DP is true, then...”

Determine the minor premise:

”What we measure or observe is...”

”The evidence is...”

”The result is that...”

∴ Conclusion:

T/I/TA/DP is refuted or confirmed.

major premise:

If { “Proposition A: Greater information transparency through the use of a performance monitoring information system (providing valid measures of behaviors and outcomes) will lead to greater goal congruence between the principal (hospital) and the agents (physicians) [p. 371] } is true, then we will observe the following: { “the physicians [will] begin to use the data [from the clinical DSS] to examine their practice and ultimately adopt quality improvement and/or cost cutting clinical procedures...” [p. 372] }.

minor premise:

The action researchers observed the “failure of the wider physician community to utilize the clinical DSS” [p. 374].

conclusion:

Proposition A is refuted (thereby calling for an improved or new theory to be developed and then also tested).

A Scientific Basis for Rigor and Relevance in Information Systems Research

One logic usable by positivist, interpretive, action, and design-science research

- Positivist research and interpretive research both strive for rigor. Modus tollens provides a scientific basis by which to achieve the rigor.
- Action research and design-science research both strive for relevance. Modus tollens provides a scientific basis by which to achieve the relevance.

A Scientific Basis for Rigor and Relevance in Information Systems Research

Signs: When Information Systems Research Accepts Modus Tollens

- Information-systems researchers will no longer commit the fallacy of affirming the consequent, particularly in their commentaries on case studies.
- Information-systems researchers who now differentiate and separate themselves based on the approaches they take – which include positivism, interpretivism, action research, and design science – will instead see themselves as members of the same team who are building on the same scientific basis and who are complementing each other's approaches in their collaborative effort of building a cumulative body of knowledge.
- Information-systems researchers will, more often than not, give due recognition to summative validity and not end their research efforts upon achieving formative validity.
- Information-systems researchers will come to regard research as rigorous only if also relevant. They will regard pragmatic research with all the same prestige that they now accord basic research.