REVIEW

Measuring Metacognitive Knowledge, Monitoring, and Control in the Pharmacy Classroom and Experiential Settings

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Objective. In this review, we discuss how to measure the quality of students' metacognition in classroom and experiential settings. Our purpose is to provide a user's guide on measuring metacognition in authentic contexts, so that instructors and researchers can explore their students' metacognition with an aim towards improving their metacognitive processes and achievement.

Summary. Metacognition refers to people's knowledge about and regulation of their cognitive processes, and these aspects of metacognition are important for supporting students' success in academic and experiential settings. In particular, students who know about the best learning strategies, can accurately monitor their progress, and make effective study decisions are more likely to meet their learning goals. Thus, measuring metacognitive knowledge, monitoring, and control can help identify struggling students who may benefit from interventions to improve their metacognitive processes.

Keywords: Metacognition, self-awareness, assessment, measurement

INTRODUCTION

Riley begins studying for an exam she will take tomorrow in her pharmacy course. She starts by diligently reviewing her notes from class. As she flips through her notes, she feels confident that she understands infusion kinetics and decides she does not need to devote any more effort to learning that topic. However, she keeps getting the concepts hepatic clearance and renal clearance confused. To overcome this confusion, Riley decides to reread the section of her textbook about these topics. At the exam, Riley is feeling a bit anxious because although she studied the evening before, she still feels that she does not fully understand hepatic and renal clearance. She completes her exam but before turning it in, she goes through each question and puts a check next to the ones she is uncertain about so she can look up the answers later. Based on this rough analysis, she estimates that she will receive about an 80% on the exam. She plans to begin studying earlier for future exams, so that she can space her study across time and use different study strategies in hopes of improving her learning of the material and performance on the next exam.

Defining Metacognition

In the scenario above, Riley is using different aspects of metacognition. Metacognition in general is defined as "thoughts about one's own thoughts"[1], or more specifically, "one's knowledge concerning one's own cognitive processes and products or anything related to them." [2 (p232)] As shown in Table 1, metacognition consists of three primary components: knowledge, monitoring, and control.[3] Metacognitive knowledge refers to facts and beliefs about how we learn, such as our knowledge about the effectiveness of learning strategies or our efficacy in our ability to learn (ie, self-efficacy[4]). Riley presumably believed that studying the night before an exam (ie, cramming) and rereading were effective learning strategies, but after taking the exam, she realized that these strategies may be limited. Metacognitive monitoring refers to evaluating the process of learning or current state of knowledge. Riley engaged in monitoring to discover that she felt confident in her understanding about infusion kinetics (and less confident for hepatic clearance) and to estimate her performance on the exam. Metacognitive control is the regulation of learning activities. Riley decided when she was going to study, what strategies she would use, and after the exam, she planned to study differently for future exams. Each of these aspects of metacognition can limit or enhance learning depending on the quality of students' knowledge, monitoring, and control processes – that is, how students regulate their learning can make a real difference in their ultimate success.

As an educator, you probably have students like Riley who are using metacognitive knowledge and monitoring to inform how they will control their learning and test taking. Some students will be sophisticated, and others much less so. The latter may have difficulties monitoring their progress and even believe that some ineffective strategies are effective, which can undermine their learning. Accordingly, we offer some advice on how to assess your students' metacognition by providing a review of the kinds of questions that can be asked (and empirically answered) about students' metacognition within authentic educational settings, including the typical measures of metacognition and the limitations associated with each. Our goal in reviewing these measures is twofold: First, we would like to help educators and discipline-based education researchers[5] assess metacognition, which can inform instruction. If, for example, you discover that many of your students tend to be overconfident with respect to particular concepts, you can alert your students to not underestimate the difficulty of the content and may decide to spend more time teaching it. Second, measuring metacognition across time will allow you to evaluate whether an intervention you are trying out (eg, a change in instruction) improves student metacognition (for advice on conducting instructional research in a classroom, see Dunlosky, Morehead, Zamary, and Rawson[6]). Unlike other factors related to achievement (eg, intelligence), metacognition is not hard-wired and is malleable – students' inaccurate beliefs can be changed, they can learn to use effective strategies, and they can be trained how to improve their monitoring and control of learning[7]. Thus, finding ways to measure and improve students' metacognitive knowledge, monitoring, and control can lead to insights into how to improve their achievement.

