Human Performance and Learning Corporation

777 First Avenue
Carbondale, Illinois 62901

Dear Mr. William Mejia:

We are pleased to offer you our report on your case. As discussed, we have studied the issues involved with helping your physics students to apply the theories taught in lecture on their given exams. At HPLC we strive to keep an open mind when using instructional design theories to solve different learning problems. Our approach is to examine the philosophy of *each* theory as it applies to your unique case before offering any recommendations or strategies. The report that follows will first describe the Learning Problem, Learning Context, and Target Learners. The report continues with insights from a variety of learning theories and then concludes with specific recommendations to assist you in overcoming the identified learning problem.

All of our suggestions emerge from the fundamentals of the learning theories discussed at the beginning of this correspondence. We hope that you will find use from them.

HPLC is available for further consultation on specific instructional design of learning objectives, content, learning activities, and criterion-referenced testing. Please feel free to contact me to discuss this report or other areas of interest or concern.

Karen Sullivan

Learning Consultant

Learning Problem

Help high school physics students in El Salvador to improve the transfer of learning from practice lessons in lecture to solving physics problems on tests.

Target Learner

The learners identified are physics student in El Salvadorian high schools. Previous knowledge varies from pre-requisite physics courses to nothing applicable. About 70 percent of the students are expected to finish their high school studies and 20 percent of those are likely to have the opportunity to continue on into college.

Learning Context

The physics students attend 4 lectures and 2 labs per week. Through out the course, 10 units are covered and approximately 5 tests are given. Grading weights are as follows: lecture tests, 50%; assignments, 25%; lab performance, 25%.

Resources and Constraints

The Universities may be an excellent resource because of their desire for increased enrollment in their physics, math, and science programs. School administrators are generally supportive, although focused on student performance on standardized tests more than college preparation. The current physics teachers can be resources or constraints for creating enthusiasm in the current students. An area of concern does arise in the reputation that physics has with incoming students, who often fear physics as being too hard for them.

Insights from Learning Theories

Behaviorism

One of the basic ideas behind behaviorism is to look at the reinforcements/rewards in place. This shows us what the students see as their reward, or punishment, for their behavior. These are things like receiving passing/failing grades on test and in the course. In a case where learners are not producing the desired behaviors, a change may be called for in terms of what behavior is reinforced and what rewards are used. Another central contribution of behaviorism is the idea of shaping and chaining behaviors. Shaping can involve relating previously known real life examples of physics to textbook definitions of the theories, and then using those as building blocks for further instruction. This offers the student the ability to realize that they already know a variety of physics laws, although perhaps not the scientific formulas behind them.

A concern of behaviorism is *learned helplessness* in which learners passively accept negative consequences such as poor grades because they believe that they cannot change the outcome. Students attribute their success or failure to forces outside of themselves. This situation in which our learner begins the task with a lack of confidence (self-efficacy) in their ability to master physics problem-solving is very difficult to overcome and is detrimental to the success of the learner. However, if the instructor can connect with the learners, by showing them they know more about physics than they may realize, it is possible to overcome. This again leads us back to the idea of chaining and shaping.

Cognitive Information Processing

Cognitive Information Processing is concerned with the organization and sequence of the instruction. Things like the structure of the lecture, how the lecture compares to the exams, how the exams are written. More specifically, the current schedule of testing after 2 units, along with the types of questions on the exams, may be contributing to learners' difficulty in transferring the problems-solving skills demonstrated during instruction on to tests. There could be an encoding problem (during instruction) or a decoding problem (during testing). CIP shows us that complex information is often "chunked" by more advanced learners. Learners can remember the proper problem-solving steps more easily if they can put the steps into a single chunk that is identified by the *type* of physics problem. In a test situation, then, the learner does not need to keep all the steps of all the types of problems in mind but instead just the types of problems. When the problem type is recognized on a test, the learner can "unpack" the chunk to recall specific steps. CIP suggests suitable formats to structure the content so that the learner has the best chance of encoding the information in a way that allows for easy retrieval when needed on the tests.

Meaningful Learning and Schema

This area of learning theories emphasizes making new content more learnable by anchoring new content with existing knowledge. Beyond facts and concepts, learning physics requires that learners "get it", that is, that they develop mental models or *schema* of physics. That is what allows learners to go beyond memorization of formulas. In the realm of physics, learners already possess a naïve schema based on every day observations. Although the instructors will ultimately replace the naïve schema with an appropriate physics schema, helping the students see the common sense behind physics in their every day lives gives them the anchor. With that knowledge the learner will activate a physics schema that they can add new knowledge from the lectures to. A challenge is to know when and how to reshape the learners' naive schema to the correct one.

Another method used in Meaningful Learning is the advanced organizer. These are used to show the relation between the new content and the existing content allowing for the learner to access the proper schema to anchor to. Currently, the table of contents of the text book is being used in this manner, but there may be ways to make it more understandable. Accuracy is less important in the advance organizer than clarity.

Situated Cognition

This is where we take a look at the relationship between the lecture portion and the lab portion of the physics class. Along with the delivery of the content through lecture it is very effective for the learner to have the opportunity to work in an environment where he can actually use the content. That's the goal of lab sections of classes. It gives the learner a chance to feel as if they are a part of a physics community. When the learner feels as if they are a participant in the context of the subject, there is created an excitement for the material that can be followed by enhanced transfer of that material. Ideally, the lab section can create authentic tasks and roles for learners, such as "product testers". Situated learning can be further enhanced by creating a learning community, perhaps lab work groups, in which learners earn their way into leadership positions. It can also be motivating to students to see people they admire (college students?) doing physics successfully and having fun with it.

