Application of the Indy Sci-Cloud Model of Instructional Design to the Development of an Online Organic Chemistry Bridge Course

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Instructional Design 8010

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November 29, 2017

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The formation of the *Indy Sci-Cloud Model (ISCM) of Instructional Design* - a modification of the Dick and Carey Systems Approach Model (2015) – is to provide a systematic means of engineering secondary and post-secondary science curricula for online delivery. Though there are many excellent models for the systematic design of instruction, there are two factors which necessitate a design model more *specific* for online science delivery: (1) the difficult nature of science content itself (termed the "tyranny of content," by Kennepohl [2012, p. 671]), and, (2) the higher dropout rates evidenced in online learners (Allen & Seaman [2009] as cited by Stavredes & Herder [2012, p. 155]).

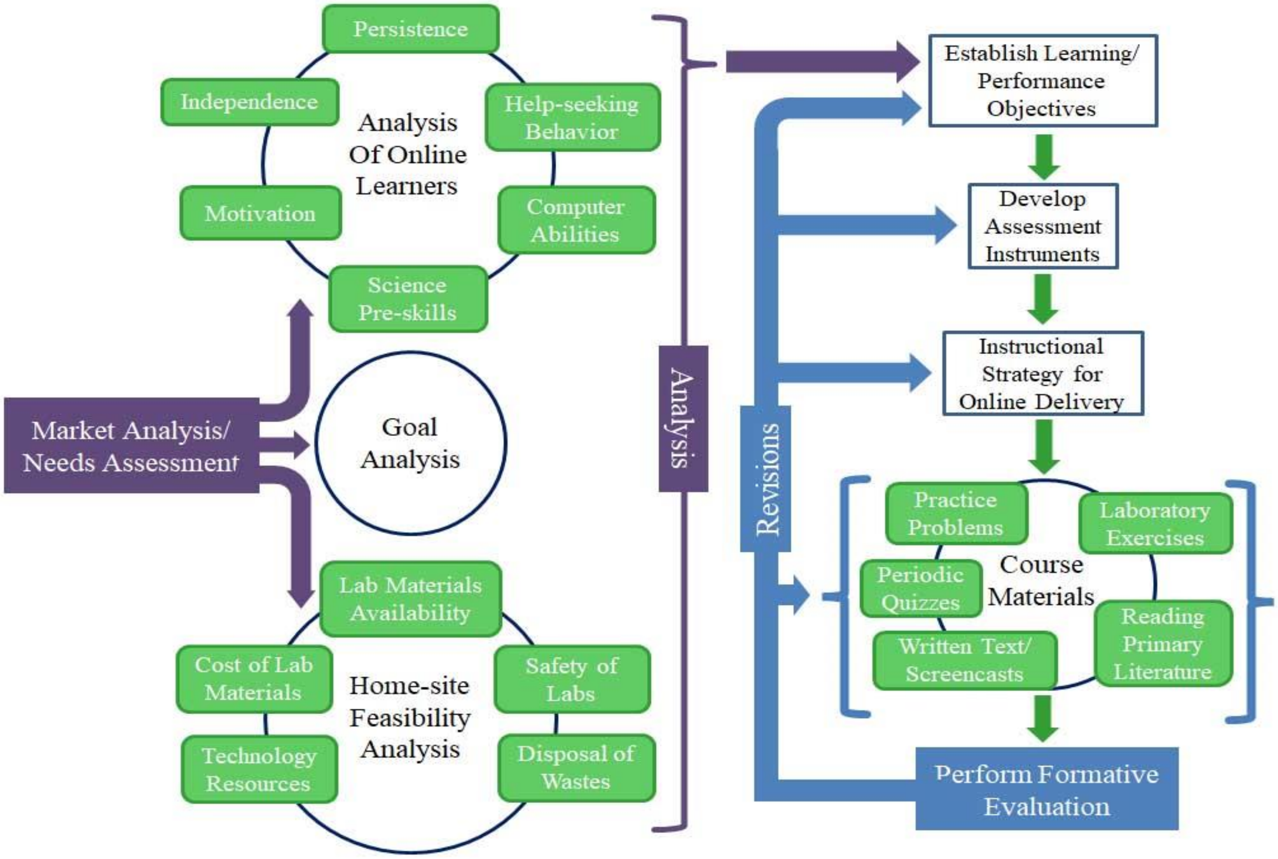


Figure 1. Indy Sci-Cloud Model of Instructional Design.

In examining Figure 1, it is apparent the ISCM requires a significant amount of front-end analyses; in particular, that of the learner and their home environment, or the *context of learning*. Since the learner will be carrying out the demands of instruction from their own home, with minimal contribution from an outside instructor, it is crucial that both learner and learning context meet specific criteria, which will be detailed in the sections that follow. The output from these analyses along with that of instructional goals, then informs learning and performance objectives, which in turn provide a framework on which to build criterion-referenced assessment instruments (Dick et al., 2015, pp. 137 – 167). With objectives and assessment instruments complete, the designer can finally turn attention to the instructional strategies, and the instructional materials that follow, in accordance with directives enumerated by the ISCM.

Given that quality instruction is iterative, it is necessary that the ISCM includes methodology for *formative evaluation*. Three principal factors make formative evaluation a necessary constituent. First of all, since online learning in the laboratory sciences is still in its infancy as a means of delivery, it remains largely experimental. The data is inconclusive as to what works and what is ineffective, as the expectations placed on both the learner and instructor changes in an online versus face-to-face environment. Secondly, the technology for content delivery is always advancing – whether this technology is manifest in learning management systems (LMS), videos, interactive games, or even conferencing software. A dynamic and contemporary design must consider these advancements. Finally, the content of science subject matter itself as the result of scientific inquiry is perpetually changing, requiring periodic updates in the primary literature - as evidenced by the replacement of science textbooks every few years. Depending upon the feedback received from the formative evaluation, revisions can be made to course materials, to the strategies for online delivery, the assessment instruments, or even the learning objectives themselves. These revisions may take one of two forms: revising the content itself, or revising certain procedures or directives within the design (Dick at al., 2015, p. 317).

Market Analysis/ Needs Assessment

The first step in the ICSM is a market analysis and needs assessment. Succinctly, if there is no learner market as determined by: (1) State- or federally-mandated academic content standards; (2) the requirements for a secondary or post-secondary program of study; or (3) private sector interests, then there is not much point in conducting analyses (learner, goal, home-site) that are costly with respect to time and resources. Dick et al., (2015, p. 24) cautions educators and trainers that the creation of unnecessary instruction incurs a tremendous cost not only in dollars, but by fostering maladaptive attitudes in students involved in it. By contrast, an informed, robust demand for a particular course of study may be worth the effort to perform such analyses - if it is indeed reasoned the resulting course is marketable, perceived as relevant by learners, or will fulfill an instructional/ training need.

For the purposes of this paper, I chose to develop an instructional model for an online high school level organic chemistry course that would effectively bridge the gap between the knowledge/ skills content of a general chemistry course and that of a second-year college organic chemistry course. This gap or “need” could be easily ascertained using Dick et al., (2015, p. 23) simple formula as follows:

Desired status – Actual status = Need

In application, the formula provides to the designer the *discrepancy* between a *desired status* for a given body of knowledge/ skills, and that of the *actual status*. My own needs assessment revealed that there appears to be a great chasm between the skills and knowledge that learners gain from a general chemistry course, and those they are expected to employ in the early weeks of their subsequent organic chemistry course. This chasm is evident by high attrition rates: 30-

50% reported by Grove, Hershberger, and Bretz (2008, p. 157); 50% stated by Karty, Gooch, and Bowman (2007); and 25% reported by Flynn (2015, p. 206). These very high attrition rates, in addition to abundantly reported student narratives concerning course angst, (Karty et al., 2007, p. 1209) lend support to the supposition that there is a great need – or market - for a high school or even college level organic chemistry bridge course. Further, since secondary schools are already reporting difficulty in filling faculty positions in the sciences (CITATION), it is logical to develop such a course utilizing off-site instructor resources.

