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Reverse Engineering a Multiple-Choice Test Blueprint to Improve Course Alignment

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Reverse Engineering a Multiple-Choice Test Blueprint to Improve Course Alignment

Abstract

Large introductory classes, with their expansive curriculum, demand assessment strategies that blend efficiency with reliability, prompting the consideration of multiple-choice (MC) tests as a viable option. Crafting a high-quality MC test, however, necessitates a meticulous process involving reflection on assessment format appropriateness, test blueprint design, and adherence to item-writing guidelines aligned with learning objectives and teaching strategies. This inherently time-consuming undertaking ideally requires a collaborative effort from a team of writers who possess expertise in both the subject domain and the specific course context — an aspiration complicated by the multifaceted demands of higher education instruction. Given these challenges, educators often seek pragmatic solutions, including the adoption or adaptation of existing MC tests. However, the utility of these tests is ambiguous if the original test blueprint and the classification of questions are unknown. This paper introduces a structured four-step "reverse engineering" test blueprint process and proposes a systematic approach to identify test questions that align with the targeted learning objectives. One crucial step incorporates the Taxonomy Table (Anderson & Krathwohl, 2001) facilitating the classification of questions in the cognitive process dimension. As we delve into the intricacies of this analytical journey, we aim to provide a valuable resource for educators seeking to optimize the effectiveness and relevance of MC tests as a high-stakes assessment option.

Les grandes classes d'introduction, avec leur vaste programme d'études, demandent des stratégies d'évaluation qui allient efficacité et fiabilité, ce qui incite à considérer les tests à choix multiples (MC) comme une option viable. L'élaboration d'un test MC de haute qualité, cependant, nécessite un processus méticuleux impliquant une réflexion sur la pertinence du format d'évaluation, la conception du plan de test et le respect des lignes directrices sur la rédaction d'articles alignées sur les objectifs d'apprentissage et les stratégies d'enseignement. Cette entreprise intrinsèquement chronophage nécessite idéalement un effort de collaboration de la part d'une équipe d'écrivains possédant une expertise à la fois dans le domaine de la matière et dans le contexte spécifique du cours - une aspiration compliquée par les exigences à multiples facettes de l'enseignement supérieur. Compte tenu de ces défis, les éducateurs cherchent souvent des solutions pragmatiques, y compris l'adoption ou l'adaptation des tests MC existants. Cependant, l'utilité de ces tests est ambiguë si le plan de test original et la classification des questions sont inconnus. Ce document présente un processus de plan de test structuré en quatre étapes « ingénierie inverse » et propose une approche systématique pour identifier les questions de test qui s'alignent sur les objectifs d'apprentissage ciblés. Une étape cruciale intègre le tableau de taxonomie (Anderson & Krathwohl, 2001) facilitant la classification des questions dans la dimension du processus cognitif. Alors que nous nous plongeons dans les subtilités de ce parcours analytique, nous visons à fournir une ressource précieuse aux éducateurs qui cherchent à optimiser l'efficacité et la pertinence des tests MC en tant qu'option d'évaluation à enjeux élevés.

Keywords: course alignment, test blueprint, multiple-choice test, taxonomy table

Large introductory classes, common in higher education, often span a broad learning spectrum, emphasizing memorizing facts and understanding conceptual knowledge. These large classes call for assessment formats that are both efficient and reliable, making multiple-choice (MC) tests a popular option. Crafting a high-quality MC test entails evaluating the appropriateness of the assessment format, devising a test blueprint that reflects the content scope, adhering to test item-writing guidelines, and aligning questions with learning objectives. Even for those well-versed in this process, it remains a time-consuming undertaking, with the creation of quality MC questions demanding significant time and effort. Ideally, this collaborative effort involves subject matter experts familiar with the course context and well-versed in the best MC question writing strategies supported by the literature. According to Petrovic-Dzerdz (2019), this aspiration is rarely achieved, considering the demands of teaching in a higher education setting. Given the challenges, the desire to save time and effort prompts educators to consider adopting or adapting existing MC tests, whether inherited from the predecessor or received from a textbook publisher.

