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Chapter Title	Formative and Stealth Assessment	
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Abstract	<p>Assessing generally refers to the process of gathering information about a person relative to specific competencies and other attributes, in formal or informal learning contexts. This should lead to valid and reliable inferences about competency levels, which in turn may be used for diagnostic and/or predictive purposes. Too often, classroom and other high-stakes assessments are used for purposes of grading, promotion, and placement, but not to enhance learning. In this chapter, we focus on formative assessment which posits that assessment should (a) encourage and support, not undermine, the learning process for learners and teachers; (b) provide formative information whenever possible (i.e., give useful feedback during the learning process instead of a single judgment at the end); and (c) be responsive to what is known about how people learn, generally and developmentally. This type of assessment has as its primary goal improvement of learning, which is critical to support the kinds of learning outcomes and processes necessary for students to succeed in the twenty-first century. It is referred to as “formative assessment,” or assessment <i>for</i> learning, in contrast to “summative assessment” (or assessment <i>of</i> learning). This chapter overviews the role of formative assessment in education generally, and also touches on stealth assessment specifically—an evidence-based approach to weaving assessments directly into learning environments (Shute, Computer games and instruction. Charlotte, NC: Information Age Publishers, 2011).</p>	

Keywords  
(separated by "-")

Competency - Evidence-centered design (ECD) - Formative assessment -  
Stealth assessment

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 23 assessment

24 **Introduction**

25 Assessment should not merely be done to students; rather, it  
 26 should also be done for students, to guide and enhance their  
 27 learning. NCTM (2000).

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In the United States, assessment currently plays a 28  
 significant (and often heavy-handed) role in educational sys- 29  
 tems. A prevalent form of assessment in education today is 30  
 the standardized test. The primary goal of standardized tests 31  
 is to ensure accountability of schools and teachers. Our 32  
 nation’s usage of standardized tests has increased consider- 33  
 ably since the No Child Left Behind (NCLB) Act was signed 34  
 into law in 2001 (Chappius & Chappius, 2008). For example, 35  
 before NCLB, 19 states required annual reading and mathe- 36  
 matics tests in grades 3–8, and one test administered in high 37  
 school. By 2006, every state required standardized testing 38  
 (Jennings & Rentner, 2006). 39

40 Although there is a little evidence supporting positive  
 41 effects of the NCLB Act, there is extensive criticism about  
 42 the hidden costs of NCLB. For instance, Stiggins (2002)  
 43 argued, “*We are a nation obsessed with the belief that the*  
 44 *path to school improvement is paved with better, more fre-*  
 45 *quent, and more intense standardized testing. The problem is*  
 46 *that such tests, ostensibly developed to ‘leave no student*  
 47 *behind,’ are in fact causing major segments of our student*  
 48 *population to be left behind because the tests cause many to*  
 49 *give up in hopelessness—just the opposite effect from that*  
 50 *which politicians intended.”* (p. 2).

51 The primary problem with current assessment practices is  
 52 that the information from the assessment currently is not  
 53 being used, as it could and should, to support teaching and  
 54 learning (e.g., Shute, 2007; Symonds, 2004; Wiliam &  
 55 Thompson, 2007). Typically, classroom assessments are only  
 56 administered at the end of some major chunk of time with  
 57 assessment results arriving too late for teachers to effectively  
 58 act on them. Symonds (2004) highlighted this problem as  
 59 she explored policies and practices in dozens of schools that  
 60 were classified into two groups: successful and unsuccessful  
 61 in closing the achievement gap. The report showed clear,  
 62 striking differences between the gap-closing versus non-gap-  
 63 closing groups—particularly with regard to the use of data.  
 64 Gap-closing schools assessed students often and used the  
 65 results to make changes in their instructional program. Non-  
 66 gap-closing schools assessed students infrequently and did  
 67 not use the data to effect instructional changes. Two recom-  
 68 mendations that emerged from the Symonds study (and  
 69 which have been endorsed by the Council of Chief State  
 70 School Officers (2004)) are the following: (1) schools need  
 71 frequent, reliable data, and (2) teachers need support to use  
 72 data effectively.

73 Broadly speaking, the type of assessment that uses test  
 74 information to support learning is called formative assess-  
 75 ment. Despite growing evidence that this type of assessment  
 76 supports student learning, we don’t see wide application of  
 77 formative assessment in classrooms. Two explanations for  
 78 the limited adoption of formative assessment in the class-  
 79 room are the following: (a) it’s hard to do, and (b) it’s often  
 80 misconstrued as yet another test. But as James Popham notes,  
 81 formative assessment is a test-supported *process* rather than  
 82 a test (Popham, 2009).

83 The goal of this chapter is to describe formative assess-  
 84 ment fully and also present a special approach to formative  
 85 assessment called *stealth assessment*. Therefore, we discuss  
 86 (a) measurement and assessment, (b) summative and forma-  
 87 tive assessment, and (c) formative and stealth assessment.  
 88 Within each of these sections, we provide definitions, exam-  
 89 ples, and relevant research. We conclude this chapter with  
 90 recommendations to help bring formative assessment into the  
 91 classroom and a discussion about how stealth assessments fit  
 92 well with a systematic approach to instructional design.

