

Instructional Module Development(IMOD) System - Assessment Feature

Husna Gafoor
Department of Engineering
Arizona State University
hgafloor@asu.edu

Abstract - *The IMOD system is an open source web application that scaffolds the user through a step-by-step process of designing a curriculum which is complete and efficient. The IMOD system abides by the principles of outcomes based education(OBE), which makes the learning objective as the spine of the system as a whole and aligns all other aspects i.e. instructional strategies and assessments to the learning objective. The report describes the assessment module of the IMOD system and an overview of features implemented within the module.*

Introduction

Motivation

Higher education teaching and learning have for hundreds of years remained very teacher-centric, with grades being the principal measure of student learning [1]. Today's classrooms have changed drastically with teaching and learning taking place not just physically in classrooms and laboratories but virtually with online classrooms, including small and large groups of students, and with one or many teachers. Thus assessments entail more than identifying the incremental changes in student grades. [2]. Science, technology, engineering, and mathematics (STEM) instruction poses a bigger challenge since most faculty come from technical backgrounds and the Ph.D. historically has never been a degree

primarily aimed at preparing people to teach. [3]. Most faculty members develop teaching skills through time spent in the classroom and by following the example of proceeding instructors [4]. If assessment did

not play an integral part of previous teaching and no activities have ever exposed them to the assessment of learning, it is unrealistic to expect faculty to show expertise in the area. Hence providing improved classroom environments equipped with better tools for student learning becomes a necessity for educators. One of the goals of STEM education is to provide a learning experience that will foster the next generation of innovators, educators and leaders. It works by creating a student –centered, inquiry-based classroom where students discover the real-world connection between science, technology, engineering, and math. An information tool that helps educators design their instructional modules by providing research-based information about pedagogical and assessment practices, automating complex tasks involved in the design is of great value. [5]

Problem Statement

Educators in STEM programs gain practical teaching experience while on the job without any formal training as such and thus, may require few years to become proficient with how and what they teach. They require gaining familiarity to the pedagogical and assessment techniques most suited for the curriculum they teach. [6] The stepping

stones to effective STEM instruction start with a well conceived and constructed curriculum, in our case an IMOD. The IMOD system currently under development aims at translating scholarship through the application of a framework informed by research in the area of instruction development for STEM disciplines, into a software platform that provides an improved teaching and learning experience for educators [7].

Proposed Solution

The IMOD system abides to the principles of outcomes based education (OBE), which is to lay emphasis on the objective or goal first and then the rest of the design follows. Hence learning objective becomes the spine of the overall structure. The other defining components associated to forming a complete and effective learning objective are derived from studies made by Robert Mager. [8]

Mager identifies the following i.e.

Performance: description of what the learner is expected to be able to do,

Condition: description of the conditions under which the performance is expected to occur.

Criteria: description of assessment criteria indicating quality, quantity, speed and accuracy.

as the core aspects in creating a well formed learning objective, to the above an additional component is included which is:

Content: description of the disciplinary knowledge, skill or behavior to be attained.

This allows for a more subjective approach to be applied in enabling the learning objective. This within the IMOD framework

is referred to as the PC³ model. The other course design elements (i.e., Content, Pedagogy, and Assessment) are incorporated into the IMOD framework through interactions with two of the PC³ characteristics.

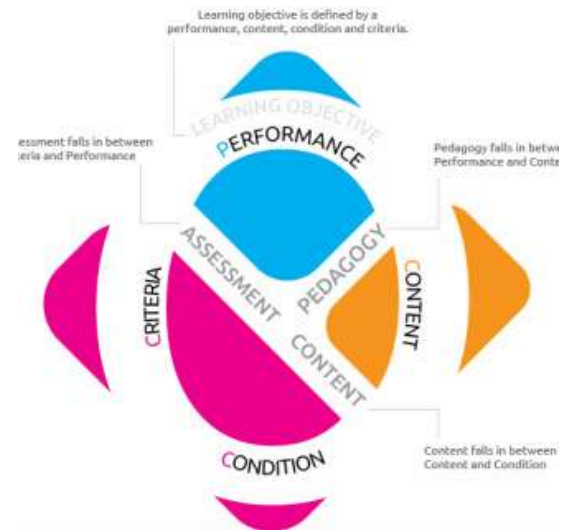


Figure 1: IMOD System Framework

Course-Content is linked to the content and condition components of the objective. The condition component is often stated in terms of precursor disciplinary knowledge, skills or behaviors. This information, together with the content defined in the objective, can be used to generate or validate the list of course topics. Course-Pedagogy is linked to the performance and content components of the objective. The types of instructional approaches or learning activities used in a course should correspond to the level of learning expected and the disciplinary knowledge, skills or behaviors to be learned. The content and performance can be used to validate pedagogical choices. Course-Assessment is linked to the performance and criteria components of the objective. This affiliation can be used to test the suitability of the assessment strategies since an effective assessment, at the very least, must be able to determine whether the learner's performance constitutes competency. [7]

