

ERROR-CONTINGENT AI GUIDANCE AND INDEPENDENT PROBLEM SOLVING IN METROLOGY EDUCATION

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Abstract. An instructional procedure is proposed for moving textile engineering students from error-specific artificial intelligence (AI) guidance to independent metrological reasoning. An initial unaided attempt is followed by a targeted question, source verification and a justified revision. Support is reduced according to performance on new tasks, with provision for restoring it when a difficulty persists. A waste-composition example distinguishes a reported percentage from an unsupported claim about production losses. Correct and flawed recommendations are included in the same exercise set to assess evidence-based judgement. The contribution is a teaching procedure and an assessment proposal; no classroom trial or learning gains are reported.

Keywords: metrology education; error-contingent feedback; scaffolding; source verification; independent problem solving; textile engineering.

Introduction

A correct laboratory answer does not establish whether a student can justify it without assistance. Atkinson, Renkl and Merrill [1] found across two experiments that combining the withdrawal of worked solution steps with prompts about underlying principles improved near and far transfer. The finding supports a distinction between explaining an example and merely reproducing its final answer.

AI-assisted practice requires the same distinction. In a high-school mathematics experiment involving nearly a thousand students, Bastani et al. [2] reported that the unrestricted AI group scored lower than the no-AI control after access was withdrawn; teacher-designed safeguards substantially reduced that disadvantage. The result concerns a particular educational setting, not textile laboratories. The present paper proposes how assistance can be adjusted to a student's error while retaining responsibility for checking the evidence.

Materials and approach

The paper combines a focused comparison of pedagogical studies with task design based on a supplied textile dissertation. Van de Pol, Volman and Beishuizen [3] distinguish support fitted to current understanding, its gradual withdrawal and the transfer of responsibility. Those distinctions inform the proposed sequence. Source selection was purposive; neither a systematic review nor an empirical intervention was undertaken.

Here, "error-contingent" refers to guidance adjusted to a mistake in the student's explanation. It does not redefine measurement error. The International Vocabulary of Metrology distinguishes measurement error from mistakes and treats measurement uncertainty as a separate concept [4, entries 2.16 and 2.26]. The teaching case preserves a reported waste-composition value [5, p. 63]; additional masses and assumptions are explicitly introduced as classroom conditions.

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Proposed method and illustrative case

Each task begins with a brief unaided submission stating the quantity sought, the proposed calculation and the evidence needed. The instructor or AI assistant then asks for the reasoning behind the first questionable step. A wrong final number alone is insufficient to establish the cause. Misreading a denominator, omitting a unit and applying an unsuitable requirement demand different questions, as illustrated in Table 1.

Only one targeted prompt is given at a time. If the student remains unable to proceed, support increases from a conceptual question to a source pointer and, where necessary, a short worked example using different values. The student returns to the original task and explains the correction. Missing prerequisite knowledge warrants direct teaching rather than an indefinite series of questions. References, numerical limits and unfamiliar claims supplied by AI must be checked against instructor-approved documents.

Table 1. Matching a prompt to the student's difficulty

Difficulty in the response	Example of permitted guidance	Evidence required before fading
Wrong denominator	"What does the percentage refer to?"	Identifies numerator and denominator; rewrites the ratio.
Inconsistent units	"Can the stated quantities be combined?"	Shows the conversion and retains units.
Unverified requirement	"Which document passage supports that limit?"	Checks scope and clause, or records missing evidence.
Unsupported conclusion	"Which part of the claim follows from the data?"	Separates supported findings from unresolved claims.

Author-developed prompts and decision criteria; not observations of students or a tested AI system.

The revised submission retains the first answer, identifies the disputed step, cites the relevant evidence and explains the change. On a new task, the instructor initially withholds the last form of help supplied. If the student completes and explains the corresponding step, the reduced support is retained. Otherwise, the last useful assistance is restored. A provisional rule for full withdrawal is two consecutive new tasks completed without task-specific hints, with correct reasoning and justified limits on the conclusion. The rule is a proposal for piloting, not an established mastery threshold.

The proposed exercise set contains sound advice, contradicted advice and advice for which evidence is insufficient. Students accept, reject or suspend judgement with a reason. Unsupported does not necessarily mean false. Including correct recommendations prevents blanket rejection of AI output from being mistaken for critical judgement. The instructor prepares the challenge statements and checks the answer key; deliberately flawed examples are identified as constructed teaching material, not recorded model behaviour.

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A case from Maxammetov [5, p. 63, Table 3.4] makes the distinction concrete. The row for Lot 1, the first equipment set and waste category 7/11 reports 71.41% under “cleaned fibre” within the waste sample. A deliberately flawed recommendation reads: “Treat 71.41% as the proportion of incoming cotton lost as fibre.” The reported percentage describes the waste sample's composition. It does not by itself establish the fraction of incoming material entering that waste stream.

The initial prompt asks the student to identify the reference material for 71.41%. A second prompt, supplied only if needed, asks which additional mass would be required to express fibre entering the waste stream relative to the feed. A justified revision identifies the missing waste-to-feed ratio and checks whether the sample represents the stream. Neither a plausible AI explanation nor the percentage alone supplies the missing observation.

For a separate completion exercise, the instructor explicitly stipulates a mass basis and hypothetical quantities of 5 kg of waste per 100 kg of feed. Representative sampling and matched conditioning are assumed. With the reported fraction set at 0.7141, the calculation gives $0.7141 \times 5 \text{ kg} = 3.5705 \text{ kg}$ of cleaned fibre in the waste, or approximately 3.57% of the stipulated feed mass. The masses and assumptions are teaching additions, not measurements reported for the enterprise. No actual production-loss estimate follows from the exercise.

Assessment and limitations

Assessment records assisted correction and independent performance separately. Each response is examined for its definition of the quantity, use of units, source checking, calculation and conclusion. For a pilot, each criterion can receive 0 for an incorrect or absent explanation, 1 for a partly justified response and 2 for a justified response. Assistance level is recorded alongside the score rather than added to it. The proposed rubric requires expert review and checks of agreement between assessors before research use.

The independent task changes values and at least one condition, such as the reporting basis or available evidence. AI hints are unavailable, while permitted calculators and source documents remain identical for all students. A short oral explanation checks understanding of a selected step. A later transfer task would test whether the reasoning persists. Any comparative trial must also account for initial preparation and equal teaching time; improvement cannot be assumed from a polished assisted submission.

Conclusion

The proposed method connects each hint to an identifiable difficulty and each reduction of support to an independently explained step. Its specific contribution is a reversible procedure for withdrawing assistance, combined with exercises that distinguish incorrect advice from insufficiently supported advice. The textile case shows that an accurately quoted percentage does not justify a conclusion based on a different denominator. Classroom evaluation is still required to establish whether the procedure improves independent metrological reasoning.

References

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