However, such repurposing requires familiarity with the taxonomy of educational objectives framework and associated concepts. This might prove challenging for instructors with limited time to design new assessments. Therefore, the guidance of teaching support professionals, who are familiar with the taxonomy framework and the outlined processes, becomes crucial. This paper addresses the shared interests of instructors, instructional designers, and educational developers by proposing a deductive four-step "reverse engineering" test blueprint analytical process for designing MC tests. This method aims to evaluate the original test utility, ensuring alignment with course objectives, and selecting questions suitable for course assessment.

Classifying Educational Objectives

To implement the reverse engineering procedure outlined in this article, instructors should possess familiarity with some classification system to effectively categorize MC questions and align them with the corresponding learning objectives. The analytical process presented here is grounded in Anderson and Krathwohl’s (2001) taxonomy introduced in *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom’s Taxonomy of Educational Objectives.* Commonly referred to as the "revised Bloom’s taxonomy," this framework serves as the basis for the proposed analytical process, facilitating a standardized approach to classifying educational objectives, teaching and learning strategies, and assessment.

Upon examination of many publicly accessible higher education institutional websites at the time of composing this manuscript, it became apparent that many still exclusively reference Bloom’s (1956) original classification. In instances where the 2001 revised version is mentioned, closer scrutiny often reveals a conflation of the original and revised taxonomies, lacking proper citation. This is regrettable, considering that the revised edition integrated five decades of advancements in cognitive psychology and science, a shift from the mid-20th century dominance of behaviourism as the primary learning theory, acknowledgment of diverse knowledge types (including the introduction of metacognitive knowledge), and a divergence of the knowledge and cognitive processes dimensions, resulting in a two-dimensional revised framework. Most importantly, a revised taxonomy represents a shifted focus from a taxonomy of only learning objectives to a taxonomy for teaching, learning, and assessment, thus emphasizing course alignment. Instances utilizing the Taxonomy Table, a visual representation of the revised framework crucial to the process expounded in this paper, are infrequently observed, despite its inclusion on the inside covers of the 2001 book as an essential tool for assessing course alignment.

These findings pose a certain degree of perplexity for the author of this paper, given that it has been nearly a quarter of a century since the revised version was published by prominent experts in the field. These experts include one of the authors of the original taxonomy, David Krathwohl, who is also the primary author of the *Taxonomy of Affective Domain* (1964), and Lorin Anderson—a graduate student of Benjamin Bloom. However, this situation might not have been mystifying to Bloom himself, as he previously characterized the original handbook as "one of the most widely cited yet least read books in American education" (Anderson & Krathwohl, 2001, Preface XXIII, as cited in Anderson & Sosniak, 1994, p. 9). It appears that the revised taxonomy might be undergoing a comparable fate. The anticipation is that this paper will stimulate interest among higher education instructors, instructional designers, and educational developers to become more closely acquainted with all the revisions of the original 1956 framework. This interest is particularly warranted, given that the primary author of the framework, Benjamin Bloom, envisioned continuous updates as our understanding of the field of learning advances (Anderson & Krathwohl, 2001).

My focus on the cognitive process dimension, as opposed to the psychomotor, affective, or interpersonal domains, is warranted due to the inherent constraints of MC questions in evaluating the achievement of learning objectives within these domains. As the cognitive process and knowledge dimensions form the bedrock of this analytical "reverse engineering" method, I will provide a summary outline of the revised taxonomy framework.

A Brief Overview of the Taxonomy for Learning, Teaching, and Assessing

According to the revised taxonomy (Anderson & Krathwohl, 2001), the six categories of learning objectives within the cognitive process dimension are remember, understand, apply, analyze, evaluate, and create. Each category is clearly defined to facilitate clarity and enhance communication among educators so that they can speak a common language when talking about learning objectives, teaching and learning strategies, and assessment. In the Cognitive Process Dimension, the emphasis is on the 19 cognitive processes within the six categories (see Table 1). Most of the time, if we think of cognitive learning objectives for our course, we can find a close fit with one of these 19 processes.