The Assessment feature of the IMOD system allows mapping a learning objective defined to corresponding assessment techniques based on the performance and criteria selected by the user. The current IMOD system interface is divided into the following tabs:



Figure 2: Assessment tabs

The user defines a course overview and a learning objective before moving to the other tabs.

Listed below are the various features of the assessment module defined within the current IMOD system:

- A. *Displaying Learning Objective*
The Learning objectives that have been defined in the Learning objectives tab are displayed here. When no objectives are defined “No Objectives defined” is displayed.
- B. *Indicating which piece of the PC³ is being applied to Objective*
An indication that the tab uses performance and criteria pieces of the PC³ model.
- C. *Create New Assessment Techniques*
User can define new assessment techniques that he may choose to apply to learning objective each of which when once saved is displayed as a technique matched up to the learning objective.
- D. *Display Assessment Techniques*
The assessment techniques that map to the learning objective selected are displayed in the ideal match or extended match sections of the page based on the filters applied.
- E. *Filtering Assessment Techniques*
The filters are provided as selectable values on the left menu of the page and

are divided into 3 different section filters namely Knowledge Dimension, Learning Domain, Domain Category.

- F. *Assigning assessment techniques to learning objective*
Assessment techniques can be assigned to a particular learning objective based on users requirements.
- G. *Favorites defined for the user*
Assessment techniques can be favoritized for a particular user.
- H. *Assessment Plan*
Indicates all the learning objectives defined for a particular user and the techniques that are assigned.

Literature Review

The triad that forms the epicenter of any good educational enterprise defined by Pellegrino [9] comprises of Curriculum, Instructional activities and Assessments. Pellegrino further believes that effective teaching and learning can never be achieved without the alignment of all the components in the triad. The Backward-design principle of developing curriculum introduced by Wiggins & McTighe [10] advocates defining the objective/goal to be achieved at the end of the class to be the starting point in designing the curriculum and later assessments are defined to verify if the goals are achieved.

In the outcomes-based approach to education, *learning objectives* are statements that describe significant and essential learning that learners have achieved, and can reliably demonstrate at the end of a course or program. Learning Outcomes identify what the *learner will know and be able to do* by the end of a course or program – the essential and enduring knowledge, abilities (skills) and attitudes (values, dispositions) that constitute the integrated learning needed by a graduate of a course or program

[11].One of the most widely used ways of defining objectives is according to Bloom's Taxonomy of Educational Objectives. Bloom's Taxonomy uses a multi-tiered scale to express the level of expertise required in organizing measurable student outcomes to select appropriate classroom assessment techniques for the course [12]. Bloom defines the categories of objectives/goals into *knowledge-based* goals, *skills-based* goals, and *affective* goals (affective: values, attitudes, and interests); accordingly, there is a taxonomy for each. Within each taxonomy, levels of expertise are listed in order of increasing complexity. This taxonomy was later revised by Anderson and Krathwohl's where they redefined the cognitive domain as the intersection of the Cognitive Process Dimension and the Knowledge Dimension [13].

The Knowledge Dimension classifies four types of knowledge that learners may be expected to acquire or construct— ranging from concrete to abstract shown **Error! Reference source not found.**

The Knowledge Dimension – major types and subtypes

concrete knowledge		abstract knowledge	
factual	conceptual	procedural	metacognitive*
knowledge of terminology knowledge of specific details and elements	knowledge of classifications and categories knowledge of principles and generalizations knowledge of theories, models, and structures	knowledge of subject-specific skills and algorithms knowledge of subject-specific techniques and methods knowledge of criteria for determining when to use appropriate procedures	strategic knowledge knowledge about cognitive tasks, including appropriate contextual and conditional knowledge self-knowledge

Figure 3: Knowledge Dimensions

The cognitive process dimension is further broken down and classified into Learning Domains each further classified into Domain Categories shown in **Error! Reference source not found.**