Constructivism

Constructivism is geared more towards learner control of a learning situation. For a learner to feel as if they have some management over their participation and over their personal creations of meaning in physics may allow them to transfer and retain the new knowledge better. This might be achieved by having students generate ideas for physics experiments. This can lead to *discovery learning*. Being mindful of the environment of a physics lab, however, instructor guidance is never completely removed from the situation. In this kind of lab, the role of the teacher may need to change from the traditional role of a teacher to the higher-level role of a guide.

The idea of constructivism has beneficial implications for lab environments. This could offer situations for learners to find their calling, or for students to finally “click” with the content. Learner control can significantly add to the willingness and confidence of the learner.

Strategies and Instructional Implications

Based on insights from the learning theories described, we make the following recommendations to address the learning problem of physics students not adequately transferring learned problem-solving skills from instructional to test environments. Our recommendations are intended to fit within the current lecture/lab structure.

Pre-Testing

This offers the instructor a chance to get an idea of what the students already know about physics. The instructor can see what kind of common sense schema of physics the students have already. Instructors can develop their lessons around this; designing lessons for areas where there is already a naive schema set up in the learner, designing projects to anchor to an already strong sense of a physics law, or knowing the right time to just start transferring the learners’ naïve schema into a mature physics schema.

Gaining Attention

A pre-test may be presented as an attention-getting activity in which learners are challenged to solve everyday physics problem. Trying to relate a previously unknown physics law to a common everyday occurrence in a student’s life can give the student something real to hold on to. This can increase the desire to learn more by giving the learner the *feeling* that they already know basic laws of physics. For example, everyday they see airplanes, helicopters, birds and kites flying around. That is physics in action. A simple law; as velocity increases, pressure decreases…and there you have just learned Bernoulli’s Principle. Relating new knowledge to old knowledge gives them the ability to grow previously existing schema that they may not even realize they have. This also gives the instructor a way to begin rewarding successive approximations of the physics problem solving behavior that is the ultimate target. We feel that, beyond the instructional value, it is vital that students experience immediate success with physics to overcome fear of the subject.

Classroom Rules

At the beginning of the class, the instructor should inform the students of the types of reinforcements used. Currently, the grades given for tests and the course seem to be the only type used. We would like to suggest that more be used. For example, use quizzes between tests to keep the content fresh, and if the quizzes are successful, allow the students to use these quizzes as “cheat sheets” during test taking. Another example, have the option for group learning, where students can take group challenges to show their ability to apply the course material. *Be careful here!* It would be advised for the instructor to assign the groups rather than the students choosing themselves.

Lecture Design

Lecture design is critical to the learners' ability to retain the new content being taught. There are three main points we wish to point out here: learning objectives, matching practices with tests, and "chunks". The instructor must be able to clearly define the objectives, the goals that the learners should be working towards. Make sure they know what their expected performance is going to be, how well they should be able to perform, and the conditions under which they are to perform. Closely related to this, is making sure that the objectives given during lecture, in practices and examples, match the objectives that are expressed on the tests. This helps the learner to match the previously unseen test items with the items already seen throughout lecture and the practices. The primary learning problem is that learners are not transferring problem-solving skills that appear to have been mastered during instructional and practice stages into the testing stages. This is common, as the physics problems in a unit are similar. The challenge to learners is not in *solving* physics problems but rather in *identifying* physics problems. When the type of problem is recognized, the process of solving it is easier.

Chunking. This is how much content is thrown into each unit. In other words, how many chapters are covered between each test. The typical person can retain 7 to 9 chunks of information. The key is to make solution steps associated with the type of problem so that, on a test, the learner can retain 7 to 9 types of problems and be able to unpack them as needed. Be mindful of this when developing lecture and test schedules. If it is possible, offer more test throughout the course. Or instead of having 5 big tests, have plenty of smaller "quizzes", and use those to average the students' grade for the course.

Drill and practice. Although most people see learning as understanding the content to the point where the learner can apply it, there is still a lot to be said for repetition. Simple formulas and rules in physics lend themselves to repetition exercises. Drill and practice should be used to *automate* required calculations, but also to *recognize* problem types. Students can be presented with a large number of problems that they must a large number of problems that they must recognize as a certain type, and perhaps identify a correct formula. But not always solve the problems all the way through. Drills can be made more engaging by having a score based on time as well as accuracy and giving learners to beat their own score and try to make the class high score list. Our experience shows that learners enjoy the efficiency of drills and get satisfaction from the mastery of skills.

Lab Section

The lab that is currently set up in the course is a great arena for situated learning. This is where the students get the chance to actually see physics in action instead of as formulas written on paper. Consider the option of making the lab section as close as possible to a live working lab, perhaps conducting tests of everyday products. Let the instructor act as a Lab Manager and assign group leaders based on their class performance or simply rotated among students. This sort of social and authentic environment can be more conducive to learning. In this live lab, activities should match the lessons that are being taught in the lecture section of the course. Activities like that will make the content stick better with the learner. This requires that there is collaboration between the lecture and lab instructor.

Some other suggestions that may or may not be feasible are things like extra curricular activities or having former students, which have gone into physics in their studies at the Universities, come in to help with the lab sections of the course. Maybe there is a chance to set up activities for the learners to attend physics labs at the Universities, to get a more advanced look. This could be used as a catalyst to push interested students further into the field. This could be used as an extra credit incentive for the high school students. The idea of having former students coming back and helping out with the lab sections, offers the students the chance to see people who they are more likely to see as their peers involved in physics. This can boost interest as well.

We believe that these recommendations can help increase the students learning of physics from a *declarative knowledge* level to a *procedural knowledge* level in which students go beyond memorizing formulas and start to think like scientists and engineers in using physics principles to solve interesting and important problems.