Table 1

The Cognitive Process Dimension (Definitions and 19 Processes Within Six Categories)

Categories	Definition	Cognitive Processes
1. Remember	Retrieve relevant knowledge from long-term memory	1.1 Recognizing 1.2 Recalling
2. Understand	Construct meaning from instructional messages, including oral, written, and graphic communication	2.1 Interpreting 2.2 Exemplifying 2.3 Classifying 2.4 Summarizing 2.5 Inferring 2.6 Comparing 2.7 Explaining
3. Apply	Carry out or use a procedure in a given situation	3.1 Executing 3.2 Implementing
4. Analyze	Break material into its constituent parts and determine how the parts relate to one another and an overall structure or purpose	4.1 Differentiating 4.2 Organizing 4.3 Attributing
5. Evaluate	Make judgments based on criteria and standards	5.1 Checking 5.2 Critiquing
6. Create	Put elements together to form a coherent or functional whole; reorganize elements into a new pattern or structure	6.1 Generating 6.2 Planning 6.3 Producing

Note: Reproduced and adapted from Anderson and Krathwohl (2001) with permission from Lorin Anderson.

In employing the above framework to categorize a learning objective within the cognitive domain, the initial step involves identifying the primary (or multiple) among the 19 processes that most closely align with a learning objective. This determination establishes the category within the cognitive process dimension. Anderson and Krathwohl's (2001) comprehensive book provides detailed descriptions and illustrative examples for each of these processes. For instance, if the learning objectives are centred on students' ability to provide examples, classify, or summarize, according to the revised taxonomy, these cognitive processes (2.2, 2.3, and 2.4 in Table 1) fall within the "Understand" category.

A notable strength of the revised taxonomy lies in its heightened emphasis on knowledge, recognizing it not merely as the foundation of learning but also as a distinct dimension comprising four major types: factual, conceptual, procedural, and metacognitive knowledge (see Table 2). Note that metacognitive knowledge is now included in the revised taxonomy. This represents one of the major updates that reflects the advances in the field including our evolving understanding of the complexities of processes involved in learning. Much like the cognitive process dimension, each knowledge type is delineated into subtypes (see Table 2). For instance, within factual knowledge, subtypes encompass knowledge of terminology and knowledge of specific details and elements. Similarly, when referring to procedural knowledge, we are referring to knowledge of specific skills, algorithms, techniques and methods, etc.

Table 2

The Knowledge Dimension (Four Major Types and 11 Subtypes)

Major Types of Knowledge	Definition	Subtypes of Knowledge
Factual	The basic elements students must know to be acquainted with a discipline or solve problems in it.	Knowledge of… • terminology • specific details and elements
Conceptual	The interrelationships among the basic elements within a larger structure that enable them to function together	Knowledge of… • classifications and categories • principles and generalizations • theories, models, and structures
Procedural	How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods	Knowledge of… • subject-specific skills and algorithms • subject-specific techniques and methods • criteria for determining when to use appropriate procedures
Metacognitive	Knowledge of cognition in general as well as awareness and knowledge of one's cognition	Knowledge of… • strategy • cognitive tasks, including appropriate contextual and conditional knowledge • self

Note: Reproduced and adapted from Anderson and Krathwohl (2001) with permission from Lorin Anderson.

The knowledge and cognitive processes dimensions together form a comprehensive two-dimensional framework, visually encapsulated in the Taxonomy Table (see Table 3). This tool serves as a critical element in our reverse-engineering analytical process. As we apply this approach, each learning objective is aptly classified within one or more of the 24 cells (six cognitive processes combined with four knowledge types categories) integrated into the Taxonomy Table (Anderson & Krathwohl, 2001; Krathwohl, 2002). It is important to note that certain combinations of cognitive process and knowledge dimensions manifest more frequently within learning objectives, such as "remember + factual knowledge" (cell 1.A. in Table 3.), "understand + conceptual knowledge" (cell 2.B. in Table 3) or "apply + procedural knowledge" (cell 3.C. in Table 3).