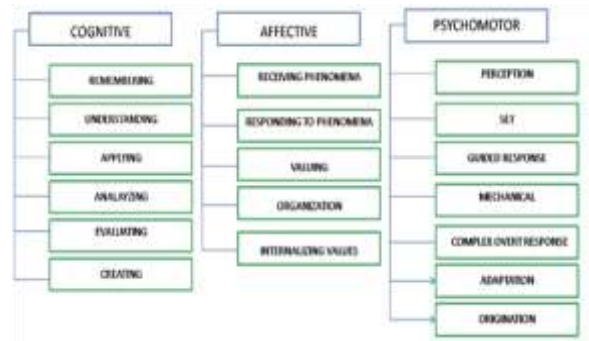


Figure 4 : Learning Domains

Every learning objective contains a verb (an action) and an object (usually a noun).

- ✓ The verb generally refers to [actions associated with] the intended cognitive process.
- ✓ The object generally describes the knowledge students are expected to acquire or construct [13]

The PC³ model of the IMOD divides the Learning objectives into Performance, Content, Condition and Criteria. The learning domain classified into domain

categories along with the knowledge dimensions define the verbs and nouns mapped with the performance and content features of the PC³ model. The criteria which are further classified into Speed, Accuracy, Quality and Quantity in conjunction with performance parts of the learning objectives are used to classify assessment techniques [14].

The revised taxonomy reinforces the perspective that different types of objectives require different types of assessment, whereas similar types of objectives (regardless of subject matter) require similar approaches to assessment [14]. The information obtained during the assessment process is influenced to a great extent by what has preceded it during the instructional process. Educational assessment do not exist in isolation, but must be aligned with curriculum and instruction if it is to support learning [15]. Misalignment may lead to undermining student motivation and learning. Thus forming an alignment triangle that is essential for effective curriculum design.

Example Scenario: Your objective is for students to learn to *Apply* analytical skills, but your assessment measures only *factual* recall. Consequently, students hone their analytical skills and are frustrated that the exam does not measure what they learned.



Figure 5: Alignment Triangle

Types of Assessments

Formative Assessments

The goal of formative assessment is to help students identify their strengths and weaknesses and target areas that need work help faculty recognize where students are struggling and address problems immediately. Formative assessments are generally *low stakes*, which means that they have low or no point value. Examples of formative assessments include asking students to:

The following Classroom Assessment Techniques [16] have proven effective for computational science and STEM classrooms

Background Knowledge Probe: This activity goes beyond the common practice of asking students what courses they have already taken in the field. Using a survey, the instructor elicits information that can be used to focus instruction on appropriate content and level of difficulty. The questions address information the students will need to know to succeed on course assignments and activities, include both easy and difficult questions, and avoid general knowledge areas. A more advanced application of the technique could entail implementing the survey pre- and post-course.

Pro & Con Grid: This technique helps faculty determine how well students can imagine more than one side to an issue by having them develop lists of pros/cons, costs/benefits, advantages/disadvantages to an issue. The instructor identifies a decision/judgment/issue that has relevance in the context of the course and writes out a question that will elicit thoughtful responses to the topic. A more advanced application of the technique could involve role playing as students choose a character (project

manager, programmer, technical artist, etc.) and answer the question.

Student-generated Test Questions : By having students write test questions and compose answers, faculty discover what students identify as key content, what they consider reasonable test questions and how well they can answer the questions they create. Instructors pre-determine the types of questions (essay, multiple choice, short-answer, etc.) and the topics to be addressed. The questions can then be compiled for a study guide or, as an added incentive, chosen (if suitable) to appear on the actual test.

Minute Paper: This popular CAT helps ascertain what students felt was the most important information they learned during a particular class meeting and if they have any lingering questions about the content. Answers to these questions help faculty focus instruction, make mid-course corrections or identify areas that need more emphasis.

Muddiest Point: This very simple technique identifies areas of confusion from a lecture, discussion, homework or other activity. When students write out the answer to the question, "What was the muddiest point in _____?" they not only must reflect on the content material but also articulate their thoughts. This CAT works well when large amounts of information has been presented.