Convinced there is a market and a need, the next step in the ISCM is to generate various analyses. These analyses, comprehensive in nature, will then inform the learning and performance objectives for the course.

Analyses

The analyses section of the ISCM is broken down into three main constituents: that of (1) online learners, (2) instructional goals, and (3) home-site feasibility. There is much emphasis on analysis at the front-end of the design, since the success of any online science course is verily contingent upon learner characteristics, learning goals that are specific, and the degree to which any activities such as labs and demonstrations, can be carried out in the home environment. If careful analyses are not conducted in these domains, then perhaps the best design in the world may not really make a difference, since all instruction, activities, exercises, and laboratories will take place in the home environment.

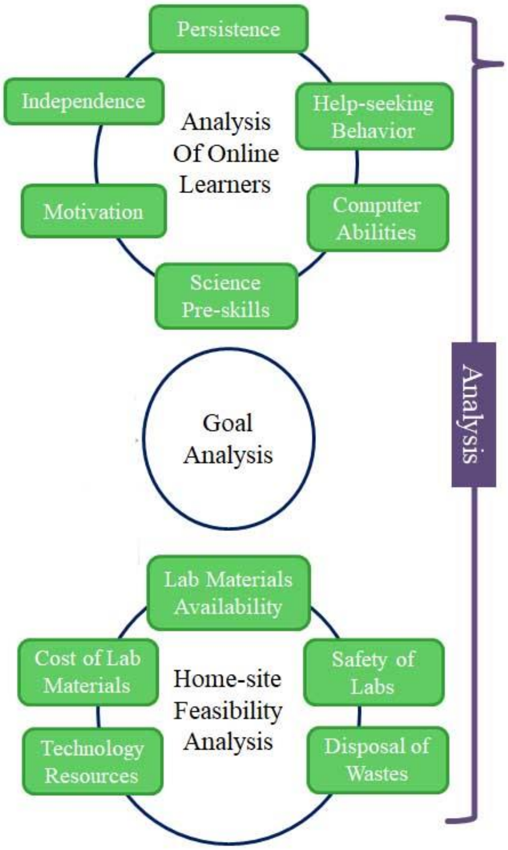


Figure 2. Analyses Section of the ISCM.

Online Learners

From an instructional design perspective, it is imperative to recognize those variables which significantly impact the ability of learners to enjoy academic success, especially since instruction is typically engineered for groups of learners having certain characteristics in common (Dick et al., 2015, p. 96). In recognizing these variables and addressing the factors which impact them, instruction can then be tailored to leverage these so as to maximize learning outcomes. The ISCM has identified three broad areas of learner characteristics: *the psychological components of the learners*, *their ability to use technology*, and *science pre-skills.*

Psychological components of the learners. Online learners are unique, in that they are expected to complete course expectations with very little instructional support from an instructor. For their own academic success, it is crucial that they demonstrate a suite of behaviors, such as (1) persistence, (2) independence, (3) adaptive help-seeking behavior, and, (4) adequate motivation. The designer, through clever design, has much control in sustaining these behaviors in learners through the use of many teaching strategies.

Persistence. Stavredes and Herder (2012) recognize that ". . . online learners must overcome many challenges to persist and successfully achieve their goals," (p. 155). There are many factors which either enhance or undermine learner persistence, such as social and academic integration, ethnicity, educational goals, prior GPA, and outside encouragement, along with psychological variables such as stress, self-confidence, and motivation (p. 156). Stavredes and Herder (2012) suggest that the instructional designer/ course facilitator can do much to enhance student persistence by creating a strong online presence; this presence can be broken down into *social*, *cognitive*, and *teaching* presences (pp. 156 – 160).

Social presence is defined as the degree to which a learner feels perceived as a real person, thus allowing them to participate in a learning community, and enabling them to build relationships with other learners and the instructor (Stavredes & Herder, 2012, p. 157). The extent to which learners are able to construct meaning and engage in higher-order thinking processes characterizes *cognitive presence*. The critical thinking skills that illustrate cognitive presence can be facilitated with purposeful course design and cleverly juxtaposed instructor intervention (p. 158). Finally, *teaching presence* - a requisite for learners to develop social and cognitive presence - is accomplished when both the course is designed, and the facilitator is proactive, so students can achieve the stated learning outcomes. To establish such a presence, the instructor needs to enforce deadlines and netiquette; acknowledge student contributions; set the climate for learning; provide direct instruction; inject knowledge from diverse sources; and respond to technical concerns, to name just a few proactive measures.

The necessity for enhancing persistence in online organic chemistry students cannot be overstated. For many, they come into the course already full of angst; by establishing an active online presence, they can collaboratively work on problem sets, form online study groups, and share study tips and resources. The directives proffered by Stavredes and Herder (2012), if carried out by both the designer and instructor, would do much to facilitate learner satisfaction, and by extension persistence, and independence in learners.

Independence. The online science (organic chemistry) student will be required to perform many tasks on his or her own, such as making sense of demanding content, navigating through a learning management system, collaborating with other students in problem-based learning exercises, taking online assessments, completing practice problems, and safely carrying out laboratory exercises. Facilitating learner independence, or *autonomy*, is central to learner success. Interestingly, many online learners enjoy the sense of having more control over their own learning outcomes (Kennepohl, 2012, p. 674). There is much the designer can do to facilitate this independence, such as providing a comprehensive syllabus, detailed pacing schedules, and thorough directions for every assignment (Jeschofnig & Jeschofnig, 2011, pp. 67-72).

For the online organic chemistry course, students will experience enough cognitive load inherent in the material itself without having to endure the confusion that accompanies a course that is not well planned out. Ideally, the student should never feel they have to contact the facilitator to find out *when* an assignment is due, *where* the resources for the successful completion of an assignment are located, or even have to seek *clarity* on assignment directions.

Adaptive help-seeking behavior. One of the ways self-regulated learners overcome academic adversity is by seeking help from an instructor, peers, or other academic sources. Newman (2002) has identified several specific competencies and motivational resources required for what he and others term, *adaptive help-seeking*. These are: (1) *cognitive competencies*, which involves knowing when help with content is necessary, and then knowing *how* to craft a question that yields a precise answer; (2) *social competencies,* that is, knowing who to seek help from, and how to approach them in a socially acceptable way; (3) *personal motivational resources*, which is impacted by self beliefs, comfort level with difficult tasks, and a sense of personal agency; and (4) *contextual motivational resources*, which is impacted by classroom or course factors.

Science courses are notoriously replete with abstract concepts, problems to solve (frequently including mathematical operations), laboratories to decipher/ perform/ and interpret, and other activities which often lead to students feeling overwhelmed as they experience cognitive overload, due to this tyranny of content (Kennepohl, 2012, p. 671). Realizing this, it is important that online science students (especially organic chemistry learners) are competent in adaptive help-seeking behavior. Purposeful course design can facilitate this in many ways: by providing a narrative in the learning materials themselves fostering an adaptive mindset rather than one that is maladaptive, learners will be encouraged that if they *apply* themselves and work diligently, they will be successful; by providing training to students on how to appropriately write an email to an instructor asking for help; and by creating an online classroom atmosphere that welcomes questions.

Adequate motivation. Effective instructional design must take into account the learner's degree of *motivation*, since they will only learn if they have adequate interest and want to learn (Feng & Tuan, 2005, p. 463; Dick et al., 2015, p. 97). Feng & Tuan (2005) noted that *effort* is the major measurable outcome of motivation. With motivation then forming the underlayment on which effort rests, the online science course designer would be wise to recognize the psychological foundations for motivation and then develop an instructional model that aligns with such foundations (Hannafin & Land, 1997), especially since science content is often difficult, requiring a voluminous amount of effort from the learner.