To help foster research, we have assembled a list of questions (in Table 2) that can be asked about metacognition, both within classroom and experiential settings. Also, although we illustrate some concepts in the context of a pharmacy course, our discussion of measurement of metacognition is relevant to any course. Thus, if you find a particular question worth addressing, our overview below will provide some basic research tools to begin answering it within your course, whether it focuses on pharmacy, chemistry, physics, psychology, and so forth. We included a few representative articles that have sought to answer each question, which provide more in-depth illustrations for how one might approach answering a particular question. By no means is this list comprehensive; instead, it illustrates some of the questions that we and others have been interested in pursuing – both within laboratory settings and in authentic educational contexts.

MEASURING METACOGNITIVE KNOWLEDGE AND BELIEFS

Research focused on learning has identified the relative effectiveness of different study strategies (for in-depth overviews of various strategies, see Dunlosky and Rawson[8] and Dunlosky et al[9]). But, do students know which strategies are most effective, and do they consistently use them? This kind of question can be answered by assessing students' metacognitive knowledge. In the scenario above, Riley believed reviewing her notes and rereading her textbook would lead to effective learning. Unfortunately, such relatively passive strategies are less effective than strategies that require a more active part on the learner, such as practice testing[10,11] or self-explanation[12]. This example demonstrates one reason to measure students' knowledge and beliefs: Students can be misguided and have misconceptions about what works best[13], perhaps because many students are not formally taught about basic principles of learning and how to study effectively[14]. Accordingly, assessing students' knowledge and (if necessary) providing guidance about when and how to use effective strategies may benefit their achievement.

Another important aspect of metacognitive knowledge pertains to students' beliefs about their ability to succeed. For instance, as students progress through a course, are they more confident in their ability to learn new material and perform well on exams? As students advance in their experiential curriculum, do they feel more confident in completing their professional activities (eg, entrustable professional activities), such as educating a patient on their medications or identifying a patient's medication-related problems? These questions refer to students' self-efficacy, or people's beliefs about their ability to succeed in specific situations[4]. Self-efficacy is important because it is related to effective self-regulation – students who are confident in their ability to succeed are more likely to set achievable goals and use effective strategies to reach them[15]. Doing so ultimately leads to higher achievement, as supported by the relationship between self-efficacy and grade-point average[16]. To reiterate an important point, however: Self-efficacy pertains to people's beliefs about their ability and not to students' actual ability. And, although people's beliefs about their ability may be related to their actual ability, beliefs and performance can also be misaligned. That is, an intervention can enhance students' efficacy yet have no impact on their performance. Thus, we strongly recommend that measures of self-efficacy be viewed as beliefs about ability and not used as surrogates for ability or achievement. We recommend measuring both students' self-efficacy (a belief) and performance, so that you can explore the degree to which students' beliefs align with their performance. We return to this issue of measuring judgment accuracy under measuring metacognitive monitoring below.

Given the importance of metacognitive knowledge and beliefs, how can they be assessed? Metacognitive knowledge and beliefs are typically measured through questionnaires, such as those listed in Table 3. (For a description of other questionnaires measuring study habits, skills, and attitudes, see Credé and Kuncel[17]). The questionnaires are useful because they can be easily modified to meet a specific research goal and can generate informative (and extensive) data sets in a brief session. For instance, several questionnaires have multiple scales, some of which tap students' knowledge about strategies, their use of strategies, and their self-efficacy for learning. Accordingly, as an instructor, you may be interested in only a subset of the questions pertaining to those scales that are most relevant to the question(s) being addressed. Once equipped with information about students' metacognitive knowledge, you can address knowledge gaps and potentially use the responses to understand why particular students are struggling. With respect to motivating students to adopt more effective strategies, the good news is that research suggests that instructing students on effective strategies leads to greater endorsement of them (eg, [13,18]).

Before administering any questionnaire, we suggest reviewing the properties of each scale and thinking critically about what each one is assessing. Some questionnaires combine outcomes from multiple questions into a single scale, but sometimes, the answers to a specific question may be of most interest. For instance, one scale of the Motivated Strategies for Learning Questionnaire[19] combines items relevant to both ineffective and effective strategies. We would not expect use of ineffective strategies to predict performance in the same way that effective strategies would, so using this "Learning Strategies" scale would not make sense if you are only interested in students' knowledge about effective strategies. Therefore, we recommend carefully considering how each question of a scale is relevant to your assessment goals. With this recommendation in mind, note that a full discussion of the challenges associated with using questionnaires is beyond the scope of this paper (for details, see Krosnick[20]).