Table 3

The Taxonomy Table

The Knowledge Dimension ⇩	The Cognitive Process Dimension					
	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
A. Factual Knowledge						
B. Conceptual Knowledge						
C. Procedural Knowledge						
D. Metacognitive Knowledge						

Note: Reproduced and adapted from Anderson and Krathwohl (2001) with permission from Lorin Anderson.

Test Blueprint and Taxonomy Table

In the creation of tests, particularly in high-stakes assessments like midterms or final exams, the customary approach involves initiating the process with the design of a test blueprint. The test blueprint, at a minimum, encompasses the topics intended for assessment and the corresponding percentage of questions allocated to each topic. This allocation is guided by the emphasis placed on these topics in our course design, delivery, and teaching/learning activities (see Table 4).

Table 4

An Example of a Simple Test Blueprint for a Test Assessing Three Topics with 30 Questions

TOPICS	Number of questions	Percentage of TOTAL
Topic A	10	33%
Topic B	15	50%
Topic C	5	17%
TOTAL	30	100%

In this illustration, the test comprises 30 questions, encompassing three topics—topics A, B, and C. Notably, topic B holds the greatest emphasis, as evidenced by 50% of the questions on the test originating from topic B, followed by 33% from topic A, and 17% from topic C. While this test blueprint serves as a foundational step in test planning, it provides insufficient information for designing a high-stakes exam with a focus on course alignment. We aim to guarantee that questions effectively tap into the designated cognitive and knowledge dimensions aligned with the learning objectives under assessment, enabling students to demonstrate their acquired knowledge. In essence, a well-aligned course manifests agreement among its learning objectives, teaching strategies, learning activities, and assessments. Therefore, it is imperative to ensure that test questions are crafted in coherence with the specific types of learning objectives associated with each topic.

In the subsequent phase of the test design process, we systematically organize Topic Learning Objectives (LOs) by meticulous classification, adhering to the definitions of cognitive processes (see Table 1) and knowledge subtypes (see Table 2). For the sake of illustration, let's assume the following classification for the Learning Objectives:

Topic A:

- LO1 – Remember factual knowledge
- LO2 – Understand conceptual knowledge

Topic B:

- LO1 – Remember factual knowledge
- LO2 – Understand conceptual knowledge

- LO3 – Apply procedural knowledge

Topic C:

- LO1 – Understand conceptual knowledge
- LO2 – Apply procedural knowledge

Next, we must take into account the desired quantity of questions allocated to each learning objective we have classified for inclusion in the test, mindful of their alignment with the learning activities in which students participated within each topic. Combining this information with Table 4, we construct an advanced version of a test blueprint (see Table 5). This blueprint incorporates the names of the test topics, the quantity and percentage of questions assigned to each topic on the test, and the count of questions within each combination of cognitive and knowledge dimension categories that represent learning objectives. This careful process ensures the harmonization of the assessment with teaching and learning strategies, underscoring the importance of alignment with the targeted learning objectives. A brief examination of this test blueprint indicates a predominant focus on assessing remembering factual knowledge (60%). Additionally, approximately one-third of the test will evaluate the understanding of conceptual knowledge (33%), with a minor proportion of questions (2%) dedicated to appraising the application of procedural knowledge.

Table 5

Test Blueprint with Learning Objective Classification

Topics	Number and percentage of questions	Remember factual knowledge	Understand conceptual knowledge	Apply procedural knowledge
Topic A	10 (33%)	8	2	0
Topic B	15 (50%)	10	4	1
Topic C	5 (17%)	0	4	1
Total on the test	30 (100%)	18 (60%)	10 (33%)	2 (7%)

By amalgamating information from Table 5 and the Taxonomy Table (Table 3), we construct a multi-dimensional table, hereby termed the Test Blueprint Taxonomy Table (TBTT). This visual representation encapsulates the configuration of the assessment tool, delineating the requisite number of questions to be composed per topic and classified based on their cognitive and knowledge dimensions (see Table 5).