John Keller, in his ARCS Motivation Model, suggested that the motivational aspect of an instructional environment is not indeed a "soft" area – hit or miss – found only within the domain of skilled teachers (1987). He suggested instead that there were four categories of very identifiable and actionable components to sustaining and enhancing learner motivation, designated by the acronym, "ARCS": "A" - *attention*, "R" - *relevance*, "C" – *confidence*, and "S" - *satisfaction*. In application to the ISCM, embedded within every design learners should encounter features which capture and maintain their attention (such as an interesting demonstration); content that demonstrates relevance (current applications of organic chemistry); activities that foster learner confidence (assistance with problem sets); and exercises or laboratories that garner satisfaction.

Once the psychological factors that impact learners are addressed, attention can then be turned to still other learner constituents. All the analyses and engineering for psychical factors will have little impact if designers do not take into account the learner's computer abilities and more importantly, the science pre-skills they enter the class with.

Computer abilities. Online instruction - unlike its face-to-face counterpart - demands of the learner an extensive complement of computer skills. If these skills are unrealized, instruction comes to a halt. These skills include but are not limited to: navigating through an LMS such as Blackboard or Moodle; accessing videos and screencasts from various sources; navigating through various research databases; taking online quizzes and exams through the LMS or other apps such as Socrative or Quizlet; meeting up with other students or facilitators using apps such as WebEx or Appear.in; how to scan/ submit documents; how to work on shared Wiki's or other documents; and finally, how to correspond through email.

When using the ISCM for designing online science instruction, the designer should make available tutorials for these various apps, prior to the first day of instruction, so the learner does not get discouraged by cognitive overload.

Science pre-skills. Before the beginning of instruction, incoming learners must have demonstrated mastery of specific science skills, and certain prior knowledge of the topic area (Dick et al., 2015, p. 97). For every course developed using the ISCM, prerequisite skills and verbal knowledge will be clearly defined and assessed using a pre-skills exam. As an example, for students entering the organic chemistry class, they will have to score 70% or higher on a pre-skills assessment covering various topics of general chemistry (such as atomic/ molecular structure and bonding, kinetics, thermodynamics, molecular geometry/ VSEPR theory, acid-base chemistry, and solutions chemistry). These pre-skill assessments need to be a part of every course, since it is well-established that learners typically interpret new content in light of the associations they can make with past learning.

The learner analysis is the most comprehensive part of the ISCM, since, the model itself attracts a very specific type of learner. In short the learner must be mature enough to handle the rigors of an online science course, must be independent, persistent, demonstrate excellent computer skills, and possess prerequisite science skills. The learner analysis is but one part of the total analyses that inform the learning and performance objectives. The instructional goals analysis will actually provide a basis for the content itself.

Instructional Goal Analysis

The market analysis and needs assessment data should assist the designer merely in *identifying* more general instructional goals. It is in the process of *analyzing* these goals, however, that we identify the skills and knowledge that should be demonstrated by the learner in the successful execution of that goal. Once we identify these skills and knowledge, we can write one or more goal statements which will drive our instructional design (Dick et al., 2015, p. 42). Since goal statements reflect visible actions taken by the learner, the steps into which they are broken into should *demonstrate actions performed by the learner*, not the instructor (p. 47).

Categorizing goal statements. Once goal statements have materialized, it is helpful to classify them according to the kind of learning that will take place in their realization. For the sciences, there are four useful categories derived from Gagne’s domains of learning as follows: (1) verbal information, (2) intellectual skills, (3) psychomotor skills, and (4) cognitive strategies. To see how goal statements may be categorized, consider the following goal statements for an online organic chemistry class:

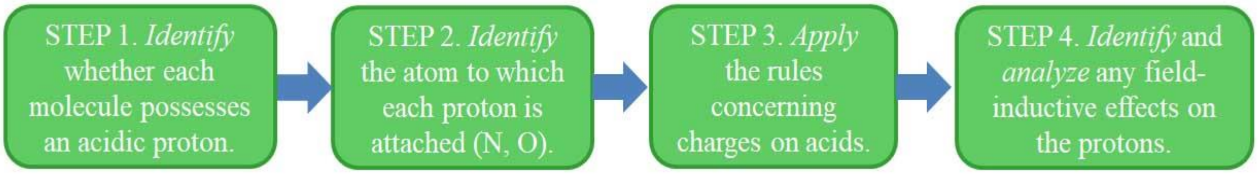
1. Provided images of the seventeen main functional groups, identify and name each.
2. When shown an array of organic molecules, identify the one with the most acidic proton.

3. Construct a glucose ring from a molecular modeling kit, placing it first in the chair conformation, then in the boat conformation.

4. When presented with a pair of reactants and reaction conditions, predict products.

Each of these four goal statements can be classified into one of the four above-mentioned domains. The kind of learning for the first goal statement requires the dissemination of *verbal information* only, as there is no problem to solve, or psychomotor action to perform. Goal statement number two requires some problem solving, thus it is an *intellectual skill*. The third goal statement, requiring learners to assemble a glucose ring from a molecular modeling kit represents a *psychomotor skill*, and the complexity inherent in satisfying the fourth goal statement requires the painstaking development of *cognitive strategies* (Dick et al., 2015, pp. 43-45). Once goal statements have been categorized, the major steps required to perform the goal are sequenced; in the case of goal statements that are comprised of verbal information, the major clusters of information the learners must recall are identified (p. 42).

Sequencing goal statements. For the second goal statement above, since it is an intellectual skill, we may assume there are many mental steps the learner must engage in before there is any observable behavior on their part; those steps are as follows:



STEP 1. *Identify* whether each molecule possesses an acidic proton.

STEP 2. *Identify* the atom to which each proton is attached (N, O).

STEP 3. *Apply* the rules concerning charges on acids.

STEP 4. *Identify* and *analyze* any field-inductive effects on the protons.

Once the steps for each goal statement have been identified, the designer then has an idea as to sequencing when developing the actual materials. In the above case, students have to know what an acidic proton is (Step 1) *before* they can even think of analyzing field-inductive effects on them (Step 4); thus, the designer needs to consider this when putting together the sections within chapters, reflecting this very sequence.

Since organic chemistry requires robust problem solving skills, many of the goals can be characterized under the learning domains of intellectual skills, and cognitive strategies. Both these domains command careful consideration of sequencing, hence, the time spent in goal analysis is well spent. In a typical two semester course, it is not unusual for cognitive strategies applied late in the year (as in the fourth learning goal above), to require training in prerequisite skills starting several months prior. Many of these cognitive strategies may even tap skills learned the *year* before in the general chemistry course. By contrast, most psychomotor skills used in an organic chemistry course (building models, measuring reagents with glassware, handling lab ware) may similarly be analyzed, but do not require the same degree of *sequencing*.

Clustering verbal information goals. While the sciences are largely conceptual, there are occasions where instructional goals are comprised simply of verbal information, that is, goals that ask the learner to *state, list,* or *describe* (Dick et al., 2015, p. 43). The skills within these goals are best sequenced chronologically; when such order is not apparent then they may be sequenced based upon their relationships to one another (p. 49).

Table 1 on the next page, provides a rubric, modified from the Dick et al., (2015, p. 56) model for evaluating the quality of the steps of instructional goals for an online science course.

Goal analysis can take place simultaneously with learner analyses and the home-site feasibility analysis. Constraints imposed by either the learner, or the home-site are expected to have an impact on the goals. As an example, if the home-site has no access to a burner of any kind, then there is no point in developing goals or subskills requiring an open flame (it could be argued there is no point in even bothering with a chemistry class of any kind). The omission of a piece of laboratory equipment this fundamental would very much impact learning objectives, instructional strategies, and laboratory exercises.

Table 1.

Rubric for Evaluating the Steps within Goal Analysis

No	Some	Yes		Individual Step Statements: Is/ are the
_____	_____	_____	1.	Behavior/ action, expressed by a verb included?
_____	_____	_____	2.	Outcomes of the step observable?
_____	_____	_____	3.	Science content focused and specific?
_____	_____	_____	4.	Steps delineating learner actions as opposed to teacher actions?
_____	_____	_____	5.	Size/ chunks of each step manageable?
_____	_____	_____	6.	Steps placed in a logical sequence?
_____	_____	_____	7.	Are verbal skills placed in chronological order when possible?
_____	_____	_____	8.	Are verbal skills clustered in logical groups when possible?