MEASURING METACOGNITIVE MONITORING

Assessments are administered to evaluate student progress toward achieving learning objectives, which allows instructors to assign grades (ie, summative evaluation[21]). But assessments can also provide instructors, preceptors, and students with formative evaluation, or information about students' understanding of the course material[22]. You can use this information to modify your instruction to target more difficult concepts and doing so comprises one of the most effective teaching practices[23]. Students can also use this information to identify concepts that they have not yet learned. Students can receive targeted feedback about what concepts they are struggling with, or they can discover for themselves through monitoring their performance. Note that accurate metacognitive monitoring is crucial for students to gain this formative evaluation. For instance, Riley's confidence in her understanding of infusion kinetics influenced her decision to stop studying that topic. If she overestimated her understanding, then she would have benefitted from studying infusion kinetics more thoroughly. That is, if students are overconfident in their knowledge for a concept, they may not spend enough time studying[24]. Underconfidence may also be problematic, because students may spend too much time on material that is already well-learned, which leads to inefficient use of students' limited study time. Ultimately, accurate monitoring can support the most efficient and effective control of learning.

Monitoring can be measured at difference phases of learning in the classroom or in experiential settings, which is illustrated in the top of Figure 1 (adapted from Nelson and Narens[25]). If you are interested in a students' level of understanding during learning (or acquisition), you would have them judge their current understanding before attempting to demonstrate what they have learned. For instance, you could ask students, "How confident are you that you understand infusion kinetics?" If you are interested in students' level of understanding after learning but before they answer questions on an exam, you could have them predict their upcoming performance on an exam: "How confident are you that you will correctly answer questions about infusion kinetics on the exam?" Finally, if you are interested in students' level of understanding after completing an exam, you could have students estimate how many questions they accurately answered on an exam after completing it (ie, make retrospective judgments of performance). In a clinical setting, students could judge their ability to perform particular tasks (ie, perform a comprehensive medication review), either before or after doing so and receiving feedback from their preceptor.

As implied by the examples above, monitoring can also be measured at different grain sizes. At the global level, students judge their performance for all questions over an entire exam. At the concept level, students judge performance on particular concepts or topics, such as judging how well one will perform on all questions pertaining to the concept of renal clearance. And, at the item level, students judge whether they correctly answered a particular question on an exam. Most research on metacognitive judgments has focused on the global or item level and relatively little research has focused on the concept level. The relative lack of information about how well students can judge their concept-level knowledge is unfortunate, because monitoring at this level is particularly relevant to providing useful formative evaluation. For instance, accurately judging that one performed about 70% on an exam (global level) will not necessarily help a student figure out what is not understood, whereas accurately judging that test performance was lower than desired because of a failure to perform well on questions about specific concepts (eg, infusion and nonlinear kinetics) would allow a student to effectively guide restudy.

Collecting monitoring judgments can be incorporated into your classroom or clinical routine. For example, instructors could include a prediction cover sheet on exams or have students make confidence ratings as they answer quiz questions. A supervising clinician could have students assess their ability to complete tasks within a particular domain (eg, answering drug information questions). An example of a cover sheet (that involves predicting exam performance) that has been developed for the course Foundations in Pharmacokinetics is in the Appendix. This cover sheet was used to obtain monitoring judgments at both the global level and at the concept level, with the latter focusing on concepts being tested on the upcoming exam. A similar sheet could be used after the exam to obtain students judgments about how well they performed on the exam. Of course, what grain size (and at what stage of learning and testing) you assess students' monitoring will depend on the questions being addressed.

Once students have made judgments about their knowledge or test performance, how do you estimate their monitoring (or judgment) accuracy? Measuring students' level of judgment accuracy can help you discover the extent to which students can accurately estimate their own knowledge and if any change in instruction influences their judgment accuracy. Monitoring accuracy involves comparing judgments with performance, and two types of accuracy – absolute and relative accuracy – highlight different aspects of the relationship between students' judgments and their performance. We discuss each measure in turn below.

