1. DESCRIPTION

Introduction

This project has three linked phases:

i. To develop a new system for structuring learning and specifying objectives, and for operating courses and assessments, which I call an Objectives-Mastery Modular System (OMMS),

ii. To implement the system in a complete physics course,

iii. To study the effects on student learning outcomes and learning behaviors.

The method involves several components: Organizing the course topics and concepts to be learned into Learning Units; providing detailed Learning Objectives for each such unit; implementing Mastery Learning, with feedback and second attempts; devising both Formative and Mastery Assessments, and recording attainment by ongoing Accumulation of Learning and Mastery Credits. The system is designed to be holistic in that all components are designed to work together. The way the course operates is significantly different from the way most conventional courses are run. Note that Assessment for Learning plays a central role throughout, with the goal being to maximize learning and ultimate student attainment.

I have already conceptualized the components and the whole system, and piloted initial versions. The full refined system will be developed during the summer, then implemented in the Physics 2500 Waves and Optics course, which I teach each fall. It is a small class of 15-18, mainly physics majors and secondary education majors, which is ideal for developing, testing and researching as a proof-of-concept. I have been thinking about such systems for a while now, and have even previously tried out initial versions of some aspects in selected parts of my physics course, leading to better ideas, so I feel confident the full project will work. The main features of the Objectives-Mastery (O-M) system are described below.

Components of the objectives-mastery system

The system is not merely a single teaching strategy to run within conventional courses, but is actually a new way of structuring and operating courses and conceptualizing assessments. It is a holistic system with several interrelated components, aligned to work together effectively. These are outlined below.

Structuring into Learning Units

Courses and textbooks normally divide subject-matter into chapters and topics, with the focus on logical presentation of content. However, for learning purposes we can go beyond this and more finely structure a topic or concept into a natural sequence of Learning Units (LU). There are multiple facets to any concept, e.g. conceptual, facts, physical insight, theory, experiment, math formalism, experiential, etc., so learning units aim to provide a cognitive learning path for new learners to acquire an effective understanding of all such facets. This approach also reflects the rich nature of expertise, which we hope to help the students construct.

To go with this, our instructional ‘lesson plans’ and detailed objectives can be organized by learning units, with assessments closely aligned. A set of appropriate learning units and assessments will then constitute the overall topic or chapter material.

Learning Objectives

Detailed Learning Objectives are formulated for each topic and learning unit, for identified aspects of understanding and abilities involved. Detailed concept-specific objectives let students know what the various important aspects are that they should master, and makes explicit what is expected of them, and what will kind of thing will be assessed. Such objectives will be provided in class at the appropriate stages of instruction in each unit, as well as posted on eLearning. Specific objectives should make for greater clarity of purpose, improved motivation, and better learning. There are also broader general goals for a topic as a whole.

To complement the sets of detailed learning objectives, student attainment records and mastery credits can be presented as a quite specific listing of particular objectives mastered by a student, rather than by simply
giving aggregated percentage ‘quiz scores’, for example. In fact, conventional ‘quizzes’ or ‘tests’ are no longer a structural organizing feature, but specific learning tasks and mastery tasks are.

**Mastery Learning**

The course and assessments will use a “Mastery Learning” philosophy and approach. Our ultimate goal is for each student to demonstrate high-level mastery for each objective on each assessment. To this end, students who do not attain mastery for an objective or task on first try are given formative feedback and opportunity to improve by relearning and trying again on a similar assessment. This approach is in contrast to a conventional homework/quiz/exam system, which grades students summatively the first time using point scores and percentages. In our case, mastery at a high level is the goal for all, and even the initially weaker students should be able get there, given the opportunity. Moreover, proper mastery of one topic often forms a necessary basis for effective learning of the next.

My version of mastery learning might be called a Focused-mastery or Targeted-mastery system, having a fairly fine-grained ‘unit of analysis’, namely each specific learning objective. This also makes feedback focused, timely, and actionable. This is in contrast to using an entire chapter or topic as a modular basis, which is often the case in other mastery systems, which I find unnecessarily inefficient, even frustrating, having tried a chapter-based method elsewhere.