Summative Assessments

The goal of summative assessment is to *evaluate student learning* at the end of an instructional unit by comparing it against some standard or benchmark. Summative assessments are often *high stakes*, which means that they have a high point value. Examples of summative assessments [16] include:

Final Grades: constitute the most commonly known summative assessment. It is important to note that grades commonly reflect performance in multiple content areas and should not be used as a measure of achievement of individual student learning outcomes. A single letter-grade eliminates the context of a student's achievement and provides little useful information for improvement [17].

Capstone projects: Capstone projects generally represent the culmination of a student's experiences in a degree program, have some relevance to their degree and career interests and are often applied in nature. Assessment can focus on higher-order thinking and problem-solving skills, ability to work in groups or design experiments, communication skills, writing skills, project management and planning or any related skill that demonstrates attainment of the desired learning outcomes for the curricula. The assessment process may also involve a committee of faculty members who determine the student's eligibility to graduate.

Practicum or Internship: The purpose of the practicum or internship is to provide students with supervised experience in an actual work setting similar to one in which the student might end up after graduating. Assessment generally involves analysis of work performance by the student's supervisor, grading of a formal report by the faculty member, and a self-analysis written by the student.

Midterm exam, final project, paper presentations, senior recital are some other common examples. Information from summative assessments can be used formatively when students or faculty use it to guide their efforts and activities in subsequent courses.

Assessment Framework

Assessment: Educational assessment determine how well students are learning and are an integral part of the quest for improved education. Assessment is simply the process of collecting information about student learning and performance. Assessments should reveal how well students have learned what was intended to be learned while instructional strategies ensure that they learn it.

Every assessment, regardless of its purpose, rests on three pillars:

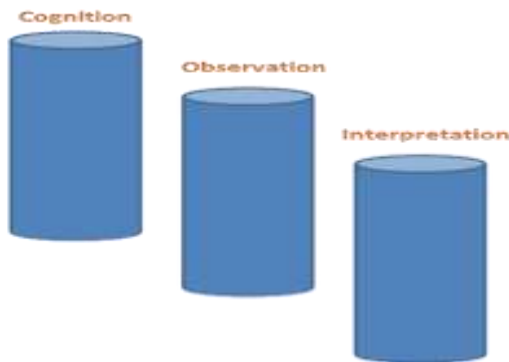


Figure 6: Assessment Pillars

A. Cognition:

A model of how students represent knowledge and develop competence in the subject domain. How they will learn, misconceptions, difficulty areas identified. Define how levels of progression may be classified i.e. Novice --> Expert.

B. Observation:

Tasks or situations that allow one to observe students' performance. This means the actual tasks they will perform.

C. Interpretation:

Method for drawing inferences from the performance evidence thus obtained. Analyze the data collected during the Observation.

The Assessment framework takes input from these two parts (namely domain category & criteria) of the learning objective and maps **verbs** associated with each domain category to assessment technique(s). A basic mapping of verbs and techniques with different categories is shown in the table below.

	Remember	Understand	Apply	Analyze	Evaluate	Create
Factual Knowledge	'Recall' Memory Matrix	'Restate' One sentence Summaries	'Employ' What's the Principle	'Distinguish' Concept Maps	'Select' Classroom Opinion polls	'Arrange' Classroom Opinion polls
Conceptual Knowledge	'Define' Empty Outlines	'Describe' One sentence Summaries	'Translate' Directed paraphrasing	'Compare' Pro & Con Grid	'Defend' Class Presentation	'Combine' Concept Maps
Procedural Knowledge	'Relate' Documented Problem solution	'Identify' Categorizing Grid	'Demonstrate' Annotated Portfolios	'Contrast' Analytics Memo	'Integrate' Process Analysis	'Construct' Paper or Project Prospectus
Meta-cognitive Knowledge	'Review' Background Knowledge probe	'Express' Approximate analogy	'Examine' Group work evaluation	'Deduce' Content Form & Function Outline	'Discriminate' Pro & Con Grid	'Propose' Paper or Project Prospectus

Figure 7: Assessment Mapping

The Assessment module of the IMOD system provides users with a list of assessment techniques that match either as Ideal matches or Extended matches. The Figure 7 shows the overview of the entire Assessment framework and further defines data associated with each assessment technique.

Assessment Techniques

Each Assessment Technique has the following

Set of LO's it is associated to

This refers to the Learning objective(s) the Assessment technique defines.

Description

This is a short description of the assessment technique, and its key features

Procedure

A step by step flow of how the assessment is carried out.

Samples

Provides examples of how the assessment technique can be applied. Some techniques may also have standard rubrics associated with them.