Absolute accuracy refers to how well students can estimate their actual level of performance. Absolute accuracy can be measured in multiple ways: Bias, absolute bias, and calibration. Each measure captures a different aspect of how well the judgments match performance, and each one is first computed at the level of each student. Example values based on a hypothetical student are presented in Figure 2. In this figure, we have included judgments and test scores at both the global and concept level, which pertain to the cover sheet shown in the Appendix. This student's global prediction was 85, with the concept-level predictions ranging from 75 (for hepatic clearance) to 95 (for infusion kinetics).

Bias is simply the mean level of judgment minus actual performance, with positive values indicating overconfidence and negative values indicating underconfidence. As shown in Figure 2, this student demonstrated overconfidence for the global judgment, with bias being +10. For bias at the concept level, the mean judgment (in this case, M = 85) is compared to actual performance, and the student's judgments were also on average overconfident at the concept level (bias = +5). Note also that the student was underconfident for one of the concepts (ie, single dose intravenous kinetics). Averaging across all students' bias scores (which would be a standard approach to presenting descriptive analyses) can be misleading, because a mean of 0 (which would appear to be perfect absolute accuracy as measured by bias) could result from large discrepancies in both directions. That is, some students may show extreme overconfidence and others could show extreme underconfidence, yet the bias could average to 0. We recommend analyzing frequency distributions to evaluate whether excellent (close to 0) bias is resulting from averaging across bias values from both over and underconfident students. Another way to resolve this potential problem is to compute the absolute value of bias, which is called absolute bias. By computing the absolute value, then over and underconfidence across students will not reduce the magnitude of the overall bias, so absolute bias will provide a better estimate of how discrepant the judgment magnitude is from actual performance.

Another measure of absolute accuracy is called calibration, and it is based on an analysis of an entire calibration curve, which maps percent performance as a function of increasing judgments. To construct a calibration curve and to estimate the corresponding measures of calibration, it would be ideal to have more observations per student than would be typically collected for concept-level judgments. Thus, calibration analyses would be most appropriate for judgments collected at the individual item level, such as when students provide a confidence judgment for each of their answers for an exam with many questions. For details on constructing calibration curves and computing calibration indices, see [26].

To estimate absolute accuracy, students must make judgments using the same metric as task performance, because it would not be appropriate (or make sense) to subtract values that are from different metrics (eg, a judgment made on a 7-point Likert scale is not comparable to exam performance measured on a percent scale). We recommend having students make judgments on a percent scale (eg, estimate the percentage of questions you will answer correctly) because the scale makes intuitive sense to students and is a typical metric used for scoring exams.

Relative accuracy (also referred to as resolution) refers to students' ability to discriminate between different levels of performance across items or concepts. Many different measures of relative accuracy have been proposed, each with their own strengths and weaknesses (eg, [27-31]). One common way to estimate resolution is to compute an intra-individual correlation between each student's judgments and their performance. A strong, positive correlation is observed when a student can accurately judge the likelihood of correct performance on one item (or concept) relative to another. In Figure 2, resolution was computed as a Goodman-Kruskal gamma correlation (as recommended by Nelson[30]), and for the hypothetical student, resolution was close to perfect (which, for a correlation, would be a value of +1.0). Other correlations (eg, Pearson's r) can be used as well (for an argument in favor of Pearson's r, see Schraw[31]). By contrast, others have argued that the correlational approaches provide more biased estimates of resolution as compared to measures based on signal detection theory (for introductions to the debate, see Higham and Higham[33]). Our recommendation is to evaluate whether each measure supports the same conclusion by computing as many measures of resolution that are viable given the structure of the data.

MEASURING METACOGNITIVE CONTROL

Consider Riley once again. After taking her first exam, she plans to study even more in the future. Because she would eventually like to practice pharmacy professionally, her goal is to master all the material she is taught so that she can apply it when she is working in the field. Given this goal, she makes a schedule outlining when and what she will study each day. As she studies and judges her progress, she revises her plan based on her understanding of particular concepts and also decides that she is going to use some new study techniques that promise to promote long-term retention.

