

# Introducing adaptive assistance in adaptive testing

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**Abstract.** In this paper, we discuss the development of a theoretical framework for introducing adaptive presentation in adaptive testing. To this end, a discussion of some aspects concerning the adaptive selection mechanism for hints is presented. Some axioms that hints must fulfil are also determined, providing a hint validation procedure.

## 1. Introduction

Testing is commonly used in many educational contexts with different purposes: grading, self-assessment, diagnostic assessment, etc. In order to improve the efficiency of the diagnosis process, adaptive testing systems select the best question to be asked next according to relevant characteristics of the examinee. In this way, higher accuracy can be reached with a significant reduction in test length. One of the most commonly used approaches for adaptive testing is *Item Response Theory* (IRT) [1], which assumes that the answer to a question depends on an unknown latent numerical trait  $\theta$ , which in educational environments corresponds to the knowledge of the subject being tested.

In any adaptive educational system, it is necessary to have accurate estimations of the student's knowledge level in order to take the more suitable instructional action. In this sense, *Computerized Adaptive Tests* (CATs) [2] based on IRT provide a powerful and efficient diagnosis tool. In our group we have used this framework to design and implement SIETTE<sup>1</sup> [3], [4], which is a web-based assessment system that implements CATs based on a discretization of IRT.

There can be little doubt that one of the main contributions to educational psychology in the XX century is Vigotsky's *Zone of Proximal Development* (ZPD) [5]. A short operational definition useful for our purposes is given in [6]: the zone defined by the difference between a person's test performance under two conditions: with or without assistance. Soon after the definition of the ZPD, attempts to apply this concept were made in the context of the administration of tests, typically with the aim to classify students with the goal to allocate them in the more appropriate educational program. But the main goal of the work presented here is different: to build a model that allows the integration of adaptive assistance in the adaptive testing procedure within the SIETTE system.

It is widely accepted that hinting is a general and effective tactic for teaching. In [7] it is shown that human tutors maintain a rough assessment of the student's performance (the trait  $\theta$  in our approach) in order to select a suitable hint. Many Intelligent Tutoring Systems also give hints to the student, like for example, ANDES [8] and Animalwatch [9].

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<sup>1</sup> <http://www.lcc.uma.es/SIETTE>

In our framework, assistance will be represented by *hints*,  $h_1, \dots, h_n$  that provide different levels of support for each test item. By *adaptive assistance* we mean that the hint to be presented will be selected by the system depending on how far in the ZPD is the item, in such a way that it provides the minimal amount of information so that the student is able to correctly answer such item.

The work presented here aims to extend our previous research [10] on the introduction of hints and feedback in adaptive testing. The main goal is now the definition and evaluation of a theoretical framework for adaptive hinting. This paper addresses the definition of such framework, and is structured as follows: next, we discuss several aspects concerning the introduction of hints in adaptive testing environments and then we present some conclusions and future lines of research.

## 2. Introducing hints in an Adaptive Testing environment

As aforementioned, SIETTE implements CATs and IRT in a web-based assessment tool. In contrast with traditional IRT,  $\theta$  is defined as a discrete variable. To introduce hints in this model, let us first define some terms:

- *Item*. We use this term to denote a question or exercise posed to a student. The solution of such task will be provided by answering a multiple choice question, that is the conjunction of a stem and a set of possible answers, where only one is correct.
- A *test* is a sequence of items.
- *Hint*. A hint is an additional piece of information that is presented to the student after posing a question and before he answers it. Hints may provide an explanation of the stem, clues for rejecting one or more answers, indications on how to proceed, etc. Hints can be invoked in two different ways: a) *active* (the examinee asks for it) or b) *passive*, (the system decides when to present it).

As an example, consider the following test item and some possible hints:

What is the result of the expression:  $1/8 + 1/4$ ?

a)  $3/4$       b)  $3/8$       c)  $2/4$       d)  $2/8$

Hint 1:  $1/4$  can be also represented as  $2/8$   
 Hint 2: First, find equivalent fractions so they have the same denominator  
 Hint 3: d is incorrect

For our purposes, a simplifying assumption is that *hints do not modify student's knowledge*. This assumption (that the trait  $\theta$  remains constant during the test) is usual in adaptive testing, and in this case means that hints do not cause a change in examinee's knowledge but a change on the ICC shape. In this way, the hint brings the question from the ZPD to student's knowledge level. In this sense, the combination of the item plus the hint can be considered as a new item. This new (virtual) item is represented by a new ICC whose parameters can be estimated using the traditional techniques. However, both ICC's are not independent. First, the use of a hint should make the question easier, which can be stated as:

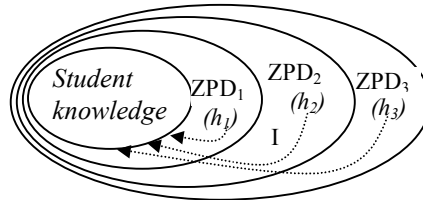
*Axiom 1. Given a question  $q$  and a hint  $h$ , let  $ICC_q$  and  $ICC_{q+h}$  be the ICCs associated to the question and to the combination question+hint, respectively. Then,  $ICC_q(k) \leq ICC_{q+h}(k)$ .*

If the examinee uses a combination of hints, the question should become even easier:

*Axiom 2. Given a question  $q$ , a set of hints  $H$  and a hint  $h \notin H$ , for all knowledge levels  $k$ ,  $ICC_{q+H}(k) \leq ICC_{q+H+\{h\}}(k)$ .*

If the parameters for such ICCs have been estimated and the axioms above are not satisfied, it means that the "hint" misleads the student and should be rejected. This simple approach provides with a useful empirical method to validate hints.

In adaptive environments, it makes sense to look for a criterion for adaptively selecting the best hint to be presented. Under the ZPD framework, if the student is not able to solve the item but the item is on his/her ZPD, the best hint to be presented would be the hint that brings the item I from the ZPD to the zone of the student's knowledge. So for example if an item I has three associated hints  $h_1$ ,  $h_2$  and  $h_3$  at different levels of detail, it means that each hint is suitable for a different part of the ZPD, as represented in Figure 1.



**Fig.1.** Student knowledge, ZPDs and hints

A possibility for adaptive selection of hints is to use classical adaptive mechanisms: given the knowledge estimation  $\theta(k)$  for a student, and given two hints  $h_1$  and  $h_2$ , the best hint is the one that minimizes the expected variance of the posterior probability distribution. This mechanism is simple to implement and does not make substantial modifications in the adaptive testing procedure, because the test is used for evaluation and not for learning. However, the use of hints can provide positive stimuli and increase student self-confidence.

### 3. Conclusions and future work

This paper has presented some ideas about introducing adaptive hints in an adaptive testing environment, based upon IRT constructs. Hints are considered not as knowledge modifiers, but as modifiers of the ICC of a question. Some formal axioms that every model of hints must satisfy have been stated and informally justified. A preliminary evaluation study (not reported here due to lack of space) suggests that the use of adaptive hints in such environments is adequate and feasible. The next step is the calibration of ICCs for each pair item-hint using empirical data. The obtained ICCs will allow validating such hints and serve as a basis for the integration and implementation of this model in SIETTE to allow for adaptive selection of items and hints in our testing system.

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