**Measurement and Assessment**

93

94 Different models of educational measurement are associated  
 95 with different instructional practices in the classroom and  
 96 thus have different effects on student learning. Historically,  
 97 the main aim of measuring students’ educational progress  
 98 was to identify differences among students in order to rank  
 99 order them by achievement. This type of measurement model  
 100 makes heavy use of summative assessment, which is useful  
 101 for accountability purposes but only marginally useful for  
 102 guiding day-to-day instruction and supporting student learn-  
 103 ing. In contrast, student-centered measurement models rely  
 104 mostly on formative assessment, which is associated with  
 105 meaningful feedback that can be very useful in guiding  
 106 instruction and supporting student learning.

107 Assessment is a general term that typically applies to  
 108 individuals and may include testing, observation, and so  
 109 forth. Progress toward educational goals is usually assessed  
 110 through testing of some type. Assessment can refer to both  
 111 an instrument and a process by which information is obtained  
 112 relative to a known objective or goal (Shute, 2009). Since  
 113 inferences are made about what a person knows on the basis  
 114 of responses to a limited number of assessment tasks or  
 115 items, there is always some uncertainty in inferences made  
 116 on the basis of assessments. The goal in educational mea-  
 117 surement is to minimize uncertainty or error; thus key aspects  
 118 of assessment quality are validity and reliability. Reliability  
 119 refers to the consistency of assessment results—the degree  
 120 to which they rank order students in the same way. Validity  
 121 refers to the extent to which the assessment accurately mea-  
 122 sures what it is supposed to measure, and the accuracy of the  
 123 inferences made from task or test results to underlying  
 124 competencies.

125 The focus of this chapter concerns not only measuring  
 126 students’ existing and emergent competencies accurately and  
 127 reliably but also using that information to render diagnoses  
 128 and instructional support. Consequently, the focus is on for-  
 129 mative assessment (FA) rather than summative assessment.  
 130 Later, we describe stealth assessment which involves embed-  
 131 ding formative assessment into the learning environment  
 132 such that it is invisible and hence does not disrupt learning  
 133 and engagement.

**Summative and Formative Assessment**

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135 When the cook tastes the soup, that’s formative; when the guests  
 136 taste the soup, that’s summative. Robert Stake

137 The choice and use of a particular type of assessment  
 138 depend on the educational purpose. As mentioned earlier,  
 139 schools in the United States today generally make heavy use  
 140 of summative assessment (also known as assessment of

learning), which is useful for accountability purposes (e.g., unidimensional assessment for grading and promotion purposes) but only marginally, if at all, useful for supporting personal learning. In contrast, learner-centered measurement models rely mostly on formative assessment, also known as assessment *for* learning, which can be very useful in guiding instruction and supporting individual learning, but may not be particularly consistent or valid. That is, one current downside of the assessment-for-learning model is that it is often implemented in a non-standardized and hence less rigorous manner than summative assessment, and thus can hamper the validity and consistency of the assessment tools and data (Shute & Zapata-Rivera, 2010).

## 154 Summative Assessment

Summative assessment reflects the so-called traditional approach used to assess educational outcomes. This involves using assessment information for high-stakes, cumulative purposes, such as for grades, promotion, certification, and so on. It is usually administered after some major event, like the end of the school year or marking period, or before a big event, like college entry. Benefits of this approach include the following: (a) it allows for comparing learner performances across diverse populations on clearly defined educational objectives and standards; (b) it provides reliable data (e.g., scores) that can be used for accountability purposes at various levels (e.g., classroom, school, district, state, and national) and for various stakeholders (e.g., learners, teachers, and administrators); and (c) it can inform educational policy (e.g., curriculum or funding decisions).

## 170 Formative Assessment

Formative assessment reflects a more progressive approach in education. This involves using assessments to support teaching and learning. Formative assessment is incorporated directly into the classroom curriculum and uses results from students' activities as the basis on which to adjust instruction to promote learning in a timely manner. A simple example would be a teacher giving a "pop quiz" to his or her students on some current event, immediately analyzing their scores, and then refocusing his or her lesson to straighten out a prevalent misconception shared by the majority of students in the class. This type of assessment is intended to be administered more frequently than summative assessment, and has shown great potential for harnessing the power of assessments to support learning in different content areas and for diverse audiences (e.g., Black & Wiliam, 1998; Hindo, Rose, & Gomez, 2004; Schwartz, Bransford, & Sears, 2005). In addition to providing teachers with evidence about how their

class is learning so that they can revise instruction appropriately, formative assessment directly involves students in the process, such as by providing feedback that will help them gain insight about how to improve, and by suggesting (or implementing) instructional adjustments based on assessment results.

While the scope of what comprises an assessment for formative purposes is quite broad (e.g., informal data, test responses, homework, observations), what is key in the definition is that the information or the evidence is used as feedback—by teachers (or systems) and students to improve teaching and learning, respectively. It is essential that an FA system includes support tools to help teachers learn to implement the full range of assessment types, gather evidence, make sense of the data, and adjust instruction accordingly. Such support tools may reside within a professional development strand related to the FA system. An FA system should also provide support for learners to help them improve motivation, volition, self-efficacy, problem-solving skills, and so on.