Riley's plan demonstrates a few key points about metacognitive control. First, her studying is influenced by her specific goals. And, according to all theories of self-regulated learning based on information-processing models[34-38], an effective learner develops goals and plans how best to obtain them. Students vary in their learning goals (eg, master all the material or simply pass a class), and those goals influence how they prepare for study, such as what they study, when and how they study, and for how long they study. Students' decisions on what and when to study will be influenced by other factors as well. In one survey, students reported focusing on topics they found interesting and whatever was due the soonest[14]. In addition to using surveys to assess when (and how) students prepare for exams, technology allows for additional opportunities for instructors to measure patterns of students' study behavior. For instance, researchers[39,40] have assessed when students accessed and submitted assignments through a learning management system, which provided an objective measure of students' learning behaviors such as academic procrastination. If these measures indicate your students are driven by what is due soonest, it may mean that they are waiting until the last moment to cram for important exams. If so, consider administering low-stakes quizzes each week to encourage them to study more frequently.

Second, control decisions also include the kinds of study technique that students explicitly adopt to learn material – that is, Riley is demonstrating control when she decides to stop rereading her material passively and switch to using a more effective strategy, such as successive relearning (for more on this and other effective techniques, see Dunlosky et al[9]; Dunlosky and Rawon[41]; Rawson, Dunlosky, and Sciartelli[42]). The surveys discussed above will provide some insight into students' beliefs and use of some strategies, and brief checklists can be used to assess your students' use of effective (and ineffective) techniques and how they may change their use of these techniques across a course[14].

A final point concerning Riley's control of her study is that her monitoring is likely to be intricately linked to her control (for reviews, see Dunlosky and Ariel[43]; Son and Metcalfe[44]). In particular, one function of monitoring in this context is to identify material that one is struggling to learn. A student can then decide how to engage differently with the less-well-understood material, such as by studying it more, choosing a different strategy for studying it, or seeking help from a peer or instructor. In fact, one of the main reasons that cognitive researchers have been interested in metacognitive monitoring is because students use their monitoring to make decisions about how to control their subsequent study. The rationale for such an interest is based on the importance of accurate monitoring for effective control[44], which we suspect is intuitively plausible: If Riley's judgments are perfectly accurate, then when she judges that she does not yet understand one topic and will not correctly answer questions on an exam, then in fact (because her judgments are accurate) she actually does not yet understand that topic and does need to study it more.

The main point here is that if your students are inaccurately judging their learning, and in particular, if they are overconfident in their knowledge of a topic, their poor judgments could lead them to under-perform. If you ever had a student after an exam say, “I was sure I knew all the material, so why did I perform so poorly?”, then you have already run into the problem of mis-judgment and how overconfidence can make students fall short of their learning goals. Again, using techniques to help students inform themselves about how well they understand content (eg, administering mini quizzes for use in formative evaluation) could be useful, and with the methods described above for how to collect and evaluate judgment accuracy, you could explore the degree to which any intervention (eg, mini quizzes) is actually improving your student’s ability to accurately judge their knowledge.

SUMMARY

Most learning takes place outside of the classroom, where students have limited guidance about what and how to study and are faced with ample opportunities to become distracted. Thus, effective self-regulated learning (guided by students’ metacognition) is critical for students to reach their academic goals. Discovering the extent to which your students know and use effective learning strategies, believe in their ability to succeed, and successfully monitor and control their own learning can inform your instruction (eg, how you structure your course, what you teach when, how you teach, what students need additional instruction, et cetera). Accordingly, we sought to offer a primer on measuring different aspects of metacognition that should allow you to begin evaluating how your students self-regulate their learning.

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Table 1. Aspects of Metacognition

Concept	Definition	Example from Above Scenario
Metacognitive knowledge	Knowledge or beliefs about how one learns	Believing that cramming and rereading are effective learning strategies
Metacognitive monitoring	Assessing the current state of learning or performance	Feeling confident about understanding a concept Estimating performance on a particular question, topic, or overall exam
Metacognitive control	Regulating some aspect of learning	Deciding to stop studying a concept Planning to look up material and study more in the future Changing study strategies

Modified from Dunlosky & Metcalfe[3]