- post

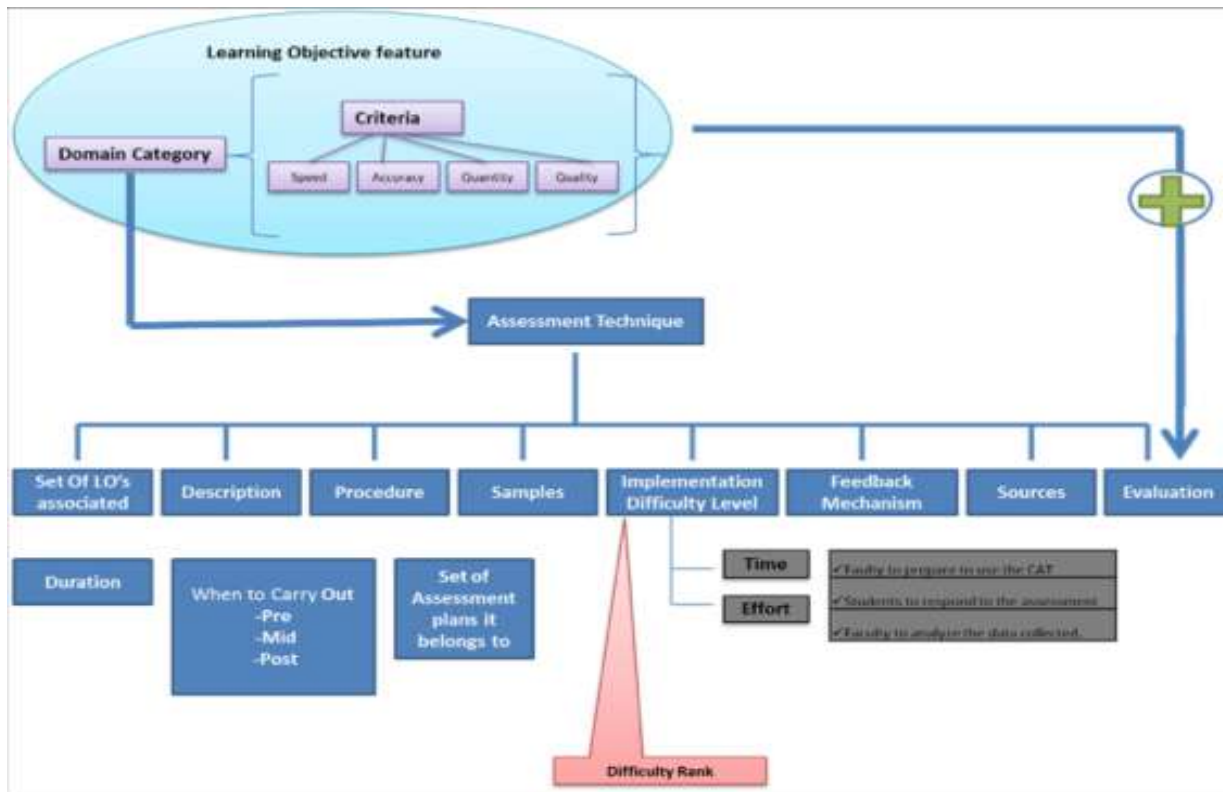


Figure 8: Assessment Framework

Duration

The time taken to execute the technique in class.

Implementation Difficulty Level

The difficulty level is calculated based on the Time & Energy required to perform the following indicated by Low, Medium or High values based on the following factors :

- Faculty to prepare to use the CAT
- Students to respond to the assessment
- Faculty to analyze the data collected.

When to Carry out

Specifies what time during the course the technique is best suited to carry out

- Pre
- Mid

Feedback Mechanism

Provides a list of various feedback strategies that will best suit the particular assessment technique.

- In-Person
- Online
- Both

Sources (more information)

This is an extended resource that provide comprehensive information relative to the assessment technique.

Use Cases

Basic flow

Actor accesses the Assessment tab.
System displays two different frames within the tab

Left Pane Actions:

List of LO (Learning Objectives) on top & Filter Options on the bottom.

- ✓ The Actor can select any one of the learning objectives.
- ✓ The Actor can choose from the Filter menus provided for Knowledge Dimension, Domain Category & Learning Domain. Each of these expands in an accordion and values are displayed as checkboxes.