Finally, notice that we use the term "formative assessment" throughout the chapter as if it were a singular entity, but there are actually two different faces of FA which may be construed as residing at opposite ends of a continuum. That is, at one end of the continuum lives formal FA, which relates to the more traditional, teacher-centric view of formative assessment; this involves administering tasks and quizzes to students, gathering students' results, and then either providing feedback or altering instructional activities on the basis of the data. The other end of the continuum—informal FA—involves the student-centric, interactive classroom activities and discussions that occur, often spontaneously, in various learning environments. Both formal and informal FA provide evidence to teachers and students about learning progress.

Table 25.1 characterizes four assessment variables (main role in the classroom, frequency of administration, typical format, and feedback) that are characteristic of summative and formative assessment. The examples, per variable, for summative and formative assessment are illustrative and not exhaustive (e.g., formative assessment formats may include other types besides constructed response, such as oral response and even multiple-choice questions). Also note that neither type of assessment is an educational panacea—both have strengths and limitations. Table 25.1 is intended to convey general aspects of each approach in terms of the variables and should not be viewed as definitive categorizations.

## Research on Formative Assessment in the Classroom

Research suggests that well-designed and implemented formative assessment is an effective strategy for enhancing student learning. Evidence to date suggests that students in classes where formative assessment was implemented learned in 6 months what would have taken a year in other

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t1.1 **Table 25.1** Assessment variables in relation to summative and formative approaches  
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t1.3 Variables	Summative assessment	Formative assessment
t1.4 Role of assessment	Assessment of learning, to quantify fixed and measurable aspects of learners' knowledge, skills, and abilities.	Assessment for learning, to characterize important aspects of the learner.
t1.5	Used for accountability purposes, often with norm-referenced tests.	The main focus is on aspects of learner growth, employing criterion-referenced tests, used to help learners learn and teachers teach better
t1.6	Produces a static/ snapshot of the learner	
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t1.14 Frequency of assessment	Infrequent, summative assessments using standardized tests. The focus is on product or outcome (achievement) assessment. These are typically conducted at the end of a major event (e.g., unit, marking period, school year)	Intermittent, formative assessment. The focus is process oriented (but needn't exclude outcomes). Assessments of this type are administered as often as desired and feasible: monthly, weekly, or even daily. Administration is normally informal
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t1.24 Format of assessment	Objective assessments, often using selected responses. The focus is on whether the test is valid and reliable more than the degree to which it supports learning	Constructed responses and an authentic context, collected from multiple sources (e.g., quizzes, portfolios, self-appraisals, and presentations)
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t1.31 Feedback	Correct or incorrect responses to test items and quizzes, or just overall score. Support of learning is not the intention	Global and specific diagnoses, with suggestions for ways to improve learning and teaching. Feedback is helpful, rather than judgmental
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t1.36		

t1.37 *Note:* This table is adapted from Shute (2007)

240 classes (Wiliam, 2006). Studies indicate that the regular use  
241 of classroom formative assessment could raise student  
242 achievement by 0.4–0.7 of a standard deviation (Black &  
243 Wiliam, 1998)—enough to catapult the United States into  
244 the top five countries in the international rankings for math  
245 achievement (Wiliam & Thompson, 2007). Finally, there is  
246 evidence that formative assessment can promote significant  
247 gains in student self-efficacy and motivation (Kim, 2007),  
248 which are predictors of high school graduation (Black,  
249 Harrison, Lee, Marshall, & Wiliam, 2003). Another impor-  
250 tant finding from studies on formative assessment relates to  
251 the benefits for disadvantaged and low-achieving students  
252 (e.g., Fuchs et al., 1997).

253 When teachers know how students are progressing and  
254 where they are having problems, they can use that informa-  
255 tion to make real-time instructional adjustments such as  
256 reteaching, trying alternative instructional approaches, alter-  
257 ing the difficulty level of tasks or assignments, or offering  
258 more opportunities for practice. Again, FA in this sense has  
259 been shown to improve student outcomes and achievement  
260 (Black & Wiliam, 1998; Shute, Hansen, & Almond, 2008).

Feedback is an important and direct component of good  
FA, and should generally guide students toward obtaining  
their goals. Helpful feedback provides specific comments to  
students about errors and suggestions for improvement. It  
also encourages students to focus their attention thoughtfully  
on a specific task rather than on getting the right answer or a  
passing grade (Bangert-Drowns, Kulik, Kulik, & Morgan,  
1991; Shute, 2008). This may be considered a direct applica-  
tion of FA.

A more indirect way (compared to feedback) of helping  
students learn via formative assessment includes instruc-  
tional adjustments that are based on assessment results  
(Stiggins, 2002). Different types of assessment data can be  
used by the teacher to support learning, such as diagnostic  
information relating to levels of student understanding, and  
readiness information indicating whether or not a student is  
ready to begin a new lesson or unit. Examples of instruc-  
tional support include (a) recommendations about how to use  
assessment information to alter instruction (e.g., speed up,  
slow down, give concrete examples), and (b) suggestions for  
what to do next, links to Web-based resources, and so forth.  
However, there is much room for improvement in teachers'  
formative use of assessment results, as one of the most impor-  
tant aspects of formative use (responding to results by modi-  
fying instruction and identifying alternative pedagogies) is  
the least used by classroom teachers and the most neglected  
with respect to professional development (see Lai, 2009).