Rubric modified from Dick et al., 2015, pp. 56, 57.

Home-site Feasibility

Since the learner will be carrying out all learning objectives in the home-site, it is imperative the site can support all the constituents of instruction; principally, the demands of technology and laboratory.

Importance of laboratory work. Since the ICSM applies to online science coursework with a laboratory component taking place within the home-site, it is necessary to consider many factors requisite for the successful execution of laboratory exercises. These factors include, but are not necessarily limited to the availability, cost, and disposal of lab materials, along with safety factors.

***Availability of lab materials*.** Before adding or developing laboratories, make sure materials are available. There are many reasons why certain materials may not be available, such as toxicity risks, disposal hazards, expense in shipping, or simply too costly. For the chemistry classroom, one chemical can often be substituted for another.

Cost of lab materials. When developing laboratories, student kits for sale will have to be assembled, or purchased, already “kitted”. It is wise to keep lab costs for a year-long course under one third the cost of tuition. The designer and institution may need to consider pricing for bulk orders, if there is adequate student demand. Oftentimes, if one chemical is too expensive, another can be substituted, yielding similar results in a given chemistry lab. For an anatomy and physiology class, if fetal pigs are too costly, then students should dissect a rat, instead. Some of the more expensive lab experiences can be enjoyed through an online simulation, or even a virtual laboratory.

Safety of laboratory exercises. When assigning and designing labs for the online student, it is advisable that we hope for the best, but plan for the worst. Laboratory exercises carried out in the home, need to be safe – with ample warning provided to students of possible toxicity of chemicals, risks for burning, or even cuts from improper disposal of glassware or from scalpels. Every course designed using ISCM, should provide video training of lab safety protocols, emphasizing the importance of wearing goggles, gloves and aprons, pinning the hair back, using caution when handling scalpels, the safe disposal of glassware and chemicals, and what to do in the event of a fire.

There are many ways to minimize risks to students: as an example, for a chemistry class, when using chemicals that are caustic or pose burn risks, labs can be written so the students use only microscale amounts – on the order of one or two milliliters. For an anatomy and physiology course, seek out dissection specimens preserved with formalin, rather than formaldehyde. Perhaps safety could be further facilitated by choosing laboratory ware made from polyethylene plastic whenever possible, as opposed to borosilicate glass.

Disposal of laboratory waste. Part of being a good science student is learning how to properly dispose of laboratory waste, so that risks of exposure to biohazards or hazardous chemicals by others is minimized. As a designer, further risk of environmental exposure can be minimized by the judicious selection of labs and materials. Before assigning a given laboratory, consult a material safety and data sheet for any chemicals used (readily available online), and lean towards those chemicals that are water-soluble. Keep in mind that since the lab will take place at the home-site of the student, the student will be responsible for the safe disposal of any waste. Along with the training of lab safety, perhaps online learners should also be trained in the proper disposal of chemical/ biological wastes.

Finally, if the designer does not want to incur the expense of assembling and distributing lab kits themselves, they may want to consider online kits, such as those provided by Hands-On Learning, Carolina Biological Supply, or Home Training Tools. These online resources sell kits expressly for online students in ". . . biology, human anatomy and physiology, microbiology, nutrition, chemistry, physics, physical sciences, geology and earth sciences, environmental sciences, and forensics," (Jeschofnig & Jeschofnig, 2011, p. 112).

Technology resources in the home. Since all student activities and correspondence will be occurring online, at a minimum students will need to have high-speed internet access, a relatively current PC or Mac, a webcam, various software, and access to apps as applicable to any given online science course. These requirements mean that students living in highly rural areas simply will not have the opportunity to participate in online instruction.

Now, with the learner, goal, and home-site analyses complete, learning and performance objectives (LPO) may be written. The ISCM places LPO's after the comprehensive analyses, because the data emerging from these will serve to either inhibit or facilitate the LPO's. In the event LPO's are written *before* the designer is informed fully of the limitations the learner and home-site bring, then any instructional materials that emerge from those LPO's will be required to undergo significant revisions when the formative evaluation is performed.

Learning/ Performance Objectives

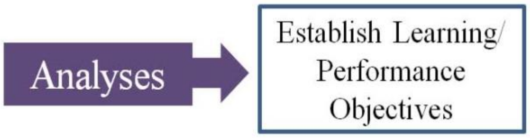


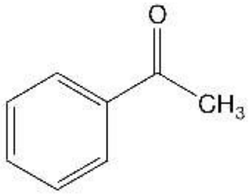
Figure 3. Analyses provide input documentation for LPO's.

With the analyses serving as the framework on which LPO's will be written, it is important to once again turn our attention to the instructional goals, and tenure of the instruction. Most laboratory science courses are one semester (15 weeks) or two (30 weeks) in length. The intellectual skills, verbal knowledge, psychomotor skills, and cognitive strategies delineated in the goal analysis will need to be strategically distributed over the duration of the course. For the organic chemistry course, material will be distributed over 30 weeks, with each week comprising a single *module*. Each module in turn, will have its own set of learning objectives.

LPO's, functionally have many forms: they can be written for the designers of instruction, for instructors or facilitators, or learners. Depending upon the consumer of them, objectives outlining the very same skills will read quite differently. For designers, they will provide complete descriptions of what the intended learner(s) will be able to do, following instruction, while also providing the input documentation for the preparation of assessment instruments, instructional materials and developing the instructional strategy, (Dick et al., 2015, p. 120). When objectives are provided in course syllabi, on a teacher website, or in the introduction of a module, they are truncated significantly. For designers, LPO's are comprised of three fundamental parts, describing the (1) observable *behavior* of the learner in the execution of the objective, (2) the *conditions* under which the learner will carry out the tasks/ skills, and (3) *criteria* by which learner performance will be evaluated (pp. 120 - 125).

In the organic chemistry curricula, we might highlight the behavior of an objective by asking learners to:

"*Estimate* the pK_a for the proton explicitly shown on each of the following compounds."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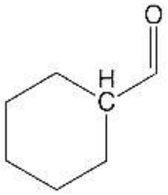
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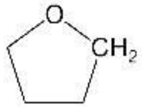
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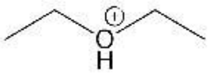
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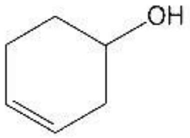
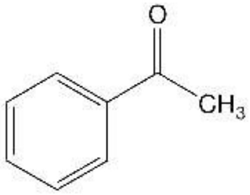

(e)

Note the action of the verb, *estimate*; other effective verbs that may be used are, *identify, generate, demonstrate,* or *classify*. Verbs such as *know, understand and appreciate* are simply too vague, and the behavior that results from these is largely unobservable.

The above LPO may be further modified by including the conditions under which the learner will carry out the task: will the student have access to data tables, charts, equations, definitions, or periodic tables? When the *conditions* are included in the objective, we are informing the learner of the resources and materials that will be available. The above objective thus may be modified:

"Using *Table 6.1 and/ or Appendix A*, estimate the pK_a for the proton explicitly shown on each of the following compounds."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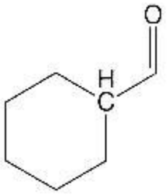
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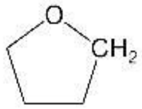
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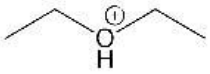
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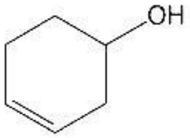
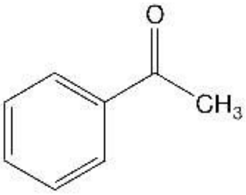
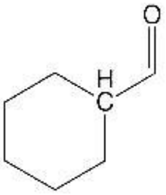

(e)

Finally, to consider any LPO complete, the *criteria* by which student performance will be evaluated needs to be included. This is often stated in the ". . . terms of the limits, or range, of acceptable answers or responses," (Dick et al., 2015, p. 120). The data-driven nature of the various disciplines in science makes this task very manageable. By including the need of a criterion for our working LPO, we may now state:

> “Using Table 6.1 and/ or Appendix A, estimate *the* pK_a *value* for the proton explicitly shown on each of the following compounds.”