Right Pane Actions:

Display 3 buttons on the top i.e. Add New Technique, Favorites, Add To Plan; The PC³ model below these indicating the Performance & Criteria of the LO being applied; Below the right pane is horizontally divided into Ideal & Extended Matches sections which are populated with Individual techniques displayed as intractable icons.

- ✓ Actor select one of the LO's, this triggers the following list of changes in the two panes in sequence.
- ✓ Actor clicks on the 'Add New Technique' button which triggers a Add Technique modal which contains a form that can be edited and either Saved or Cancelled.
- ✓ Actor chooses to save the technique , the technique displays in the Ideal matches section of the right pane with all the features (i.e. Assign /

Favorite) selected on the technique icon.

- ✓ Actor can now click on any of the techniques created or available in any of the sections in the right pane.
- ✓ When Actor clicks on the technique it triggers a Display Technique modal, which contains an option to View or Edit the technique and further save or cancel it.
- ✓ The Actor can at any point choose to click on the Favorites or the Assessment plan button on the top.
- ✓ Clicking on the Favorites triggers the creation of a new section in the right pane listing all the techniques that the user has favorite.
- ✓ Clicking on the Assessment Plan button triggers the Assessment Plan modal which lists all the assessment techniques assigned to each of the learning objectives defined by the Actor.

Interaction between the right & left pane

- ✓ The Actor can choose to move to a different learning objective anytime in the flow of usage or select any of the filters provided.
- ✓ When the Actor checks or un-checks the filters list of techniques showing up in the Ideal and extended matches sections in the right pane changes depending on which techniques map to the filters selected.