### Research on Formative Assessment in Computer-Based Learning Environments

A growing number of computer-based educational systems  
are employing formative assessment as well. A good exam-  
ple of such systems is a Web-based formative assessment  
platform called ASSISTment (Feng, Heffernan, & Koedinger,  
2006; Koedinger, McLaughlin, & Heffernan, 2010).  
ASSISTment is a Web-based platform that allows teachers to  
develop formative assessments for fourth- to tenth-grade  
mathematics classes. In a recent study, Koedinger and his  
colleagues (2010) reported that the schools using ASSISTment  
significantly outperformed matched schools on the state  
mathematics test.

Another example of a computer-based formative assess-  
ment system is ACED (Adaptive Content with Evidence-  
based Diagnosis) (Shute, Graf, & Hansen, 2005). This system  
uses an evidence-centered design approach (Mislevy,  
Steinberg, & Almond, 2003) to create an adaptive, diagnos-  
tic assessment system to assess and support pre-algebra  
knowledge and skills. Instructional support is in the form of  
elaborated feedback. A study was conducted examining its  
efficacy (Shute et al., 2008). The key issue was whether the  
inclusion of the feedback into the system (a) impairs the  
quality of the assessment (relative to validity, reliability, and  
efficiency), and (b) does, in fact, enhance student learning.  
Results from a controlled evaluation testing 268 ninth-grade

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t2.1 **Table 25.2** Summary of key formative assessment features

t2.2 Feature	Rationale
t2.3 Improves student learning	A primary purpose of an FA system is to enhance (or support) student conceptual development as well as skill acquisition. Two kinds of data to support learning include (a) <i>diagnostic information</i> relating to levels of understanding and particular misconceptions where the information from diagnostic tasks should be instructionally tractable (i.e., neither too general nor too specific) and (b) <i>readiness information</i> , where a general FA task is administered at the outset of a class or a unit and results can show who, in the class, is ready (or not) to begin a new lesson or unit
t2.9 Promotes student self-efficacy	Feedback in FA should generally guide students through toward obtaining their goal(s) (Ramaprasad, 1983; Sadler, 1989). The most helpful type of formative feedback (on tests, homework, and classroom activities) provides specific comments to students about errors, and specific suggestions for improvement, and encourages students to focus their attention thoughtfully on the task rather than on simply getting the right answer (Bangert-Drowns et al., 1991; Elawar & Corno, 1985; Shute, 2008). This type of feedback may be particularly helpful to lower achieving students because it emphasizes that students can improve as a result of effort rather than be doomed to low achievement due to some presumed lack of innate ability (e.g., Hoska, 1993)
t2.16 Provides timely feedback	Feedback must be timely to be useful (e.g., Corbett & Anderson, 1989). Whenever possible, the FA system should provide immediate feedback (ideally immediately, but within “same day” time frame). Feedback can be directed to students (e.g., regarding performance on computer-based tasks) or teachers (e.g., summary reports on classroom performance)
t2.20 Provides information at multiple levels of aggregation	FAs should report out <i>individual</i> data and may be <i>aggregated</i> to subgroup and full-group levels. Teachers and administrators may be able to specify subgroups based on student demographic variables (e.g., gender, race, attendance, mobility, socioeconomic status, etc.) and also use FA results to create groups with similar performance on specified tasks or sets of tasks
t2.24 Provides low-to-mid stakes assessment	Given the relatively low-stakes and informal nature of FAs, they should mostly be of two levels: low and intermediate (not high-stakes). Higher degrees of standardization in FAs may occur in certain computer applications. Also note that “low-stakes” does not mean they will be low in reliability or validity (see Shute et al. (2008) for an example of a reliable and valid FA system)
t2.28 Uses developmental models	Competency models should include developmental aspects that provide pre- and post-requisite relationship information. The function of the developmental part of the models relates to (1) <i>actual</i> learning (self- or criterion referenced), and (2) <i>potential</i> learning (forecasting near and far term potential—via Zone of Proximal Development and “end of school year” growth modeling research ideas)

314 students showed that the quality of the assessment was unimpaired by the provision of feedback. Moreover, students using the ACED system showed significantly greater learning of the content compared with a control group. These findings suggest that assessments in other settings (e.g., standardized, state-mandated tests) might be augmented to support student learning with instructional feedback without jeopardizing the primary purpose of the assessment.

322 Table 25.2 summarizes the key features of formative assessment, along with a brief discussion of each feature.

324 So far, we have focused on FA. But now consider the following. Rather than stopping an instructional episode at various times to collect information from students and provide support as warranted, what if there was a way to embed FA so deeply in the fabric of the learning environment that the distinction between learning and assessing became completely blurred? This idea, called stealth assessment, is presented next.