**Mastery Tasks and Mastery Credit**

After having learned a topic (with formative feedback along the way), a student can demonstrate mastery of the objectives as assessed on a Mastery Task. In physics, this is usually assessed by problems and questions on the topic, ideally multifaceted structured problems addressing various aspects of understanding. Good understanding and quality presentation will earn Mastery Credit (M) for the named objectives involved. If there are shortcomings, the work will be considered Partial Mastery, designated P. A student may learn from feedback this and try again for mastery on a similar task or problem, or sometimes on the same task. Credit earned will be the average of the two attempts. Students only need to retry on aspects they did not master the first time; things already mastered would stand. Redoing these aspects and reassessing them can then be focused and efficient. Mastery credits accumulate as the course proceeds. This leads to the final grade for the course, with each student’s record listing all the objectives mastered and the corresponding credits attained.

**Learning Tasks and Learning Credit**

During a unit, tasks are assigned for learning and practice purposes. These are designated Learning Tasks, occurring during learning as part of the formative process. It is arguably not appropriate to summatively score students simply on the ‘correctness’ of their attempts at that early stage. Nevertheless, in conventional practice this is what is often done in “grading homework”. Recognizing this anomaly, we introduce the notion of Learning Tasks, the name implying that we do not necessarily expect complete correctness or mastery right away. Instead, serious attempts at the task, and thoughtful work, will earn Learning Credit (L), even if everything is not yet completely correct or fully understood. The student also notes any difficulties they are having. The learning task approach thus re-conceptualizes ‘homework’. Learning credits also accumulate toward a student’s overall attainment. This aspect of the system thus recognizes and rewards serious effort, good work, and progress. At the same time the system also requires high standards for mastery and quality of work.

**Assessments as part of teaching and learning**

The system treats assessments of various kinds as an integral ongoing part of teaching and learning. The Assessment for Learning formative aspect should enables students to eventually attain high level Mastery on summative assessments. A Learning or Mastery assessment question for a particular objective best occurs at the appropriate stage during or soon after a unit, where it is most effective. This also shows students that all stated objectives do get tested and credited in a balanced way, which is often not the case for periodic exams alone. Note that while Learning tasks are usually done at home, where the student can take time, and Mastery assessment tasks are usually done in class, either type can actually be assigned for class or for home, as judged appropriate for the particular case.
To avoid the possibility of fragmentation of knowledge into unit compartments, there will also be periodic “integrative” assessments, requiring several aspects of the current and earlier topics to be brought together on a demanding task or problem.

As an additional feature, note that although we most often talk about formative feedback to the student, the system also provides ongoing formative feedback to the instructor, as to how things are going, how students are doing, and what is working well or not, for ongoing improvement of the instruction and procedures.

**The nature and quality of assessment questions**

Since learning and mastery assessments play such an important role in an objectives-mastery approach, the nature and quality of particular assessment questions is crucial. Devising or selecting really good assessment items for the purpose is thus a creative aspect of an instructor’s role.

**Assessing**

Assessing a student submission is by judging it as Mastery (M), Partial mastery (P), or Unsatisfactory (U), and commenting what aspect needs improving, rather than assigning specific partial point scores. Evaluating and commenting can thus be relatively straightforward and is actionable by the student. Assessing mainly for mastery is a useful feature when students themselves do guided self-assessment or peer assessment. Involving the students in mastery assessment enables them to learn how to judge the merit and quality of their own work. It also saves the instructors and teaching assistants considerable time, since the most salient points on assessment can be discussed in class, with the mastery goal being understanding of the essence, either now or later, rather than fretting about what partial points to assign to what bits. Note that well-presented work of high quality is always required for full M or L credit, which sends an early message about the nature of work expected and recognized.

**Credit attainment record**

Since we have sets of detailed learning objectives with aligned assessments, each student’s attainment can be recorded as a listing of specific objectives and credits. Overall accomplishment in the course is by ongoing credit accumulation. Our goal is that students master most of the specified learning objectives at high level and accordingly we will determine final grades from the proportion of mastery credits attained as a proportion of the total credits available.

The system itself, though different from the conventional, is relatively straightforward, and consistent in its own right, and the components link coherently. However, it will be unfamiliar at first, so that even if the advantages are clear, both instructors and students may take a while to adjust their existing mindsets and practices. Once fully into it, the benefits for learning behaviors and learning outcomes should become evident as a course proceeds.