(a)



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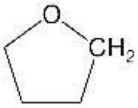

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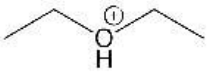

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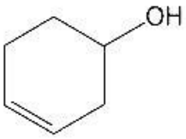

(e)

Table 2 below provides a basic rubric for evaluating learning and performance objectives for an online science course.

Table 2.

Rubric for Evaluating Learning and Performance Objectives (LPO) for an Online Science Course

No	N/A	Yes		Does the LPO include:
_____	_____	_____	1.	Observable ***behavior***/ action of the learner expressed by a verb included?
_____	_____	_____	2.	Specified ***resources, materials,*** and ***tools*** allowed for learner’s use in task/ skill execution?
_____	_____	_____	3.	***Specific*** enough so test construction specialists can develop assessment instruments from it?
_____	_____	_____	4.	Are ***criteria*** described whereby student performance can be fairly evaluated?
_____	_____	_____	5.	Is it ***feasible*** with respect to time constraints outlined by pacing schedules?
_____	_____	_____	6.	It is ***achievable*** given laboratory and other resources at the learner’s home-site?
_____	_____	_____	7.	Is it ***reasonable***, given the developmental stage of the learner?

Rubric derived from Dick et al., 2015, Chapter 6 – Writing Performance Objectives

In summary, the starting place for any LPO is a description of the desired observable behavior of the learner. Recollect that since LPO's are also informed by learner and home-site analyses, any limitations either of these presents need to be considered. The greatest constraints will be those imposed by a lack of laboratory resources at the home-site. Once the behavior component of the LPO is stated, then learning or performance conditions, and the criteria by which learner success is measured are appended. When all constituents are included, the resulting LPO's are informative enough so that test specialists can develop assessment items, and designers can develop an instructional strategy and accompanying course materials.

Developing Assessment Instruments

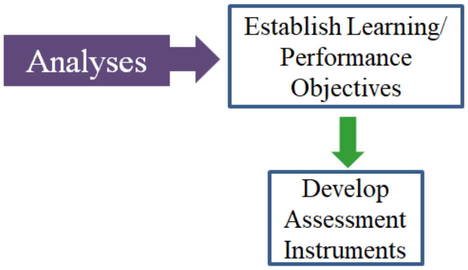

Figure 4. The relationship between analyses, LPO's and assessment instruments of the ISCM.

In keeping with the sequence articulated in the Dick et al., (2015) model of systematic instruction, the ISCM similarly places the *development of assessment instruments* right after the establishment of learning objectives. Dick et al., (2015, p. 138) emphasizes the importance of test items corresponding one to one with performance objectives. In keeping assessment items such as questions, problems, projects, and exercises, aligned with LPO's, the science content can stay focused. Due to the already mentioned "tyranny of content," (Kennepohl, 2012) it is quite easy for students to experience cognitive load as they find themselves lost among the trees within the forests of voluminous science content. Cognitive load may be reduced by judiciously developing materials that support already-developed assessment instruments, which in turn are tightly aligned with LPO's.

The ISCM prefers the administration of *criterion-referenced assessments*, which are instruments that directly evaluate skills described in one or more of the LPO's. For science content (organic chemistry, in particular) there is an important place for *norm-referenced* *assessments* (such as national standardized tests published by the American Chemical Society), but their administration is too infrequent (one time a year) to be the sole source of assessments.

Assessments serve many functions: for the instructor, they provide a glimpse as to the academic success or failure of their students. For students, there is a powerful learning opportunity to be gained when they are placed in the position to *retrieve* information - as opposed to merely *reviewing* material - to satisfy the promptings of an assessment (Dempster, 1996, 1997; Roediger & Karpicke, 2006, as cited by Nilson, 2010). Practice tests similarly allow learners the opportunity to rehearse new knowledge and skills, and with instantaneous feedback enable them to judge for themselves their own level of understanding (Dick et al., 2015, p. 140). Finally, the ISCM's purpose is to provide a framework for online science instruction, thus, learner independence and the study/ organizational skills that accompany this are an imperative. Regular assessments in the form of periodic quizzes keep students on top of material, by making them accountable for content learned in a timely manner.

When assessment instruments are designed, care needs to be taken to ensure questions are well-written (if applicable); that the vocabulary is age/ level appropriate; and the directions are unambiguous. It is worth mentioning once again that all assessment items need to emerge from the original LPO's. In addition, learning specialists can offer much insight as to what *type* of knowledge is being assessed for each assessment item: in the case of an organic chemistry class, if the designer's objective is to encourage students to engage in higher order cognitive skills, and to develop cognitive strategies, then test items should steer clear of rote memorization tasks.

Written tests are not the only means whereby to assess science students: project presentations, lab reports, research papers and projects provide a novel approach to evaluate student learning outcomes. In the context of the online organic chemistry course, student learning could be ascertained by the successful completion of a laboratory synthesis (such as nylon), or even a chemical separation (crystallization/ purification of a compound). Norm-referenced exams provided by the American Chemical Association can similarly provide valuable feedback; the disadvantage of these exams, however, is they are not necessarily informed by the LPO's.

Table 3 below provides some general guidelines for the development of assessment items or tasks, for online science learners.

Table 3.

Rubric for Evaluating Items on Criterion-Referenced Assessments

No	N/A	Yes		Does the assessment item(s):
_____	_____	_____	1.	***Align directly*** with one or more established LPOs?
_____	_____	_____	2.	Provide ***clear directives*** for its successful completion?
_____	_____	_____	3.	Contain scientific terms ***consistent*** with what the learner has been learning?
_____	_____	_____	4.	Provide data tables, graphs, equations, when necessary?
_____	_____	_____	5.	Provide adequate prompts or cues to facilitate successful memory retrieval?
_____	_____	_____	6.	Provide a fair and objective means to evaluate student success?

Rubric derived from Dick et al., 2015, Chapter 7 – Developing Assessment Instruments.

Criterion-based assessment instruments, having been informed by the LPO's, provide the foundation upon which an instructional strategy can now be constructed. Since these represent nearly the most reduced and stripped-down constituent of the design (following the objectives), what follows their development are instructional strategies engineered to facilitate the very learning that the assessment instruments evaluate.

Instructional Strategy for Online Delivery

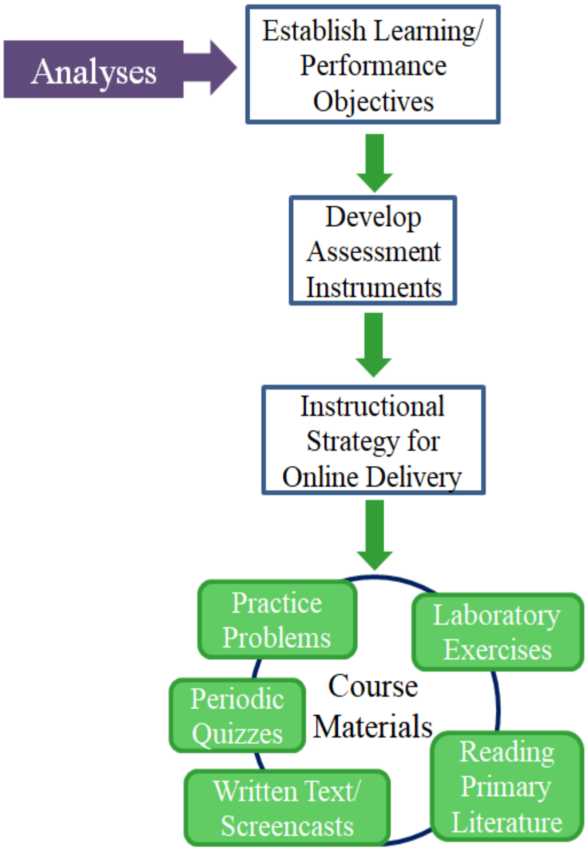

Figure 5. Note the strategic placement of the *instructional strategy* – informed by *assessment instruments*, and logistically informing *course materials*.