### 332 Formative and Stealth Assessment

333 New directions in educational and psychological measurement allow more accurate estimations of students’ competencies, and new technologies permit us to administer formative assessments during the learning process; extract ongoing,

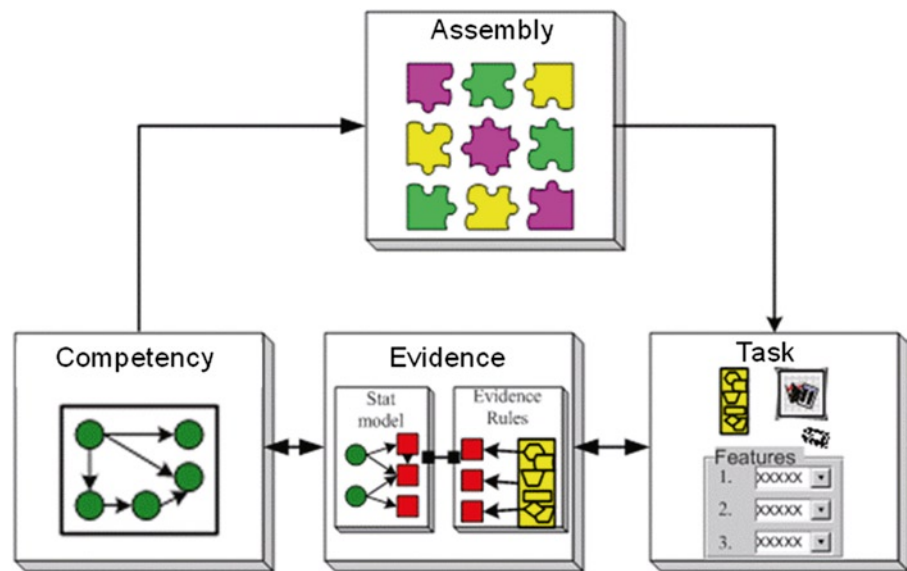
multifaceted information from a learner; and react in immediate and helpful ways. When formative assessments are seamlessly woven into the learning environment and are thus invisible to learners, we call this *stealth assessment* (Shute, 2011; Shute, Ventura, Bauer, & Zapata-Rivera, 2009).

Stealth assessment can be accomplished via automated scoring and machine-based reasoning techniques to infer things that would be too hard or time consuming for humans (e.g., estimating values of evidence-based competencies across a network of skills). One big question is how to make sense of rich data collected in order to provide meaningful feedback and other support for learning. Another major question concerns the best way to communicate a variety of student-performance information in a way that can be used to inform instruction and enhance learning.

### Definition of Stealth Assessment

Stealth assessment is an evidence-based approach to assessment where the tasks that students are engaged with are highly interactive and immersive, such as within video games or other computer-based instructional systems. Like FA, stealth assessment is intended to support learning of important content and key competencies. This represents a quiet-yet-powerful process by which learner performance data is

**Fig. 25.1** Conceptual assessment framework of ECD (adapted from Mislevy et al., 2003)



continuously gathered during the course of playing/learning and inferences are made about the level of relevant competencies (see Shute et al., 2009). Inferences on competency states are stored in a dynamic model of the learner. Stealth assessment is intended to support learning and maintain flow, defined as a state of optimal experience where a person is so engaged in the activity at hand that self-consciousness disappears, sense of time is lost, and the person engages in complex, goal-directed activity not for external rewards, but simply for the exhilaration of doing (Csikszentmihalyi, 1990). Stealth assessment is also intended to remove (or seriously reduce) test anxiety while not sacrificing validity and reliability (Shute et al., 2008). Again, the goal is to blur the distinction between assessment and learning.

Key elements of the approach include (a) evidence-centered assessment design, which systematically analyzes the assessment argument concerning claims about the learner and the evidence that supports those claims (Mislevy et al., 2003), and (b) formative assessment and feedback to support learning (Black & Wiliam, 1998; Shute, 2008). Additionally, stealth assessment provides the basis for instructional decisions, such as the delivery of tailored content to learners (e.g., Shute & Towle, 2003; Shute & Zapata-Rivera, 2008). Information is maintained within a learner model and may include cognitive as well as noncognitive information comprising an accurate and up-to-date profile of the learner.

Evidence-centered assessment design (ECD), the key element for stealth assessment, is a conceptual design framework to help in the creation of coherent assessments. It supports a broad range of assessment types, from classroom quizzes to simulation-based assessments (Mislevy et al., 2003). The conceptual framework includes several models

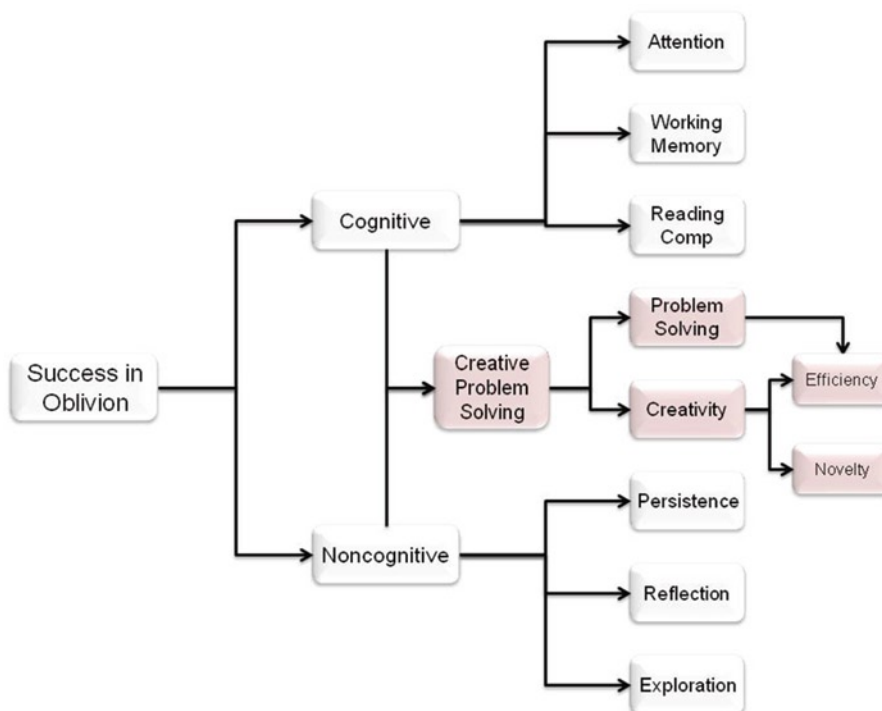
that work together to answer specific questions, such as “what attributes are to be measured?” and “how do we score them?” (see Fig. 25.1).

