

The Hidden Transfer Problem: Why Reproducing a Procedure Is Not Reproducing a Result

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Abstract

A written procedure can be reproduced line by line while the physical experiment changes. Different instruments, operators, environmental states, material lots, geometries, timing, software implementations and local practices can alter the measurement system even when the nominal protocol is identical. Conversely, two laboratories can use different procedures and still realise equivalent physical states. The hidden transfer problem is the assumption that procedural identity guarantees result identity. This methodological article separates documentary reproducibility from physical equivalence and explains why transfer requires explicit control of the state variables that carry the scientific claim. The central proposition is that a protocol is a recipe for attempting to recreate a measurement system, not proof that the same measurement system was actually recreated.

Keywords: transfer; reproducibility; method transfer; protocol; laboratory; operator; equipment; process equivalence; tacit variable; robustness

1. Purpose and evidence boundary

HEB-001 states that reproducibility of a procedure is not the same as validity of a procedure [1]. ER-005 retains the working-curve reproducibility problem [2], and ER-209 retains interlaboratory round-robin design [3]. HEB-015 asks the more general inferential question: what physical state must survive when a method or result is transferred?

2. Written steps omit physical state

A protocol may specify exposure time but not delivered spectrum, mixing time but not achieved homogeneity, room temperature but not specimen temperature, cleaning time but not mass-transfer state. The written action and the realised physical condition are different levels of description.

3. Tacit variables travel through people

Laboratory methods are often learned by demonstration. How vigorously a sample is mixed, how a surface is judged clean, how a specimen is positioned or when an instrument is considered stable may not appear in the document. Transfer exposes these tacit variables because a second operator or laboratory no longer shares the same local habits.

4. Equipment equivalence is not model-name equivalence

Two instruments of the same model can differ in calibration, wear, optical alignment, fixtures, software version and environment. Two different instruments can sometimes produce equivalent measurement states if the relevant measurands are matched. Transfer should therefore compare delivered physical variables rather than brand labels alone [4].

5. Material identity is not state identity

A common resin batch reduces one source of variation but does not guarantee common temperature, oxygen history, ageing, mixing, build orientation or post-processing. The broader lesson is that material identity is only one coordinate of experimental state. ER-209 retains the application-specific round-robin architecture [3].

6. Protocol inheritance can preserve the same error

A procedure that contains an uncontrolled variable can be reproduced faithfully and propagate the same bias. Agreement between laboratories is valuable evidence of reproducibility but does not by itself establish trueness. A common mistake can travel extremely well [5].

7. Transfer requires anchor measurands

The strongest transfer strategy identifies the physical quantities that must be equivalent for the claim: spectral irradiance, temperature, geometry, concentration, timing, specimen state, reference relation or another state variable. The procedure can then vary locally provided those anchors remain within defined bounds.

8. Transfer has levels

A method can transfer between operators on one instrument, between instruments in one laboratory, between laboratories, between material lots, between scales or between application states. Success at one level does not establish success at the next. The intended transfer population should be defined before the validation claim.

9. Deviations can be informative

When a transferred method fails, the difference between sites is evidence. Instead of forcing compliance by undocumented adjustment, compare state variables and identify which divergence predicts the result. Transfer studies are therefore diagnostic experiments about hidden variables as much as demonstrations of reproducibility.

10. Questions a transfer claim must answer

A transfer claim should make it possible to ask: What scientific purpose is being transferred? Which physical states and anchor measurands matter? Which variables were merely documentary settings, and which were demonstrated to control the result? What evidence would show that the receiving implementation recreates the state relevant to the claim? These are inferential questions, not a universal qualification checklist; method-specific acceptance rules remain with the corresponding Engineering Reviews.

11. Interlaboratory evidence reveals hidden transfer variables

Published interlaboratory working-curve studies show that substantial dispersion can remain when procedure, light-engine state and measurement execution differ among laboratories [6,7]. Their value here is diagnostic: disagreement can reveal a hidden transfer variable rather than merely a poorly copied instruction.

12. Evidence for equivalence must remain inspectable

A defensible transfer argument should leave an inspectable chain between each claimed equivalent state and the evidence used to support it. The scientific point is not to prescribe a matrix or tolerance table, but to prevent a vague statement of equivalence from outrunning the measurements that connect the original and receiving systems.

13. Robustness and equivalence are different transfer claims

A robust method tolerates bounded variation without changing the conclusion. An equivalent method may use a different procedure to realise the same decision-relevant state. These ideas overlap but are not identical. Demonstrating robustness to operator timing, for example, does not prove equivalence between two instruments with different spectral responses. Conversely, two instruments can be made equivalent for one measurand while each remains sensitive to local environmental variation. Transfer plans should therefore state whether they seek robustness within one method, equivalence between implementations, or both. Blurring the terms can lead to a validation study that answers the wrong transfer question.

14. The receiving site should challenge, not merely imitate

A strong transfer exercise includes deliberate perturbations at the receiving site. Small, predefined changes in operator, day, instrument, material lot or environment can reveal whether the method is truly controlled or only works under a narrow undocumented condition. The objective is not to make the receiving laboratory fail. It is to establish which variations are benign and which require tighter control. This converts transfer from a ceremonial reproduction of the source protocol into an experiment on the method's operating envelope. A method that survives bounded challenge is more transferable than one that succeeds once under heavily coached conditions.

15. Conclusions

Procedural identity is neither necessary nor sufficient for physical equivalence. Transfer succeeds when the variables that carry the scientific claim are recreated within demonstrated bounds and the result remains robust to allowed local variation. The hidden transfer problem is controlled by validating state, not merely copying steps.

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Knowledge boundary

HEB-015 owns the general distinction between procedural reproduction and physical transfer. ER-005, ER-203 and ER-209 retain their specific working-curve, radiometric and interlaboratory qualification scopes.

Limitations

This methodological article is a bounded synthesis of the controlled HEB and Engineering Review corpus. It does not report a new experimental dataset, does not establish universal numerical thresholds, and does not convert examples from one domain into application-wide specifications. Claims that require application-specific qualification remain with the corresponding technical review or primary study.