Table 5

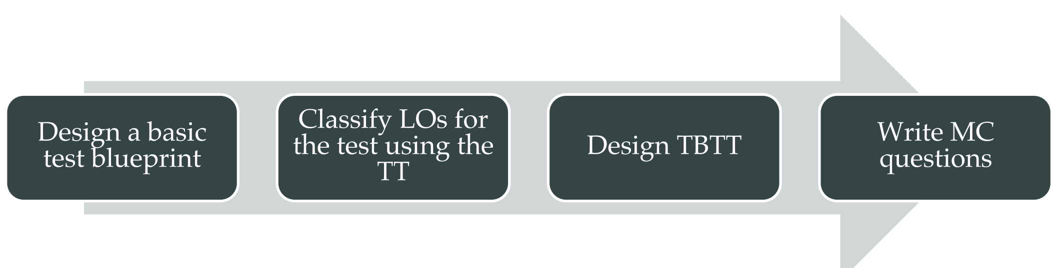
An Example of the Test Blueprint Taxonomy Table (TBTT)

The Knowledge Dimension ⇩	The Cognitive Process Dimension					
	1. Remember	2. Understand	3. Apply	4. Analyze	5. Evaluate	6. Create
A. Factual Knowledge	Topic A (8) Topic B (10)					
B. Conceptual Knowledge		Topic A (2) Topic B (4) Topic C (4)				
C. Procedural Knowledge			Topic B (1) Topic C (1)			
D. Metacognitive Knowledge						

Table 5 emerges as a principal resource, serving as a comprehensive test blueprint for crafting MC test questions. This pivotal table guides the development of questions by ensuring they align with the appropriate cognitive and knowledge combination for each topic, culminating in the final step of the process, writing MC questions. Numerous valuable resources for crafting "good" MC questions are available, including those authored by Haladyna et al. (2002) and Dibattista (2011). The delineated process for designing a well-aligned MC test is encapsulated in Figure 1.

Figure 1

The Process of Designing a MC Test With Emphasis on Course Alignment



The outlined procedure for developing a methodically aligned multiple-choice (MC) test through the incorporation of a Taxonomy Table, positioned as an essential initial stage in formulating a high-stakes assessment, is a practice I aim to advocate within the educational community. It is vital to recognize, however, that the final step in this process—the crafting of “good” MC test items—constitutes the most time-intensive component. This time constraint prompts instructors to consider repurposing tests inherited from peers or acquired from textbook publishers. To streamline this process and encourage effective “recycling” of existing MC tests, I have developed a reverse-engineering approach. Instructors equipped with pre-existing MC tests can utilize this method to assess whether the test or specific questions within it, are suitable for repurposing—either in their original form or with modifications—to align with their assessment objectives. The subsequent section outlines the step-by-step procedure of the reverse engineering process.

Reverse Engineering Multiple-Choice Test Blueprint

Assuming familiarity with the concepts and processes explained in the preceding section—specifically, the classification of educational objectives in the cognitive domain, and the definitions of cognitive subprocesses and knowledge subtypes (see Tables 1 and 2), the Taxonomy Table (see Table 3), the test blueprint (see Table 4), and the Test Blueprint Taxonomy Table (see Table 5)— we are prepared to embark on the four-step reverse engineering process.

Step One: Construct a TBTT

Following the procedures delineated in the preceding section, construct a Test Blueprint Taxonomy Table (TBTT) for your upcoming test. For illustrative purposes, let's consider the scenario where you intend to design a 30-question test. Following the outlined process, you have successfully formulated the TBTT, as depicted in Table 5.