The competency model defines variables related to students’ knowledge, skills, abilities, and other attributes that we wish to measure. This model accumulates and represents current beliefs about targeted aspects of skill, expressed as probability distributions per variable (Almond & Mislevy, 1999). The evidence model provides detailed instructions about (a) what the student says or does that can count as evidence for those skills (Steinberg & Gitomer, 1996), and (b) how the evidence statistically links to variables in the competency model (Mislevy, 1994). Task/action models express situations that can evoke required evidence. And the assembly model specifies how the competency, evidence, and task/action models work together to form a valid assessment.

### Example of a Stealth Assessment

To illustrate the stealth assessment approach, here is an example relating to creative problem solving in a commercial game called *Oblivion* (*The Elder Scrolls IV: Oblivion*, 2006, by Bethesda Softworks). *Oblivion* is a first-person, 3D role-playing game that is set in an imaginary medieval world. Players enter the game by selecting a character to play (e.g., Argonian, Orc, or Dark Elf). Each character has a particular specialization (e.g., combat, stealth, and magic) and special abilities. The primary goal of the game is to develop the character’s skills by completing a series of quests. These quests represent the character’s journey to save the empire

**Fig. 25.2** Illustrative competency model for Oblivion (from Shute et al., 2009)



421 from dark magic, and are typically quite complex problems  
 422 that players need to solve. During the course of the game,  
 423 there are about 20 skills that a character needs to develop  
 424 (e.g., alchemy, illusion, and heavy armor) to level up or to  
 425 avoid being killed by dark monsters.

426 Creative problem solving is the main competency in the  
 427 example, defined as the process of coming up with novel but  
 428 efficient solutions to a given problem. The shaded competency  
 429 model variables in Fig. 25.2 represent the nodes of  
 430 interest in this example.

431 The evidence model links the specific actions that a player  
 432 takes in the game with relevant competency variables. This  
 433 requires the specification of particular observations, and how  
 434 they differentially inform the level of mastery for different  
 435 competency variables. The statistical machinery (such as  
 436 IRT or Bayesian networks) serves to “glue” this information  
 437 together (i.e., the observable performance data with the  
 438 unobservable competency variables).

439 The action model (i.e., task model) in the example relates  
 440 to the various quests and possible actions that players take in  
 441 relation to quests. For example, consider a player faced with  
 442 the problem of having to cross a river full of dangerous fish.  
 443 Table 25.3 contains a list of actions to solve this problem, as  
 444 well as the indicators that may be learned from real data, or  
 445 elicited from experts. For the system to learn indicator values  
 446 from real data, estimates of *novelty*, for example, may be  
 447 defined in terms of the frequency of use across all players.  
 448 For instance, swimming across the river is a high-frequency,

**Table 25.3** Example of action model with indicators for novelty and efficiency

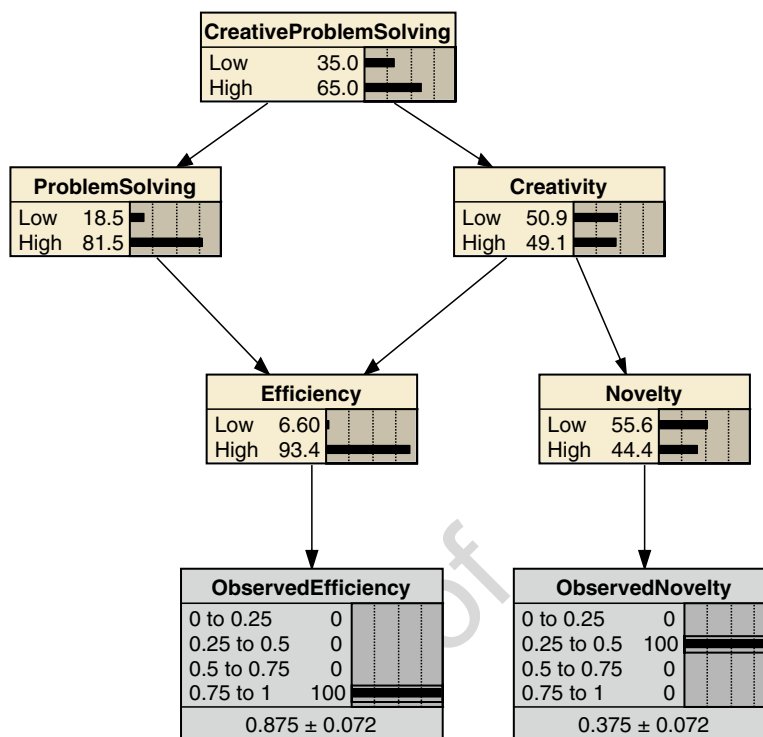
Action	Novelty	Efficiency
Swim across the river	$n=0.12$	$e=0.22$
Levitate over the river	$n=0.33$	$e=0.70$
Freeze the river with a spell and slide across	$n=0.76$	$e=0.80$
Find a bridge over the river	$n=0.66$	$e=0.24$
Dig a tunnel under the river	$n=0.78$	$e=0.20$

449 common solution, thus associated with a low “novelty  
 450 weight.” An estimate of *efficiency* may be defined in terms of  
 451 the probability of successfully solving a problem given a set  
 452 of actions—based on time and resources expended.