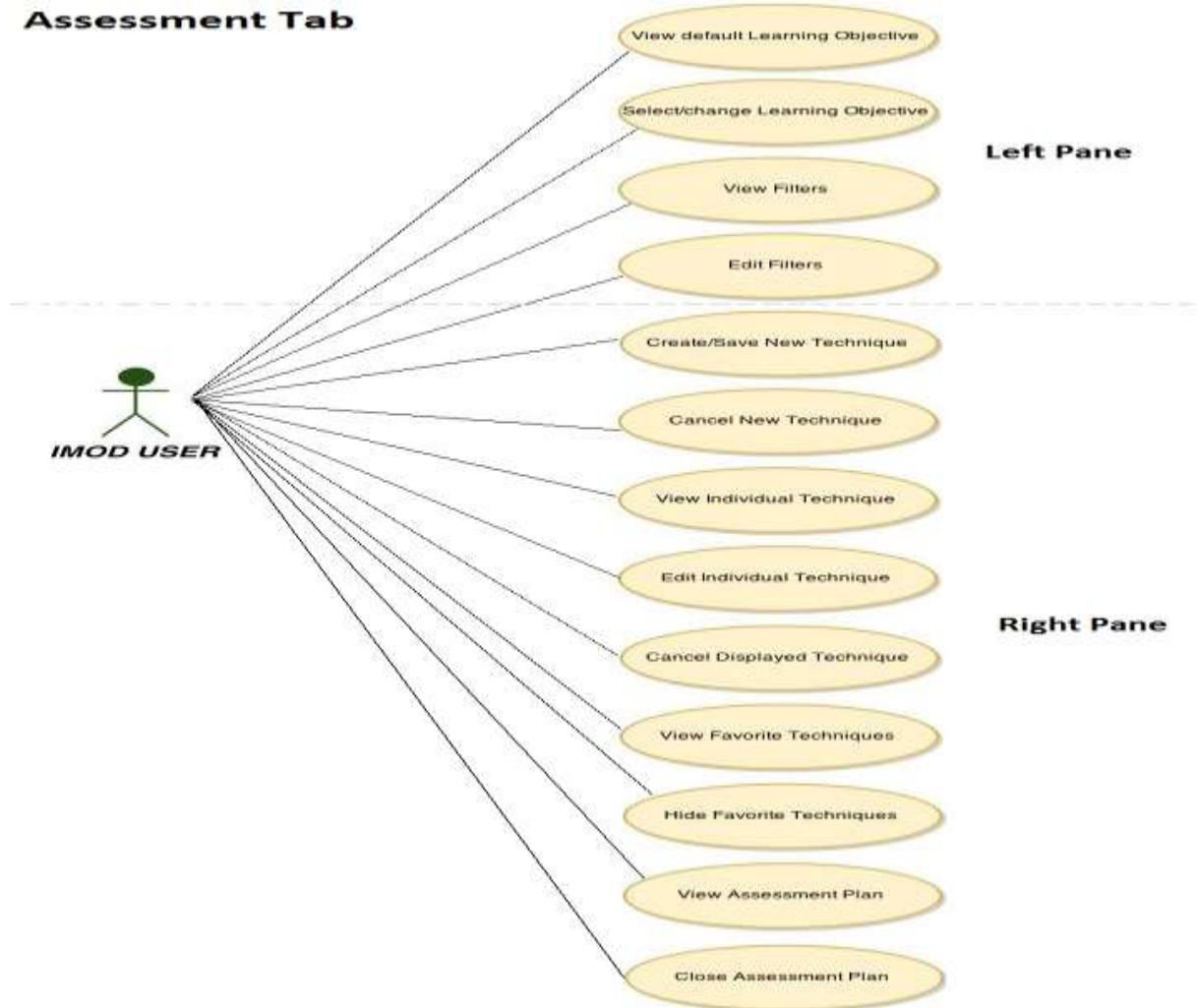


Figure 9 : Use Case Diagram for the Assessment Tab

Implementation

The current IMOD system under development is built using:

- Grails as the development framework
- PostgreSQL as the backend technology
- GIT as the subversion technology.
- UI Technologies - JQuery, jstree, HTMLHint, font-awesome, JQuery Qtip.

Code

The code can be broadly divided into Controllers, Domain Classes and the front-end gsp's. The Assessment module contains two domain classes currently, each of which represent tables in the database.

AssessmentTechnique.groovy

This is the main domain class that the system interacts with to define and retrieve data from the database. The following snippets of code define different sections of the domain class

```

static hasMany =
[
assignedLearningObjective:LearningObjecti
ve,
domainCategory: DomainCategory,
knowledgeDimension:KnowledgeDimensio
n,
learningDomain: LearningDomain,
userFavorite: ImodUser
]

```

```

static belongsTo =
[
ImodUser,
LearningObjective
]

```

```

static constraints = {
assignedLearningObjective nullable: true
description nullable: true, blank: true
procedure nullable: true, blank: true
duration nullable: true, blank:true
userFavorite nullable: true
assessmentFeedback nullable:true
}

```

Bootstrap.groovy section

```

if(AssessmentTechnique.count() == 0)
{
/*Assessment Technique*/
def assessmentTech = new
AssessmentTechnique(
title:"Name of technique",
description:"'",
procedure:"'",

```

```

duration:"'",
domain:
LearningDomain.findAllByNameInList([
'Cognitive'
]),
//'Cognitive','Affective', 'Psychomotor'
category:DomainCategory.findAllByNameInList([
'Remember'
]),
knowledge:KnowledgeDimension.findAllBy
DescriptionInList([
"Factual",
"Conceptual",
"Procedural"
]),
assessmentFeedback:AssessmentFeedback.fi
ndByName("Both").save()
}

```

FeedbackMechanism.groovy

The FeedbackMechanism domain class indicates the feedback method used to communicate the assessment technique. The bootstrap file contains the 3 categories defined under this i.e. In-Person, Online & Both.

```

class AssessmentFeedback {
String name
static hasMany = [
assessmentTechnique:
AssessmentTechnique
]
static mapping = {
version false
}
String toString(){

```

```

        return name
    }
}

Bootstrap.groovy section
if(AssessmentFeedback.count() == 0)
{
new AssessmentFeedback(
name:"In Person").save()
new AssessmentFeedback(
name:"Online").save()new
AssessmentFeedback(
name:"Both").save()
}

```

Each of these domain classes interacts with the UI through the controller. The Assessment module contains two controllers namely

AssessmentController

The assessmentController contains code that displays learning objectives and applies filters on the assessment techniques. The following snippets shows the logic behind the Ideal and extended matches.

```

//find all technique where both the
knowledge dimension and the domain
category match
def idealAssessmentTechniqueMatch =
AssessmentTechnique.withCriteria() {
and {
knowledgeDimension {
in' ('id', selectedKnowledgeDimensions)
}
or {
domainCategory {'in' ('id',
selectedDomainCategories)
}
}
}
}