Step 2: Select, Organize, and Classify

Examine the available test questions by initially categorizing them according to the topics designated for assessment within the MC test—excluding questions unrelated to topics A, B, or C. Subsequently, discern and choose questions that meet the criteria of being considered "good" questions, adhering to the best practices in item-writing guidelines. As an example, suppose you identified 40 questions deemed as "good" and relevant; organize and classify these questions based on their respective topics, as presented in Table 6.

Table 6

Existing Test Questions are Classified by Relevant Topics

Topic	Question number
A	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 31, 32, 33, 34, 35
B	11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 36, 37
C	21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 38, 39, 40

Step 3: Create a Reverse-Engineered TBTT

Classify the questions from Table 6 utilizing the Taxonomy Table. The resulting table may resemble Table 7, representing the reverse-engineered test blueprint taxonomy table (TBTT).

Table 7

Reverse-Engineered Test Blueprint Taxonomy Table (TBTT)

The Knowledge Dimension	**The Cognitive Process Dimension**					
	1. Remember	**2. Understand**	**3. Apply**	**4. Analyze**	**5. Evaluate**	**6. Create**
A. Factual Knowledge	**Topic A** (1, 2, 3, 4, 5, 31, 32, 33, 34, 35) **Topic B** (11, 12, 13, 14, 15, 16, 17, 36, 37) **Topic C** (21, 22, 23, 38, 39, 40)					

B. Conceptual Knowledge		**Topic A** (6, 7, 8, 9, 10) **Topic B** (18, 19, 20) **Topic C** (24, 25)		**Topic C** (29, 30)		
C. Procedural Knowledge			**Topic C** (26, 27, 28)			
D. Metacognitive Knowledge						

Step 4: Compare TBTT and Reverse-Engineered TBTT

Compare your TBTT (see Table 5) with the reverse-engineered TBTT (see Table 7) to identify questions suitable for "recycling," as well as those necessitating new development (see Table 8). Upon comparison, it may become evident that questions 29 and 30, for example, lack relevance for your test, as they do not align with your specified learning objectives. The pivotal stage in this process, however, is where you determine what MC questions you can recycle and what MC questions you need to write. Using Table 8 as an example, you can determine that:

1. **For Topic A:** 15 questions from the existing test can be utilized, yet only 10 are required. Consequently, there is a surplus of two questions evaluating remembering factual knowledge and an excess of three questions appraising the application of procedural knowledge.
2. **For Topic B:** 12 questions are usable, but 15 are needed. Therefore, an additional question assessing remembering factual knowledge, one question evaluating understanding conceptual knowledge, and one question gauging students' knowledge in applying procedures need to be crafted.
3. **For Topic C:** The six questions in the "remember factual knowledge" category are unnecessary. Two additional questions evaluating the understanding of conceptual knowledge should be devised, resulting in a surplus of two questions in the "apply procedural knowledge" category.