The development of the *instructional strategy* in the ISCM is strategically placed between the development of the assessment instruments and course materials, as in the Dick et al., [2015] model. This is perhaps the most important component of the model for a few reasons: (1) science courses already maintain a reputation of being very difficult - with organic chemistry courses suffering a very high rate of student failure (Grove et al., 2008, p. 157) , (2) online courses in general suffer from a higher dropout rate than face-to-face instruction (Allen & Seaman [2009] as cited by Stavredes & Herder [2012, p. 155]), and (3) online laboratory science education is still a relatively new enterprise, in spite of dramatic increases in course enrollment (Al-Shamili & Connors, 2010, as cited by Kennepohl, 2012, p. 675). These factors make the development of a successful online science course all the more challenging.

For our purposes, the instructional strategy encompasses the strategic sequence and placement of a vast suite of teaching/ learning activities, science demonstrations, computer simulations, laboratory exercises, worksheets and independent readings. For the online design of a difficult science course, it is not enough to cleverly sequence these materials for learner consumption. These are but minor constituents comprising the *microstrategies* of design (Dick et al., 2015, p. 173). What is instead needed is a *macrostrategy*, escorting learners from a motivational introduction of a given topic, through the body of content, reading and exercises, to the mastery of objectives. According to Dick et al., (2015, p. 175), this foray into learning can be characterized by five major components: (1) preinstructional activities, (2) content presentation along with learning guidance, (3) learner participation, (4) assessment, and (5) follow-through activities.

Preinstructional Activities

The organic chemistry student often enters the course already bewildered and intimidated. The designer can use factors within the *preinstructional activities* to assist learners in overcoming these mindsets, by (1) motivating them, (2) informing them up front what is expected of them, and (3) stimulating their own recall of the knowledge and skills they already possess.

The interest of learners may be piqued through the use of an appropriate attention getter. For the online organic chemistry class, this may be a quick video at the beginning of a module or unit of how organic chemistry impacts their everyday lives – such as how chemists develop polymers for aircraft skins, or the synthesis of new pharmaceuticals - thereby making the content relevant to them. Since lack of confidence undermines motivation, the facilitator could advise learner's up front, of the course (unit, or module) learning objectives, so there are no surprises; these objectives could be followed up with assurances the learners can master these if they are willing to put in the time (Dick et al., 2015, p. 176, 178). In the case of organic molecular modeling labs it would be helpful to provide learners an image of the molecules they are to construct - something of an advanced organizer. That way, learners feel they can comfortably evaluate their own success in completing the model. Finally, every new module or unit should tie the content from the previous module with that of the new, so that learners have a memorable framework in which they can integrate new content (p. 178). In doing this, learners can observe an obvious progression of information and skills, and they may not see the need to resort to memorization.

It is within the domain of preinstructional activities that learners find their bearings as they integrate yesterday’s information with todays. For an online organic chemistry class, this may be the most important strategic component. Since the knowledge upon which cognitive strategies are built is quite cumulative, it is worth taking the time to provide direction instruction (if necessary) to link a student’s existing knowledge of chemical phenomena with new knowledge (Dick et al., p. 184). As an example, if a student has no idea why the Lewis structures they learned to draw yesterday, are predictive of the inductive effects of electrons they are learning about today, it is worth taking the time to explain the connection. This daily groundwork then becomes the foundation for the presentation of new content.

Presentation of Content

The presentation of content can take many forms; reading from a text, videos, screencasts/ audiocasts, or even games. Regardless of the media, content needs to be presented in a strictly hierarchical fashion, especially for upper level science instruction. For decisions concerning sequencing and clustering, the output documentation from the goal analysis is the most useful tool. When developing and presenting content to learners, the designer should begin with lower-level skills, progressing through the hierarchy, and at no point presenting any information prior to its related subordinate skills (Dick et al., 2015, p. 223).

When considering various approaches to the presentation of content, while constructivist, problem-solving, and inquiry-based approaches are novel – they are often too messy for upper level science, and run the risk of contributing to cognitive overload. Thus, highly conceptual science content is understood best through more direct approaches to instruction. The down side of this approach, however, is that by the time basic skills are developed - *before* getting to the interesting bits of the discipline - student interest (thus, motivation) is lost. Considering all of this, then, the effective designer must find a way to strike the perfect balance of engaging the student with interesting activities, while still delivering voluminous content.

Learner Participation

Practice exercises, problems, laboratories and projects are the best means to facilitate learner participation for science coursework. It is necessary, however, to ensure that these activities are congruent with the conditions and behaviors delineated in the LPO's, and by extension aligned to the assessment instruments (Dick et al., 2015, p. 185). Practice exercises and problems, to the greatest degree possible, should appear similar to assessment items; in keeping with this practice, students will have much higher regard for these exercises. If learners believe the successful execution of class exercises has little impact where it counts the most – in assessments that greatly impact their grade, they will have little motivation to complete them. Finally, learner participation is greatly enhanced when they receive informative feedback on their assignments (Dick et al., 2015, p. 186).

Assessment

For the learner, assessments are a way for them to monitor their own learning. Unfortunately, too often courses are developed such that poor performance on only a few assessments can take a toll on the learner's grade; understandably then, learners demonstrate some intimidation by them. Assessments not only provide an evaluative utility but also a learning activity whenever learners are required to retrieve information by way of multiple choice problems, matching, true/ false, short answer, problem-solving, and essays. The power of assessments as a teaching tool can be leveraged most positively, if the designer provides many practice tests for student use, along with frequent, periodic low-risk quizzes (Nilson, 2010).

There is nothing more frustrating for students then encountering an exam with questions that came seemingly, from “nowhere.” Science content is difficult enough for students, without dropping on them a “borrowed” test with assessment items that do not quite align perfectly with their own course LPO’s. In addition, it is imperative that the scientific terms describing a particular phenomenon expressed in the course goal analysis and LPO’s matches those used on every assessment. For illustration, chemists use several terms when describing the weak intermolecular forces between non-polar molecules (waxes, oils, other hydrocarbons) that are the result of quantum mechanical shifts in electron clouds: *induced dipole-induced dipole interactions, London dispersion forces,* and *Van der Waal’s forces*. If LPO’s and the content they informed used the term, induced dipole-induced dipole interactions, but students encounter borrowed test items instead employing the term London dispersion forces, they may experience confusion and frustration. There are many other such examples as this in the sciences, thus the designer needs to stay consistent with terminology.

Follow-Through

Since so much of science content is cumulative, it is critical that learners are consistently encouraged and even “trained” to transfer their learning to other environments and contexts. For success in an organic chemistry course, content taught in the general chemistry course the year prior will need to be retained and retrievable. One of the struggles organic chemistry students face is they quite often are incapable of employing many of the intellectual skills they should have acquired in their general chemistry course. Frequently, they do not even recollect much of the verbal information they learned. Follow-through strategies designed to maximize content retention should be a part of normal, systematic instruction. For information that is verbal, students may need to elaborate on it, by trying to conceptually link it with other information (Dick et al., 2015, pp. 186, 187, 189).

Table 4 below provides some general guidelines for developing an instructional strategy for an online science course.

Table 4.