```

```

learningDomain {'in' ('id',
selectedLearningDomains)
}
}
}
resultTransformer
org.hibernate.Criteria.DISTINCT_ROOT_ENTITY
}
//find all technique that are not ideal, but
have the learning domain
def extendedAssessmentTechniqueMatch =
AssessmentTechnique.withCriteria() {
and {
learningDomain {'in' ('id',
selectedLearningDomains)
}
not {
and {
knowledgeDimension {'in' ('id',
selectedKnowledgeDimensions)
}
or {
domainCategory {'in' ('id',
selectedDomainCategories)
}
learningDomain {'in' ('id',
selectedLearningDomains)
}
}}}}
resultTransformer
org.hibernate.Criteria.DISTINCT_ROOT_ENTITY
}
}
}

```

AssessmentTechniqueController

The `assessmentTechniqueController` contains code for saving and retrieving data related to the individual assessment techniques. The following snippet indicates how a technique is created and values assigned and saved to the database.

```
def newTechnique = new
AssessmentTechnique()
// Store text fields
newTechnique.title = params.title
newTechnique.description
params.description
newTechnique.procedure =
params.procedure
newTechnique.duration= params.duration
newTechnique.assigncheck =
params.assignedToLearningObjective as
boolean
newTechnique.favcheck =
params.favoriteTechnique as Boolean
newTechnique.assessmentFeedback=
AssessmentFeedback.findByName(params.a
ssessmentFeedback)
newTechnique.addToAssignedLearningObjec
tive(
LearningObjective.get(learningObjectiveID)
)
newTechnique.addToDomainCategory(
DomainCategory.findByName(params.doma
inCategory)
)
newTechnique.addToKnowledgeDimension
(KnowledgeDimension.findByDescription(p
arams.knowledgeDimension)
)
```

```
newTechnique.addToLearningDomain(
LearningDomain.findByName(params.learni
ngDomain)
)
```

```
// persist new technique to database
newTechnique.save()
```

The following snippets indicate how the `Assign & Favorites` variables are set.
// This checks when a technique is assigned to a learning objective

```
if(params.assigncheck == true) {
// get current user object
def currentLearningObjective =
LearningObjective.findById(learningObjecti
veID)
```

```
// add the technique to the user's favorite list
currentLearningObjective.addToAssessment
Techniques(newTechnique)
```

```
// store relationship
currentLearningObjective.save()
}
```

// This checks when a technique is favorited to by a user

```
if(params.favcheck == true) {
// get current user object
def currentUser =
ImodUser.findById(SpringSecurityService.c
urrentUser.id)
```

```
// add the technique to the user's favorite list
currentUser.addToFavoriteAssessmentTech
nique(newTechnique)
```

```
// store relationship
currentUser.save()
}
```

Testing

Grails provides many ways to making testing easier from low level unit testing to high level functional tests. Whenever a controller or view is generated in Grails, the accompanying unit tests are automatically generated under the test/unit directory in the Grails applications. These tests are executed by running the 'test-app' grails command. Further user interface testing was performed by using Chrome's developer tools and firebug plugin on Firefox. The following screen-shots depict testing done for the basic flow of the use cases.

Assessment Tab with Learning Objective, Filters and right pane populated with matching assessment techniques:

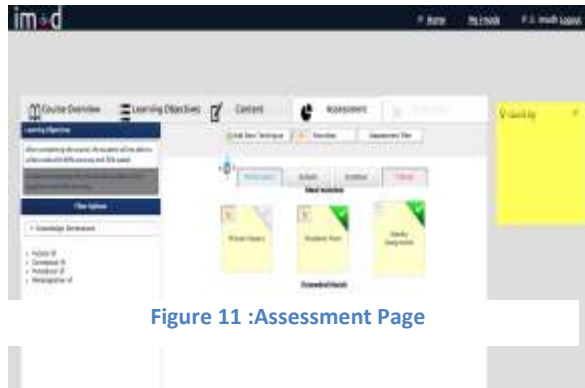


Figure 11 :Assessment Page

Add New Technique click

Figure 10 : Add New Technique Modal

Display technique when individual technique clicked

Figure 12: Display Technique

Favorites Button click



Figure 13 :Favorites

Filters



Figure 14 : Filters

Future Scope

The future development efforts on the Assessment module of the IMOD system can be focused on adding more data variables to the assessment technique domain class. The assessment techniques currently added in the bootstrap.groovy file are a limited list and as the IMOD system grows more techniques can be added to the database and also based on edits made by users on the currently existing techniques updates can be made on the actual hands on use of the techniques. With future development Semantic Ontology algorithms can be applied for alignment with the learning objective.

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