453 Swimming across the river would thus have a low  
 454 efficiency value because of the extra time needed to evade  
 455 the dangerous fish. On the other hand, digging a tunnel under  
 456 the river to get to the other side is judged as highly novel, but  
 457 less efficient than, say, freezing the water and simply sliding  
 458 across, the latter being highly novel and highly efficient. The  
 459 indicator values shown in Table 25.3 were elicited from two  
 460 *Oblivion* experts, and they range from 0 to 1. Higher numbers  
 461 relate to greater levels of both novelty and efficiency.

462 Actions can be captured in real time as the player interacts  
 463 with the game, and associated indicators can be used to provide  
 464 evidence for the appropriate competencies. This is accomplished  
 465 via the evidence model using Bayesian network software. Figure  
 466 25.3 shows a Bayes net after a player elected to cross the river  
 467 by levitating over it.

**Fig. 25.3** Bayes net estimates from levitating over the river (from Shute et al., 2009)



468 Even though the player evidenced just average creativity  
 469 in that solution, the parent node of creative problem solving  
 470 infers that she is somewhat “high” on this attribute—  
 471 illustrating that problem solving (based on efficiency) is a  
 472 more valued competency than creativity, based on the way  
 473 that the conditional probability distributions were set up in  
 474 the competency model. Further, the player has more chances  
 475 to improve this skill during game play. This information can  
 476 be used in two different ways: (a) as formative feedback,  
 477 which can be directly communicated to the learner, and (b)  
 478 adjusting the sequence of quests to focus more emphasis on  
 479 improving creativity.

480 **Conclusion**

481 In this chapter, we discussed formative assessment in rela-  
 482 tion to measurement and summative assessment. We also  
 483 described stealth assessment as a particular instantiation of  
 484 formative assessment, as employed within a video game or  
 485 other immersive environment. Despite their intuitive appeal,  
 486 both formative and stealth assessment have some challenges  
 487 that need to be addressed for them to be widely adopted in  
 488 classrooms today.

489 First, for formative assessment to be embraced more  
 490 widely there should be more support—such as through pro-  
 491 fessional development—for teachers. This would enable

them to be more comfortable and skilled using formative  
 assessment in their classrooms. In particular, teachers should  
 learn to (a) diagnose students’ competencies (at various grain  
 sizes) based on different sources of information, (b) figure  
 out what to do next given the obtained data, and (c) build up  
 and employ a pool of rich tasks, probing questions, and other  
 instructionally fruitful activities that can serve to elicit more  
 evidence to inform student models and concurrently support  
 students’ learning. In short, teachers should acknowledge  
 that formative assessment is intended to support their deci-  
 sion making for instructional adjustment to help all students  
 grow and learn.

Following are ten recommendations for teachers about  
 how to effectively use formative assessment in the  
 classroom:

1. *Cognitive research.* Employ assessments that have been designed on a cognitive-developmental research foundation.
2. *Complex tasks.* Engage students in cognitively demanding tasks, i.e., ones that actually engage students in thinking about an issue or a problem.
3. *Learning goals.* Inform students clearly of the specific (and more general) learning goals being sought in the lesson or across longer units.
4. *Administration.* Administer assessments (of all types) frequently and usually informally, and require full-class participation in the ongoing, interactive dialog.

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- 519 5. *Feedback*. Give feedback to students in the form of con- 572  
 520 structutive comments, not grades. 573  
 521 6. *Personal accountability*. Provide students with opportu- 574  
 522 nities to assess themselves and/or their peers to support 575  
 523 personal accountability and autonomy. 576  
 524 7. *Evidence-based diagnosis*. Use evidence from formal 577  
 525 and informal FAs as the basis for diagnosing students' 578  
 526 progress (or lack thereof). 579  
 527 8. *Preplan questions and paths*. Plan questions in advance 580  
 528 that probe students' understanding and craft alternative 581  
 529 instructional paths based on response patterns. 582  
 530 9. *Leverage prior knowledge*. Build on students' preexist- 583  
 531 ing knowledge and understanding—even if it requires 584  
 532 going back through previously instructed material. 585  
 533 10. *Collaboration*. Meet regularly with other teachers to 586  
 534 select and share good tasks, discuss student work, plan 587  
 535 effective questions, discuss “lessons learned,” and so on. 588