Table 8

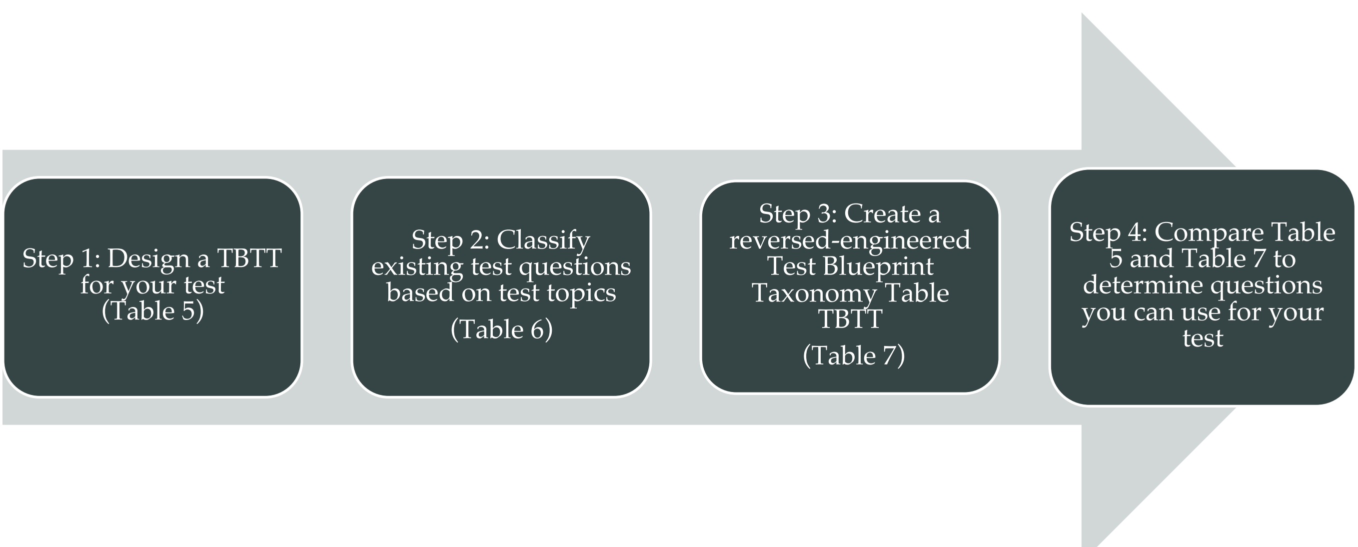
Questions You Can "Recycle" and Questions You Need to Write

	Remember Factual		Understand Conceptual		Apply Procedural	
	You have	You need	You have	You need	You have	You need
Topic A	10	8	5	2		
Topic B	9	10	3	4		1
Topic C	6		2	4	3	1

Based on Table 8, we determine that, in total, there is a requirement for crafting five new questions, accompanied by a surplus of seven questions. In contrast to the alternative of generating 30 entirely new questions, this process offers a substantial time and effort-saving advantage. Figure 2 illustrates the previously outlined four-step process for analyzing the repository of existing test questions, enabling the identification of questions suitable for "recycling" in the development of our test.

Figure 2

Illustration of the Process of Identifying Questions Suitable for "Recycling"



Moreover, in the event of an excess of questions within any of the topic categories, as illustrated in the aforementioned example, and particularly when developing a test within a Learning Management System, this approach affords the ability to establish a question bank. This involves organizing questions into designated folders based on topics and categories, a classification you already accomplished in step three (see Table 7). Subsequently, one can structure a quiz that randomly selects the requisite number of test questions from the appropriate question folder. This ensures that students receive varied questions during the test while preserving the consistent test scope and alignment with assessment objectives. This strategic use of randomization diminishes the potential for unintended collaboration among students during the examination.

Conclusion

In a well-aligned course, assessments should mirror the content, activities, and learning objectives outlined in the course syllabus. MC tests, particularly prevalent in large introductory courses, require careful test design. The initial phase involves crafting an appropriate test blueprint, with the final step entailing the creation of well-constructed MC questions aligned with the designated learning objectives—a meticulous and time-intensive process. Failure to adhere to any step in this test design process may result in an assessment misaligned with the course, that doesn't accurately gauge student learning outcomes and teaching effectiveness. Regrettably, instances of misalignment are often attributed to the MC test format itself, overlooking the possibility that issues stem from how the format is implemented.

While the described process significantly streamlines MC test preparation for course exams, its successful execution demands requisite knowledge and skills. Therefore, the guidance of instructional designers and educational developers can prove invaluable to instructors. I hope that the practicality of this process motivates higher education professionals to familiarize themselves with *A Taxonomy for Learning, Teaching, and Assessing* (Anderson & Krathwohl, 2001), commonly referred to as the revised Bloom's taxonomy of educational objectives. An excellent starting point is Krathwohl's overview paper from 2002. I trust that increased familiarity with this taxonomy will contribute to more aligned curricula, ultimately enhancing the learning success of our students.

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