Table 2. Potential Questions to Ask about each Aspect of Metacognition

Potential Question	Aspect of Metacognition	How to Measure	Example Citation/s
As students progress through a program, how does their metacognitive knowledge (eg, about effective strategies) change?	Knowledge	Questionnaires across time/cohorts	45-47
What experiences will increase students' self-efficacy?	Knowledge (Beliefs)	Questionnaire	48
Do students know which strategies are most effective for learning? Do they report using these effective strategies when studying on their own?	Knowledge/Control	Questionnaire	14, 49-52
Can students accurately judge which concepts they know well versus which they do not know as well?	Monitoring	Judgments	53
Can students accurately predict (and/or postdict) their exam (or clinical practice experience) performance? What factors influence the accuracy of these judgments?	Monitoring	Judgments/ Questionnaires	53-56
Does monitoring accuracy improve with course/exam/clinical practice experience?	Monitoring	Judgments	55
Do students study more or differently when they feel more or less prepared for an upcoming exam or clinical rotation?	Monitoring/Control	Questionnaire	43-44
Should students change their answers when taking a test?	Monitoring/Control	Questionnaire, Test Performance	57-60
Do students know when to ask for help? Do students know when to state "I don't know" during a clinical practice experience?	Monitoring/Control	Questionnaire	61
During a test, how do students decide what questions to answer first? When working up a patient, how do students decide which conditions get priority?	Control	Questionnaire	--

In a triage situation, how do students decide which patient gets priority?			
Do students change strategies after receiving poor grades on an assignment or exam?	Control	Questionnaire	--
Do students change strategies after receiving negative feedback or a poor grade on patient assignment or presentation/journal club?			
Do learners study differently if they expect a test, or more specifically, different types of tests?	Control	Test Performance	62-64
Do students prepare differently if they expect a more challenging preceptor?			
How do students make a study schedule? What do students choose to study when?	Control	Questionnaire, Objective measures	14, 39-40
What factors influence: What students study? How long they spend studying?	Control	Questionnaire, Objective measures	44

If you are interested in a specific question, we suggest you refer to the corresponding citations, which provide some in-depth examples of how to proceed. We provide citations from pharmacy classroom studies when available; all other citations are from applied laboratory research or psychology courses. For a few questions, we did not know of any relevant research.

Table 3. Popular Questionnaires Aimed at Measuring Students' Knowledge about Strategies, Efficacy, and Control of Learning

Name of Questionnaire	What it Measures	Description	Sample Questionnaire Item	Representative Citation/s
Motivated Strategies for Learning Questionnaire	General beliefs about learning and reported learning behaviors	Focuses on motivational orientations and use of different learning strategies for a specific college course. Contains 15 scales (eg, strategy use, self-regulation).	"When studying for this course I try to determine which concepts I don't understand well."	19, 45
Learning and Study Strategies Inventory	General beliefs about learning and reported learning behaviors	Assesses students' awareness about and use of learning and study strategies related to skill, will, and self-regulation. Contains ten scales (eg, motivation, time management).	"When work is difficult I either give up or study only the easy parts."	65-67
Academic Self-Efficacy Scale	Beliefs about academic ability	Assesses students' beliefs about their ability to succeed academically. Eight items.	"I am very capable of succeeding at the university."	68
Self-Efficacy for Self-Regulated Learning Scale	Beliefs about learning ability	Assesses students' beliefs about their ability to succeed academically. Five scales (eg, general organization/planning, task preparation strategies).	"I prepare for courses when there are other interesting things to do."	45, 69
Assessing knowledge and use of effective learning strategies	Knowledge about effective learning strategies	Various questionnaires assessing learning strategy preferences, use, and perceived effectiveness	"Which of the following study strategies do you use regularly? Test yourself, recopy your notes, make outlines, reread chapters, etc."	13-14, 49-52, 70-73
Assessing knowledge and use of one particular effective learning strategy	Knowledge about one effective learning strategy	Questionnaires focused on practice testing (long-term retention is enhanced when using practice testing than restudying information[10])	"After you have read a chapter one time, would you rather: Go back and restudy, try to recall material, or use some other study technique?"	74-76

Figure 1. Inspired by Nelson and Narens[25]. Note that each grain size (item, category, global) can be measured at each time point.