536 Implementing stealth assessment also poses its own set of 589  
 537 challenges. The competency model, for example, must be 590  
 538 developed at an appropriate level of granularity to be imple- 591  
 539 mented in the assessment. Too large a grain size means less 592  
 540 specific evidence is available to determine student compe- 593  
 541 tency, while too fine a grain size means a high level of com- 594  
 542 plexity and increased resources to be devoted to the 595  
 543 assessment. In addition, developing the evidence model can 596  
 544 be rather difficult in a gaming environment when students 597  
 545 collaborate on completing quests. For example, how would 598  
 546 you trace the actions of each student and what he/she is 599  
 547 thinking when the outcome is a combined effort? Another 600  
 548 challenge comes from scoring qualitative products such as 601  
 549 essays, student reflections, and online discussions where 602  
 550 there remains a high level of subjectivity even when teachers 603  
 551 are provided with comprehensive rubrics. 604

552 How do teachers fit into this effort? In games designed for 605  
 553 educational purposes, the system can allow teachers to view 606  
 554 their students' progress relative to the students' competency 607  
 555 models. Teachers would then use that information as the 608  
 556 basis for altering instruction or providing formative feed- 609  
 557 back. For example, if the competency models during a quest 610  
 558 showed evidence of a widespread misconception, the teacher 611  
 559 could turn that into a teachable moment, or may choose to 612  
 560 assign struggling students to team up with more advanced 613  
 561 students in their quests. 614

562 Information about students' competencies may also be 615  
 563 used by the game system to select new gaming experiences 616  
 564 (e.g., more challenging, ill-structured problems could be pre- 617  
 565 sented to students exhibiting high creative problem-solving 618  
 566 skills). In addition, up-to-date estimates of students' compe- 619  
 567 tencies, based on assessment information handled by the sta- 620  
 568 tistical machinery (e.g., Bayes nets), can be integrated into 621  
 569 the game and explicitly displayed as progress indicators. 622  
 570 Players could then see how their competencies are changing 623  
 571 based on their performance in the game. Most games already 624

include status bars, representing the player's current levels of 572  
 game-related variables. Imagine adding high-level compe- 573  
 tency bars that represent attributes like creative problem 574  
 solving, persistence, and leadership skill. More detailed 575  
 information could be accessed by clicking the bar to see cur- 576  
 rent states of lower level variables. And like health status, if 577  
 any competency bar gets too low, the student needs to act to 578  
 somehow increase the value. Once students begin interacting 579  
 with the bars, metacognitive processes may be enhanced by 580  
 allowing the player to see game- or learning-related aspects 581  
 of their state. Viewing their current competency levels and 582  
 the underlying evidence gives students greater awareness of 583  
 personal attributes. In the literature, these are called “open 584  
 student models” and they have been shown to support knowl- 585  
 edge awareness, reflection, and learning (Bull & Pain, 1995; 586  
 Hartley & Mitrovic, 2002; Kay, 1998; Zapata-Rivera & 587  
 Greer, 2004; Zapata-Rivera, Vanwinkle, Shute, Underwood, 588  
 & Bauer, 2007). 589

590 How is stealth assessment related to the design of instruc- 591  
 592 tional systems? Gustafson and Branch (2002) describe five 593  
 594 core elements of instructional design: analysis, design, devel- 595  
 596 opment, implementation, and evaluation. These factors 597  
 598 ensure coherence among instructional goals and strategies, 599  
 600 as well as the effectiveness of the instruction. Moreover, 601  
 602 these five elements should be used iteratively, and evaluation 603  
 604 should reside at the center of the iterative revision process. 605  
 606 Information obtained from any stealth assessment can also 607  
 608 be used by instructional designers to improve learning/ 609  
 610 instructional systems. For example, information from a 611  
 612 stealth assessment may show that many students had difficulty 613  
 614 with a particular task. The instructional designer could then 615  
 616 examine the task to see if revisions are warranted. 617

618 In addition, components of a stealth assessment (e.g., 619  
 620 competency, evidence, and task models) are compatible with 621  
 622 steps in the instructional design process such as task and 623  
 624 content analysis and the development of performance mea- 625  
 626 sures. A common goal of both stealth assessment and instruc- 627  
 628 tional design is to coherently align learning objectives with 629  
 630 how they are measured. Therefore, if instructional designers 631  
 632 work closely with assessment developers to design and 633  
 634 develop a learning system that has built-in stealth assess- 635  
 636 ment, it can optimize the effectiveness of the instruction. 637

638 In conclusion, the ideas in this chapter relate to using for- 639  
 640 mative assessment (in the classroom) and stealth assessment 641  
 642 (in immersive learning environments). In both cases, this 643  
 644 would help not only to collect valid evidence of students' 645  
 646 competency states and support student learning but also to 647  
 648 reduce teachers' workload in relation to managing the stu- 649  
 650 dents' work products. This would allow teachers to focus 651  
 652 their energies on the business of fostering student learning. 653  
 654 The ideas in this chapter are intended to help teachers facili- 655  
 656 tate student learning, in a fun and engaging manner, of edu- 657  
 658 cationally valuable skills. 659

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Uncorrected Proof

# Author Queries

Chapter No.: 25      0001957772

<b>Queries</b>	<b>Details Required</b>	<b>Author's Response</b>
AU1	Reference citation Shute (2011) in Abstract has been expanded as per Springer style. Please check if appropriate.	
AU2	Please provide publisher name for the reference Hartley & Mitrovic (2002) if possible.	
AU3	Please provide editors name for Hindo, Rose, & Gomez (2004).	

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