**Data and analyses**

By its very nature, an objectives-mastery system automatically records and tracks the detailed performance outcomes, for every student, on every specified learning objective and assessment question, on every topic, throughout the course. We will also systematically record Mastery or Partial credits, how many students repeated to get mastery, and whether they were successful, showing the effect of feedback and repeat on learning outcomes. There will also be a record of all the learning tasks and learning credits, giving a handle on the formative assessment aspect, normally somewhat hard to measure or interpret. Data can show to what extent performance and work quality may improve over time, as students adapt to the system and take advantage of potential benefits. Overall, we will certainly have comprehensive data! Good thing we are starting with a small class!

Interesting effects, correlations and outcomes, some anticipated, some unexpected, may arise from the detailed data analyzed across different factors. With the small numbers of students, it should also be possible to interview most of them along the way to ascertain reasons for their learning behaviors and performance. Some of the quantitative results could make sense in the light of the qualitative interviews.

It may be tempting to try comparing overall student performance under this system with results when the course was previously taught conventionally. However, note the caveat that there will be other confounding factors at work, such as different students or instructors and non-identical courses, and given the relatively small
number of students this may make such comparisons less than meaningful. However, we can at least report how the overall performance and distribution may differ from that in the past. If this is substantial it may be meaningful. However, this will not be the primary focus of our analyses.

Outcomes and products

1. The first major outcome would obviously be the development of a holistic objectives-mastery system for course operations and assessments. 2. A second related outcome would be its instantiation in a particular physics course, as a detailed course structure, procedures, assessment sets and materials, available online to any subsequent instructors. 3. If our implementation and research shows the system to be reasonably successful in improving student learning and learning behaviors, this would be evidence for dissemination and adoption elsewhere. 4. Although it has not been mentioned here, most of the features do have theoretical support in models of learning and of instruction, and this aspect could be tied to the research results in subsequent papers.

Impact

If the system, once fully developed and refined, works as well as I think it could, supported by the research evidence, it could potentially have substantial impact with beneficial effects on learning outcomes and learning behaviors. Being a system change, a new way of running courses and assessments, it is more likely to be effective overall than single reformed teaching strategies. I hope first of all to show impact locally, in my own physics course. After that, bringing one or two physics colleagues on board who teach larger classes would be a promising second step, involving a hundred students or more. For the full potential impact to materialize, the approach would need to be disseminated and adopted by other departments and institutions, and I have ideas for this below.

Timeline

**Summer 2018.** Design and develop the overall system. Most aspects are already conceptualized.

**Fall 2018.** Implement in Phys 2500 Waves and Optics course. Learning outcome data collected. Student interviews. **Spring 2019.** Research analyses, results and interpretation. **Thereafter.** Further refinement and use of the system, dissemination, conferences, papers.

2. DISSEMINATION PLANS

Dissemination would be at various stages and levels. I would be interested to do this since I am enthusiastic about the system and its potential impact on learning. The first level would be local to the physics department, by seminar and a written report on the system, its rationale, and outcomes so far. I’d also invite people to see how it operates and offer my help to any colleague wishing to try it on all or part of a course. The second level would be offering seminars to any interested departments or units at the University, since the system itself is not discipline-specific, though the content and details are, of course.

Then of course, normal common methods of dissemination would be by conference presentations, workshops, and articles in both research and practitioner journals. I feel there should be enough innovative substance in the complete system for more than one of each, especially after it is further refined and tested.

However, although these channels are valuable to raise awareness and interest, I’ve never been convinced that information alone, nor even evidence, has nearly enough traction toward broader adoption of educational innovations. Thus, besides these routes, my idea is to work collaboratively on design with anyone who wished to implement such a system in their own course. It would be natural to start with a physics colleague who may be bold enough and would appreciate working together. This would also be a further ‘proof of concept’ for further dissemination. Hopefully I could motivate for some internal support and TA assistance.

If the system is as successful as I hope, I envisage writing a grant proposal for a collaborative NSF award, to work with a colleague elsewhere in implementing such a course structure and assessment system at another institution for a semester, with funding supporting both sides. As I said, information alone is rarely enough; people often have to actually see an innovation in action to fully appreciate its relevance for their own teaching or program. This may make broad dissemination slower than we would wish, but more effective for sustainable adoption.