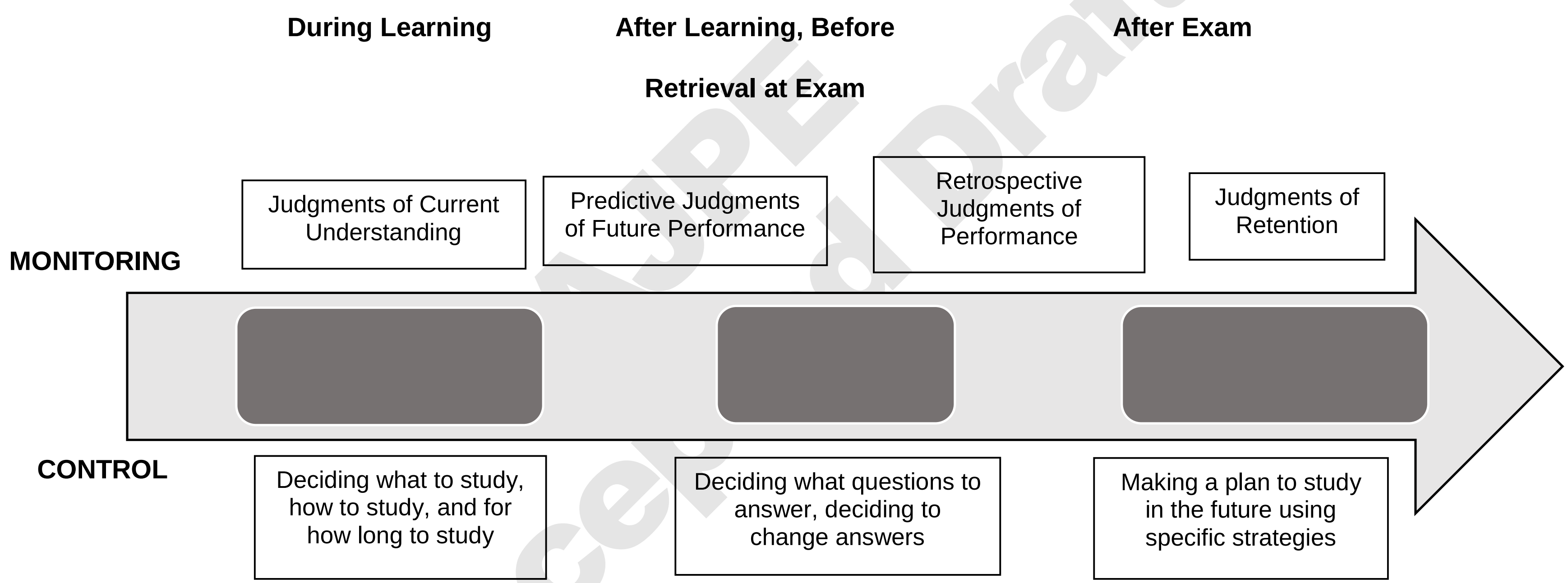

Figure 2. Judgments and exam performance from a hypothetical student

	Prediction	Actual Performance
Percentage correct across all questions	90	80
Percentage correct for specific concepts		
Single dose intravenous kinetics	85	96
Infusion kinetics	95	92
Extravascular dosing	85	91
Nonlinear kinetics	85	75
Hepatic clearance	75	65
Renal clearance	85	74
Mean across concepts	85	80

Global judgment:

Bias: 90–80=+10 (Overconfident)
Absolute bias: |(90 – 80)|=10 (10 point absolute difference)
Resolution: Not applicable

Concept-level judgments:

Bias: 85–80 =+5 (Overconfident)
Absolute bias: |(85 – 80)|=5 (5 point absolute difference)
Resolution (gamma): .75

Note. The global judgment does not need to be identical to the mean concept-level judgment, and, in most cases, mean exam performance will not equal the mean performance across topics (eg, they will not be equivalent if some questions tap topics that are not represented by the judged topics or if a different number of questions tap each topic on the exam). Resolution was computed as a gamma correlation between concept-level judgments and performance (see text for alternative measures).

Appendix: Sample cover sheet for exams - used to assess student monitoring at the global and concept level (modified from Hartwig & Dunlosky[53]).

Exam 1 Prediction Sheet

Please complete before completing your exam.

Question:	Estimate **% correct** (ranging from **0 - 100%**, rounded to the nearest whole number)
For the ENTIRE exam, what percentage of questions do you expect to answer correctly? (In other words, predict your exam score.)	

For each of the following test topics, estimate the percentage of questions you expect to answer correctly on the upcoming exam:

Topic:	Estimate **% correct** (ranging from **0 - 100%**, rounded to the nearest whole number)
(1) single dose intravenous kinetics	
(2) infusion kinetics	
(3) extravascular dosing	
(4) nonlinear kinetics	
(5) hepatic clearance	
(6) renal clearance	