Rubric for Evaluating an Instructional Strategy for Online Science

No	N/A	Yes		**Pre-instructional strategies** Does it include:
_____	_____	_____	1.	An attention getter, such as a relevant story, concept, or demonstration?
_____	_____	_____	2.	For laboratory activities, is an advanced organizer, showing the expected outcome of the experiment, or image of the model?
_____	_____	_____	3.	Are learners informed of objectives, and the purposes for a given lesson/ module/ unit?
_____	_____	_____	4.	Are links made between prior learning and new skills?
				Presentation Materials Do materials include:
_____	_____	_____	1.	Problems provided that are similar to assessment items?
_____	_____	_____	2.	Prompts linking new content to prior knowledge?
_____	_____	_____	3.	Skills and knowledge presented in an hierarchical fashion?
				Learner Participation Does the plan include
_____	_____	_____	1.	Laboratories, exercises, and problems, aligned with LPO’s?
_____	_____	_____	2.	Means to provide instant feedback on problem sets and quizzes that is informative, supportive and corrective?
_____	_____	_____	3.	Materials that are aligned with content presentation?
_____	_____	_____	4.	Materials that will build confidence and personal satisfaction?
				Assessment Does it include
_____	_____	_____	1.	Many practice tests?
_____	_____	_____	2.	Low-risk quiz opportunities for retrieval practice?
_____	_____	_____	3.	Instructive feedback?
_____	_____	_____	4.	A variety of means to evaluate learning outcomes?
_____	_____	_____	5.	Assessment items that are directly aligned with LPO’s?
				Follow-Through Activities Will the plan:
_____	_____	_____	1.	Aid in the retention of new science information and skills?
_____	_____	_____	2.	Contribute to the development of future cognitive strategies?

Rubric derived from Dick et al., 2015, Chapter 8 – Planning the Instructional Strategy: Theoretical Basis

Once an instructional strategy is formulated, the designer may now turn attention towards the selection and appropriation of materials.

Course Materials

As early as 2003, the trend toward implementing online, distance instruction was far outpacing research. Technologies employed at the time involved using email for communication, discussion boards with text chat tools, and content presented on static Web pages (Dennen, 2012, p. 282). Many instructors, in converting face-to-face courses to an online format encountered various challenges; in part, because in their attempts to maintain course fidelity, the conversion did not prove satisfactory to learners. They discovered that in order to produce a motivating and pedagogically sound online course, the same activities and assessments implemented in a face-to-face framework was not effective – they needed an overhaul; in fact, the online environment demanded the design of entirely new activities (p. 282).

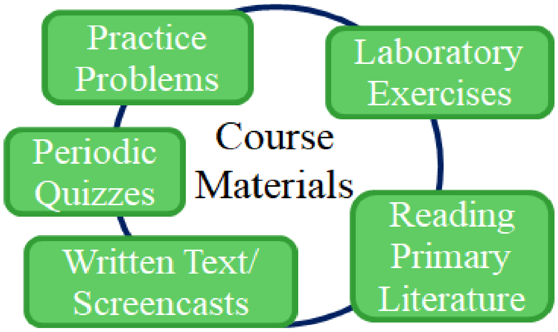

Figure 6. Some of the constituents making up course materials.

One of the main reasons face-to-face materials do not convert with perfect fidelity to the online learning genre is the interactions between student-to-student, student-to-instructor, and student-to-materials are different. The first two interactions are almost always asynchronous - as a result, students can easily feel disengaged, and grow discouraged when they encounter difficulty with the material. In a face-to-face environment, the learner has more freedom to ask questions in real time, and receive feedback, often instantly. In the online setting, however, the asynchronous nature of interaction does not make instant, instructor-to-learner feedback possible (Dennen, 2012, pp. 283 – 285). For this reason, and many others, course design and the development of materials must be engineered with absolute precision. Answer keys to homework problems must not only provide quick and pithy answers; they need also to provide detailed explanations, so the student can in effect, teach themselves whenever they generate incorrect answers. In yet another application, whenever students complete online quizzes, it is not sufficient to simply provide a score – the learner requires more comprehensive knowledge of results information; such as *which* answers were marked wrong, and *explanations* as to why. These simple efforts will assist learners in having more control over their learning.

For the online organic chemistry student, who is already facing the challenges inherent in the demanding nature of the course itself, *and* the isolation that can accompany online learning, detailed and instantaneous feedback provided by the materials is crucial for keeping the student on track. In addition, the need for designers to organize the diverse suite of materials so they act in concordance with one another, cannot be overstated. As an example, any laboratory exercises assigned should follow written text or screencast presentations covering that very same content. Assigned readings from primary sources need to similarly complement other learning constituents in the course. In the event information needs to be bridged between reading in a text, and the assignment of a laboratory, then the website itself, can provide a platform in which to bridge content.

Written Text/ Screencasts

There is nothing more undermining for a learner, than when an instructor assigns a textbook for a class, only to discover that the textbook is hardly ever used – especially if the textbook is expensive. Ideally, textbooks serve as the anchor or backbone, on which many of the other constituents of learning rest. For most major subjects in the domain of science, there is no reason why a designer cannot locate a very well written text that aligns to designated LPO’s, and the maturity level and vocabulary of the learner. Certainly there are a few sub-disciplines within science that are quite new, with information so fluid, that textbooks have not yet been written – but these disciplines for the most part would be part of a graduate program.

Not all textbooks are exactly the same for a given subject. For the online organic chemistry course, I examined four different first-year organic chemistry textbooks and while the topics covered in all four were virtually the same, the one stood that out from the rest had a superior organization and accessible narrative; making very difficult concepts manageable to young learners, by using language that met their vocabulary levels (Dick et al., 2015, p. 260). In addition, the text provided motivational cues, and interesting stories. While narrative is very important, other considerations when selecting a text are (1) *congruence* between the content in the text and LPO's, (2) *completeness* in the coverage of content, (3) *academic authority*, (4) *accuracy*, (5) *currency*, and (6) *objectivity* (p. 260).

In contrast to the limitations of even the best of textbooks, screencasts provide a great way to not only present content to learners, but to *connect* with them on a more personal level and to establish a stronger online presence, which is important to develop student persistence (Stavredes & Herder, 2012, pp. 157, 158). In more recent years, educators in *flipped* classrooms have used brief screencasts to introduce topics to their students, thereby reserving precious time in the classroom for the more difficult applications of content. Students report enjoying the opportunity to learn on demand, having the freedom to listen to such lectures at any time, day or night (Ealy, 2013, p. 303). Screencasts need to similarly be aligned to course LPO's, and with the instructor utilizing vocabulary that meets the language abilities of the learners. Finally, if there are perceived omissions within the course textbook, a quick screencast is an effective way to fill in those omissions.

Laboratory Materials

Since online laboratory science is so new, chances are the designer or instructor is going to have to write their own labs at some point, or at the very least, modify an already-existing laboratory. As already discussed, there are vast resources on the internet for purchasing lab kits specifically designed for the online learner (Jeschofnig & Jeschofnig, 2011, pp. 110-112). When selecting labs from other resources, they will need to align with course LPO's, be carried out with materials the learner has access to, and will require significant guidance to the learner (Dick et al., 2015, p. 261). This guidance may be provided by way of supportive text appended to the lab or an accompanying screencast. Most importantly, laboratory assignments need to run concomitant with textbook readings.

Readings in Primary Sources

There are many sound reasons for requiring learners to read articles from the primary science literature. For one thing, they will understand that the textbooks they read find their authority by contributions from primary literature sources. In addition, learners develop an appreciation for the various constituents inherent in any reliable scientific study, such as formulating hypotheses from already-existing theoretical frameworks, developing an experimental protocol, the role of quantitative analysis, and communicating research findings to the public. The opportunity to read such articles also allows students to expand their developing science vocabulary. Selected readings should reflect topics that are relevant to the course's LPO's, and utilizing technology the student is familiar with. The instructor can assess the learner's comprehension of the research by requiring the learner to write a brief reflection paper summarizing the article or providing thoughtful insights gained from it.

Practice Problems

In the sciences, *practice problems* and exercises provide opportunity for the learner to engage more fully with the material, following the presentation of actual content. It is particularly useful if learners are required to solve practice problems *as* they encounter the concepts which apply to them in the reading. Many texts even present sample problems with step-by-step instructions on solving.

Most science textbook publishers provide *solutions manuals* to accompany their texts. At times these manuals provide little more than just simple, correct answers to the problem sets in the text. As already mentioned, online students, because they do not have regular face-to-face access to an instructor require more comprehensive feedback. It is a wise investment of time on the part of a skilled designer in conjunction with a subject matter expert to write solutions manuals that provide not only simple answers to problem sets, but written problem-solving strategies as well. For the online organic chemistry student, when they have access to these kinds of materials, they can monitor their own learning processes, by comparing their strategies with that of an expert.

Periodic Quizzes

As briefly discussed, periodic quizzes are powerful learning instruments, as they prompt students to recall and retrieve prior learning (Nilson, 2010). In an online environment, quizzes easily administered through a LMS or apps such as Quizlet or Socrative can also serve as an incentive for students to raise their level of preparation, engagement and achievement (Nilson, 2010, p. 259). Moreover, quizzes may be used to assess students understanding of content, thereby allowing the instructor to clear up any misconceptions (which could easily be addressed by the quick publication of a screencast, if necessary).

Whether instructional materials come from a textbook, laboratories, screencasts, quizzes or selected readings, they all need to interact harmoniously, and be placed in a logical sequence.

Table 5.

Rubric for Evaluating Instructional Materials

No	N/A	Yes		**Textbook** Does (is) the text:
_____	_____	_____	1.	***Align directly*** with the instructional strategy?
_____	_____	_____	2.	Content satisfy LPO's?
_____	_____	_____	3.	Authoritative, and current?
_____	_____	_____	4.	Use vocabulary that is appropriate for the learner?
_____	_____	_____	5.	Complete in scope?
_____	_____	_____	6.	Provide motivational cues?
_____	_____	_____	7.	Provide stories/ articles that students would find interesting?
				Laboratory Assignments Does the laboratory:
_____	_____	_____	1.	Satisfy specific LPO's?
_____	_____	_____	2.	Use materials students have access to?
_____	_____	_____	3.	Provide adequate guidance in the execution of experiments?
				Readings in Primary Sources Are the readings:
_____	_____	_____	1.	Interesting and relevant?
_____	_____	_____	2.	Written so the students can understand the protocol and results?
_____	_____	_____	3.	Aligned with LPO's?
				Practice Problems Are (do) the problem sets:
_____	_____	_____	1.	Provide solutions that are *descriptive* in terms of strategic problem solving?
_____	_____	_____	2.	Inserted throughout the material, and required for completion at the *time* the relevant content is covered?
_____	_____	_____	3.	Do they progress from simple problems to more advanced, as the learners develop cognitive strategies?
				Periodic Quizzes Are (do) they:
_____	_____	_____	1.	Aligned with content from other learning elements in the course?
_____	_____	_____	2.	Have explicit and clear instructions for completion?
_____	_____	_____	3.	Written so the instructor can receive valuable feedback on the success of the student learning outcomes?

Rubric derived from Dick et al., 2015, Chapter 10 – Developing Instructional Materials.

Table 5 above provides a basic rubric for evaluating the effectiveness of the instructional materials.

Formative Assessment

The very recent emergence of online science laboratory course learning makes the process of formative assessment all the more critical in the development of effective instruction. While the ISCM of instructional design does provide a systematic basis for course development (as does the Dick et al., 2015, model), the first iteration of any design is never the one most perfect.

Note in Figure 7, the reach and scope of the revisions that occur as a consequence of formative evaluation. The term *formative* implies that design elements such as LPO's, assessment instruments, instructional strategy, and course materials are not cast in stone, but are rather considered *under development*, thus *malleable*, until a broad and thorough evaluation has been performed.

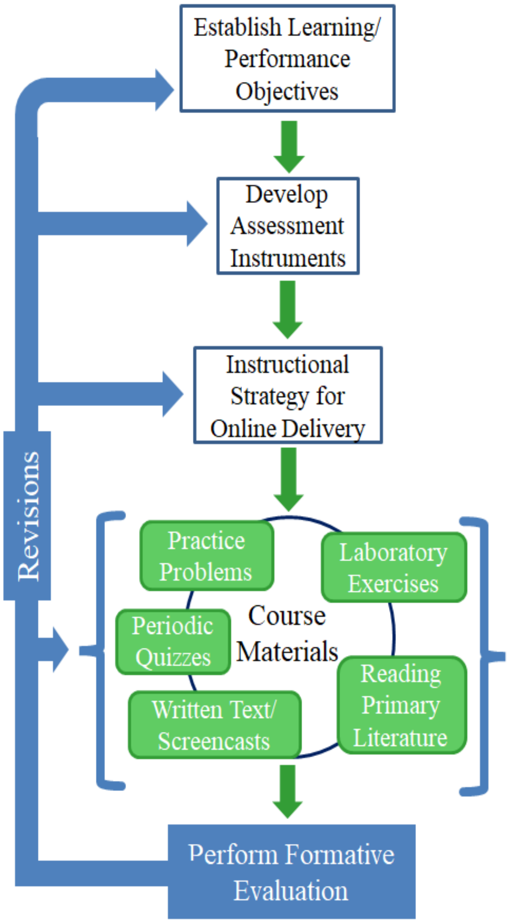

Figure 7. Note from the schematic, the reach and scope of the revisions.

Dick et al., (2015, pp. 283, 284) states that thousands of instructional products in the United States are sent to market every year without the benefits of undergoing an evaluation by target learners, and revised. Materials can be made much more effective if they are simply tried out on even a single learner, prior to their distribution. While systematic design by nature is intended to yield research-oriented and well-developed instructional designs, still, the best framework by which to evaluate the various constituents of the ISCM model are the target learners themselves, starting from trials involving one-to-one evaluation, small-group, and then field trials, as suggested by Dick et al., (2015, pp. 285-296). Learners can provide valuable information concerning (1) the ease by which the materials are understood, (2) whether they provide any motivational value, (3) if the units, chapters, or modules are presented in a logical sequence, (4) feasibility of the laboratory exercises, (5) the ease by which they could navigate the course in the LMS, and (6) their attitudes towards the content itself. Depending upon the nature of the feedback from these learners, various constituents and phases within the design may be subject to revision as shown in the schematic in Figure 7.

Targeted learners are not the only ones capable of providing worthwhile feedback on a design. *Subject-matter experts* can assess the degree to which assignments and activities are aligned with instructional goals and LPO's (Dick et al., 2015, p. 301). The accuracy and currency of course materials can be ascertained by a *content specialist* (p. 311). *Learning specialists* can inform the designer as to the "type" of learning that is facilitated by various activities (p. 288). Organic chemistry students are often reminded of the necessity to *understand* content, by *conceptualizing* chemical reactivity phenomena, and are chided for resorting to *rote memorization* (Karty et al., 2007). The learning specialist may be able to identify elements within the design itself that foster these less effective learning techniques, and provide suggestions for generating more concept-building skills.

Once a formative evaluation is complete, the designer can return to those areas of the design that necessitate revisions. By maintaining flexibility, the designer allows a design to remain student-centered, and with every iteration, improve in its ability to deliver quality instruction.

Strengths of the Model

The ISCM of instructional design was created for the engineering and development of online science laboratory courses. Since the drop-out rate of online courses is considerably higher than that of face-to-face instruction, it was necessary to provide a protocol for comprehensive analyses of learners, and the place where they will experience most of their instruction – their home-site. Only through the outputs of these analyses, can responsive and informed instruction be successfully developed for that specific type of learner.

The benefit of providing online science courses is that it requires instructional assets to be individualized, and self-instructional (Dick et al,. 2015, p. 251, 252). The advantage of self-instructional materials is they theoretically permit the student to learn new information and skills with little intervention from an instructor or other students (p. 252). In a well-thought out design, learners have greater control over their own learning outcomes. In addition, students have reported enjoying the flexibility that goes along with learning content at home and during the dates and times of their choosing (Ealy, 2013, p. 303). For media assets deliverable online, many appreciate the notion that they can watch, listen to, or read materials as many times as they deem necessary, allowing them still greater autonomy.

The greatest weakness in the ISCM is the fact it is brand new and has not undergone peer review. Theoretical models may appear robust on paper, but it is not until the models are tested in the marketplace, or through the rigors of peer reviews, are they deemed as legitimate and *working*. I look forward to modifying the ISCM in the coming months, and applying its guidelines when developing my own organic chemistry online course for high schoolers.

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